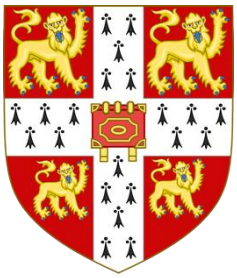


University of Cambridge
Faculty of Education

PhD in Education

Raising Awareness of Data-ethics for PGCE Computing using Ballet and Biometrics as Narrative Tools: An AgileDBR Approach

This dissertation is submitted for the degree of Doctor of Philosophy

Name: Genevieve Elizabeth Smith-Nunes

Supervisors: Prof. Pamela Burnard, Prof. Rupert Wegerif

College: Darwin College

Submission Date: June 2023

Word count: 78917

Declaration

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text. I further state that no substantial part of my thesis has already been submitted, or is being concurrently submitted for any such degree, diploma, or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. It does not exceed the prescribed word limit for the relevant Degree Committee.

Mrs Genevieve E Smith-Nunes

Raising Awareness of Data-ethics for PGCE Computing
using Ballet and Biometrics as Narrative Tools: An AgileDBR Approach
Genevieve Smith-Nunes

Abstract

In contemporary society, educating individuals about the ethical implications of sharing personal biometric data is limited despite the omnipresence of data. This doctoral study explores the use of creative computing and arts practices, specifically biometrics and ballet, to raise awareness of data-ethics among Postgraduate Certificate in Education (PGCE) trainee computing teachers.

This thesis explores the issue of how creative computing practices can effectively enhance data-ethics awareness among trainee computing teachers and contribute to widening participation in computing education. To address these research objectives, a novel methodology called AgileDBR, which combines Agile and Design-Based Research (DBR), is introduced. This methodology overcomes the limitations of traditional DBR by providing transparency, scaffolding, more flexible routines, and more fluid structures.

Purposive sampling is employed to gather data from three distinct cohorts: Computing Educators, Dancers, and Technologists. The participants are organised into three cohorts: Computing Educators (including trainee computing teachers and PGCE leads) (n=17), Dancers (n=3), and Technologists (n=1). Data collection is conducted through three increments using interpretative phenomenological analysis (IPA) and computational methods such as Natural Language Processing (NLP).

Biometric data capture involves skeleton and brainwave (electroencephalogram = EEG) recordings, using new tools to work in digital online settings. The captured data undergoes various processes, including dancer isolation, skeleton data tracking, pose estimation ML model, and joint mapping software.

The findings of this study reveal that creative computing practices with biometrics and ballet by fostering personal connection to data thus effectively raises awareness of data-ethics and potentially broadens participation in computing education. Further research is still required. The integration of machine learning and creative computing activities fosters interdisciplinary cross-curricular connections with subjects such as physical education, dance, and music, see appendix 11B.

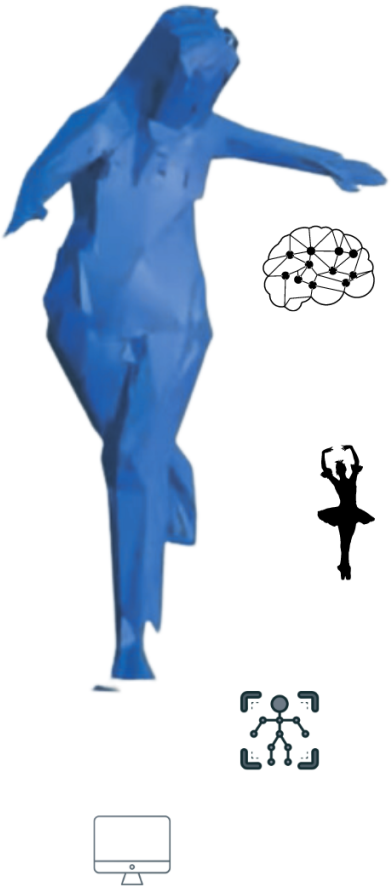
This research has significance and potential impact in aligning with Aim Four of England's Programme of Study for Computing, which emphasises the importance of creating ethical, responsible, competent, confident, and creative users of information and communication technology. The contribution to knowledge is in demonstrating that creative methods using dance and biometric data can be effective in achieving some of the objectives under this aim. Moreover, the new AgileDBR approach developed as part of this research is shown to provide a flexible and iterative research framework that enables efficient planning, evaluation, refinement, and adaptation, particularly crucial in addressing the challenges posed by the Covid-19 pandemic.

Acknowledgements

First and foremost, I would like to express my deepest gratitude to my participants and supervisors, Prof. Rupert Wegerif and Prof. Pamela Burnard for their invaluable guidance, encouragement, and unwavering support throughout my PhD journey.

I would also like to acknowledge the Disability Resource Centre at Cambridge for providing me with the necessary accommodations to enable me to pursue my academic goals despite my disabilities. Support from Helen and Aless as my dedicated advisors, along with Kitty for my dyslexia, Tim as my mentor, and Ian providing essential support during the PhD, ensuring that I had an equitable and inclusive learning journey.

I am beyond grateful to my husband and two sons, whose love, patience, and understanding have sustained me through the ups and downs of the doctoral process. Their unwavering support and encouragement have been a source of strength and motivation**.**



My appreciation and eternal gratitude to the external research groups 'Jollyologies' and 'Josa Jamboree' for their collaboration and input throughout my research. Their insights and expertise have been invaluable in helping me to develop and refine my ideas.

To Rawlight for providing me with the opportunity to practice daily yoga, which has been a vital component of my self-care routine during the PhD process. Their guidance and support have enabled me to maintain a healthy work-life balance and manage the stress of academia.

I would like to express my appreciation to my extra monitors, which have been essential in enabling me to work efficiently and effectively. Their contribution has been significant in allowing me to co-analyse data, write papers, and prepare presentations simultaneously.

Lastly, I want to acknowledge the role that KDramas have played in keeping me sane during the PhD journey. Their entertaining storylines and relatable characters have been a much-needed escape from the stresses of academic life.

Thank you all for your contributions to my PhD journey

TABLE OF CONTENTS

DECLARATION 2

ABSTRACT 3

ACKNOWLEDGEMENTS 4

CHAPTER ONE: INTRODUCTION 17

CHAPTER TWO: LITERATURE REVIEW 20

2.1 Prelude 20

2.1.1 CLARIFYING SCOPE 21

Part I Key Components 22

2.2.1 DATA-ETHICS FOR THE COMPUTING CLASSROOM 23

2.2.2 INITIAL TEACHER TRAINING: A LACK OF DATA-ETHICS 25

2.2.2.1 DATA SECURITY PRINCIPLES AND REGULATIONS 27

2.2.2.2 ETHICS: ETHICS AS A TAUGHT SUBJECT 30

2.2.3 WHAT IS COMPUTING? 32

2.2.3.1 COMPUTING EDUCATION 33

2.2.3.2 WHAT DO THE DATA SAY ABOUT COMPUTING EDUCATION? 37

2.2.3.3 ISSUE: GENDER AND COMPUTING 39

2.2.4 BALLET: BEHIND THE CURTAIN 40

2.2.4.1 BALLET AND TECHNOLOGY 41

2.2.5 PART I SUMMARY 43

PART II Context 44

2.3.1 CREATIVITY 44

2.3.1.1 CREATIVITY AND THE STEM CLASSROOM 46

2.3.1.2 CREATIVE TECHNOLOGISTS AS INSPIRATION 46

2.3.1.3 DANCE AND CREATIVITY 47

2.3.2 STEM 48

2.3.2.1 FROM STEM TO STEAM 49

2.3.2.2 DANCING WITH COMPUTING 50

2.3.3 NEUROSCIENCE 52

2.3.3.1 DANCING BRAIN 55

2.3.3.2 ETHICS BUT NOT 'THAT ETHICS' 57

2.3.4 PART II SUMMARY 60

PART III Theory and Research Ethics 61

2.4.1 THE ROLE OF THEORY 61

2.4.2 EXPLANATION OF THE NODES 62

2.4.2.1 MOVEMENT AS KNOWLEDGE: DANCING BRAIN. 62

2.4.2.2 THE VISUAL. 63

2.4.2.3 ABSTRACTION AS METAPHOR 64

2.4.2.4 PLAY 65

2.4.2.5 COMPUTER SCIENCE CONCEPTS 66

2.4.2.6 COMPUTING PEDAGOGY 67

2.4.3 RESEARCH ETHICS 67

2.4.4 PART III SUMMARY 68

2.5 Conclusion 69

CHAPTER THREE: ONTOLOGICAL KALEIDOSCOPE, THEORETICAL FUSIONS 71

3.1 What is the Ontological Kaleidoscope? 72

3.2 Consideration of Theories 73

3.2.1 POSTHUMANISM 74

3.2.2 CONSTRUCTIONISM IN COMPUTING: AN ORIGIN STORY 76

3.3 Concepts 79

3.3.1 ENTANGLEMENT 79

3.3.2 RELATIONALITY 81

3.3.3 DIFFRACTION 82

3.4 Data-Ethics Context 83

3.4.1 ETHICS OF COMPUTING 85

3.4.2 DESTROYING SUBJECT (DOMAIN) SILOS 88

3.4.3 XR IMMERSIVE, SIMULATION 92

3.4.4 BODY DATA AS AN ARTEFACT 96

3.5 The Ontological Kaleidoscope **98**

CHAPTER FOUR: METHODOLOGICAL MUSINGS **102**

4.1 Introduction **102**
4.1.1 AgileDBR origins **103**
4.2 General Methodological Discussion **104**
4.2.1 MIXED METHODS *105*
4.2.3 ETHICS OF MMR *106*
4.3 Plausible Alternatives **106**
4.3.1 ACTION RESEARCH *107*
4.3.2 Case Study **107**
4.3.3 GROUNDED THEORY *108*
4.3.4 BRICOLAGE. *109*
4.4 DBR the What and the Why? **110**
4.4.1 HISTORY OF DBR *112*
4.4.2 RATIONALE FOR SELECTING DBR *112*
4.4.3 BUILDING AND GENERATING THEORY THROUGH DBR. *114*
4.5 DBR according to Bakker **115**
4.5.1 DESIGN BASED RESEARCH: CONJECTURES AND PRINCIPLES *117*
4.5.2 FROM MAPS TO PRINCIPLES *118*
4.5.3 DESIGN PRINCIPLES IN DATADRIVENDANCE (DDD) *119*
4.5.3.1 SPOTIFY'S DESIGN PRINCIPLES 120
4.5.4 TUMULTUOUS TERMINOLOGY *122*
4.5.5 LIMITATIONS OF LEXICON *124*
4.5.6 SUMMARY *125*
4.6 What is Agile **126**
4.6.1 DBR AND AGILE: ALIGNMENT WITH INDUSTRY PRACTICES *126*
4.6.2 DBR ITERATIONS/CYCLES *127*
4.6.3 AGILE TOOLS FOR DBR *129*
4.7 Data Analysis **130**
4.8. Summary **131**

CHAPTER FIVE: METHODS **132**

5.1 Introduction **133**
5.2 Timeline Grid of PhD **133**
5.3 All Participants **135**
5.4 Materials **137**
5.4.1 PHYSICAL AND VIRTUAL SPACES *138*
5.4.2 ICONOGRAPHY *138*
5.4.3 AGILEDBR DOCUMENTATION *139*
5.4.3.1 VISION BOARD 140
5.4.3.2 PROJECT INCREMENT BOARD (PI 141
5.4.3.3 SPRINT PLANNING AND REVIEW 142
5.4.3.4 TEST AND LEARN CARDS 143
5.5 Instruments **145**
5.5.1 QUESTIONNAIRES *145*
5.5.2 INTERVIEWS *146*
5.5.3 BIOMETRIC DATA MOTION CAPTURE *147*
5.5.3.1 EPISODIC BALLET 148
5.5.4 DATA CAPTURE, GENERATION, MANAGEMENT, AND STORAGE *148*
5.5.5 DATA TYPES *150*
5.6 Data Analysis **151**
5.6.1 QUESTIONNAIRE ANALYSIS *154*
5.6.2 INTERPRETATIVE PHENOMENOLOGICAL ANALYSIS (IPA) *154*
5.6.3 AGILE ANALYTICS *155*
5.6.4 AI-IMAGERY *156*
5.7 Ethics **156**
5.7.1 CONFIDENTIALITY AND ANONYMITY *157*
5.7.2 BALLET AND INJURY *157*
5.8 Summary **157**

CHAPTER SIX: DANCING WITH DATA – STUDY DESIGN 159
6 Introduction 160
6.1 Increment One: Literature and Scoping Pilot 162
6.2 Fieldwork 163
6.3 Summary 165
CHAPTER SEVEN: EXPLORATION AND DEVELOPMENT OF INITIAL DESIGN 166
7 Introduction 167
7.1 Technological development 167
7.1.1 TECHNICAL DEVELOPMENT OVER TIME USING AGILEDBR DOCUMENTATION 171
7.1.1.2 WEEKS ONE-FOUR 172
7.1.1.3 WEEKS FIVE-EIGHT 173
7.1.1.4 WEEKS NINE–TWELVE 174
7.2 Overview by Cohort 175
7.3 Understanding Ballet in Relation to Post-Pose Estimation 177
7.3.1 DIVERGENCE-CONVERGENCE 178
7.3.2 CONVENTIONAL AND NON-CONVENTIONAL MOVEMENTS 179
7.3.3 MACHINE LEARNING MODEL 181
7.4 Ballet and Computing 181
7.4.1 CONVERGENCE: COMPUTING WITH CLASSICAL BALLET 182
7.4.2 MOVEMENT AS KNOWLEDGE – SOMATIC 184
7.5 Meaning through Data 184
7.5.1 MEANING THROUGH INTERACTION 185
7.5.2 HUMANISING DATA 186
7.6 Data-ethics for PGCE Computing 187
7.6.1 BOLT-ON-ETHICS 188
7.6.2 DATA ETHIC AS A CORE 189
7.7 Barriers 192
7.7.1 LICENSING AND SOFTWARE USAGE 192
7.7.2 TECH – NOT INCLUSIVE, NOT NEW 192
7.7.3 PGCE CONSTRAINTS 193
7.8 Summary: Inspect and Adapt 195
7.8.1 UPDATE CONJECTURES 196
7.8.2 INITIAL DESIGN ONE 196
CHAPTER EIGHT: TESTING AND IMPLEMENTING OF DESIGN ONE 197
8 Introduction 198
8.1 Implementing Design One 200
8.1.1 SESSION DESIGN AND DELIVERY. 200
8.2 Analysis and Findings 202
8.2.1 QUESTIONNAIRE DATA 202
8.2.2 BALLET AND COMPUTING ALIGNMENT 203
8.2.3 FEAR 207
8.2.4 CROSS-CURRICULAR EEG DATA 209
8.2.5 CODING COMPETENCY 212
8.2.6 CLASSIFICATION AND CATEGORISATION 214
8.2.7 DANCING WITH P5.JS 216
8.2.8 TIME 217
8.2.9 SUMMARY 218
8.3 Summary of Design One: Inspect and Adapt. 219
CHAPTER NINE: IMPLEMENTATION AND TESTING OF DESIGN TWO 221
9 Introduction 222
9.1 Implementing Design Two 223
9.1.1 SESSION DESIGN AND DELIVERY 223
9.2 IPA Analysis 225
9.2.1 BALLET PROTOCOLS VIDEO(S) 225
9.2.1.1 PRECISION 226
9.2.1.1 NON-CONVENTIONAL MOVEMENTS 229
9.2.2 EEG (GRAPH) TEST CARD 231

9.2.2.1 PLANNING WITH AND FOR TECHNOLOGY 232
9.2.2.2 DIGITAL REPRESENTATION 234
9.2.2.3 LIABILITY 237
9.2.3 LEGISLATION AND CONTROL 237
9.2.4 TEST 3D MODEL AND P5.JS 240
9.3 Summary of Design Two: Inspect and Adapt 243

CHAPTER TEN: IMPLEMENTATION AND TESTING DESIGN THREE 245

10 Introduction 246
10.1 Implementing Design Three 247
10.1.1 SESSION DESIGN AND DELIVERY 247
10.2 IPA Analysis 250
10.2.1 FRAMEVR FEATURE 250
10.2.2 NEUROTECHNOLOGY 254
UNDERSTANDING THE BRAIN 254
BODY BECOMING DATA 256
THE COMPLEXITY OF THE COMPUTING 258
10.2.3 MS LEARN AND CODED BIAS CLIP 260
10.2.4 P5.JS FEATURE. 263
SURVEILLANCE 264
ML/AI 265
10.2.5 POSTPOSE-ESTIMATION AND COMPUTING. 267
LICENSING 267
10.3 Summary of Design Three: Inspect and Adapt 271

CHAPTER ELEVEN: DISCUSSION 274

11. Introduction 275
11.1 CROSS ITERATION GROUP EXPERIENTIAL THEMES 277
11.2 Discussion and Review 278
11.2.1 REVIEWING THE DEVELOPMENT OF THE INTERVENTION 278
11.2.2 RAISING AWARENESS OF DATA-ETHICS 280
DATA-ETHICS 281
AI/ML 283
A CONSIDERATION OF NEUROETHICS 284
11.2.3 WIDENING PARTICIPATION 285
THE TRANSDISCIPLINARY APPROACH 286
COMBINING BALLET WITH COMPUTING 287
11.2.4 SECTION SUMMARY 289
11.3 Methodological 289
11.3.1 DID IT WORK? 290
11.3.2 BROADER EDUCATIONAL METHODOLOGICAL RESEARCH 291
11.3.3 SECTION SUMMARY 292
11.3 Summary 292

CHAPTER TWELVE: CONCLUSION 294

12 Introduction 295
12.1 Summary of Findings 295
12.2 Limitations and Mitigations 296
12.2.1 THE STUDY 296
12.2.2 CREDIBILITY 297
12.2.3 SCALABILITY 297
12.3 Contribution to Knowledges, Practices, and Methodology 298
12.3.1 KNOWLEDGES CONTRIBUTIONS AND RECOMMENDATIONS 298
12.3.2 PRACTICES CONTRIBUTIONS AND RECOMMENDATIONS 299
12.3.3 POLICY CONTRIBUTIONS AND RECOMMENDATIONS 300
12.3.4 AGILEDBR AS A METHODOLOGICAL APPROACH FOR ACADEMIC RESEARCH 301
12.4 Further Research 303
12.5 Conclusion 304

REFERENCES 305

APPENDICES 359

1A RESEARCH DISSEMINATION 359
3A HARAWAY 360
4A MIXED METHODS 361
4B CONJECTURE MAPPING ACCORDING TO SANDOVAL. 364
4C DOT VOTING 370
4D AGILE MANIFESTO 371
5A MINISITE 372
5B BORING AVATARS (BORINGAVATARS.COM) 373
5C CONSENT FORM 374
5D PARTICIPANT BOOKLET 376
5E QUESTIONNAIRE 380
5F INTERVIEW SCHEDULES 384
5G DATA ANALYSIS PLANNING TABLES 386
5H QUESTIONNAIRE STATISTICAL TESTS 388
5I NATURAL LANGUAGE PROCESSING (NLP) 390
5J EEG PROTOCOLS 394
6A LITERATURE & PILOT FINDINGS 395
6B PILOT STUDY SESSION STRUCTURE 404
7A RETROSPECTIVE EXAMPLE 405
7B PGCE LEAD EXTRACT 406
8A ML P5.JS CODE 407
8B FRAMEVR 408
9A FACEMESH CODE WITH & WITHOUT VIDEO 410
10A P5.JS MIC CODE 411
10B: DATA SONIFICATION PYTHON 412
10C: DATA SONIFICATION SONIC PI 414
11A CROSS-ITERATION ANALYSIS DEVELOPMENT 415
11B CROSS ITERATION THEMES RELATING TO AI 426

Note: Appendices are indexed by chapter then letter, not all chapters have appendices.

List of Figures

2.1 Zero Trust Methodology, Microsoft 29
2.2 Cyber First Gov.UK Advert (ballet) 40
2.3 Csikszentmihalyi Systems Model of Creativity 44
2.4 Waveform (Carter, 2018) 47
2.5 Summary of Brainwave Bands and Functions 54
2.6 Mind the Gap 56
2.7 My Alignment of Ed-Tech Ethic Principles and Zero Trust Methodology 58
2.8 Role of Theory Nodal Map 62
2.9 Movement as Knowledge: Dancing Brain 63
2.10 Cognitive Theory of Multimedia Learning 63
2.11 Conceptual Metaphor Theory 64
2.12 Theory of Play 65
2.13 Computing Content 66
2.14 Pedagogy 67
2.15 Data Governance Qs 68
3.1 Venn diagram of study 71
3.2 Ontological Kaleidoscope diagram 72
3.3 States within the Ontological Kaleidoscope 73
3.4 Kandinsky's Curves 95
3.5 EEG Data and Ballet 96
3.6 3D Character with 'skin and hair' textured meshes applied. 97
3.7 Live Skeleton Tracking (with errors) using MocapNet2 and BVH software 97
3.8 3D Model of Dancer, FrameVR screenshot 100
4.1 Spotify's Design Principles 2013 and 2020 121
4.2 SAFe Lean UX model 123
4.3 Fab Matrix 124
4.4 Epics Hypothesis 124
4.5 Waterfall versus Agile 127
4.6 Original and Modified Vision Board 129
4.7 Roadmap 130
5.1 Chapter Header image: Research Engine 132
5.2 Timeline 133
5.3 Literature Mapping–Connected Papers 134
5.4 Iconography 139
5.5 'boring avatars' 139
5.6 Vision Board 140
5.7 Complete Vision Board 141
5.8 Planning Increment (PI) Board Blank 142
5.9 Sprint Board 143
5.10 Test Cards 144
5.11 Learn Cards 145

5.12 Emotiv Insight Headset 147
5.13 Data Questions 150
5.14 Data Analysis Matrix 153
5.15 Data analysis plan including sub questions 154
6.1 AI-imagery Chapter header image 159
6.2 Study design 161
6.3 Research Questions 162
6.4 Increment One – Literature & Pilot 162
6.5 Increment Two – Design Phase 164
6.6 Increment Three – Implementation & Testing 164
7.1 Ai-imagery Chapter header image 166
7.2 Increment Two 168
7.3 Posenet Joint Positions 169
7.4 [data]storm Ballet body position 170
7.5 [pain]byte penché 170
7.6 PI Board 172
7.7 Sprint Board 173
7.8 Test: Awareness of Ballet Movements for Motion Capture 177
7.9 Learn: Ballet for Mocap 178
7.10 Learn: Ballet for Mocap II 180
7.11 Test: Alignment of Ballet & Computing 182
7.12 Learn: Convergence - Computing with Classical Ballet 183
7.13 Learn: Alignment of Ballet and Computing 184
7.14 Learn: Meaning through Data 185
7.15 Exploratory Notes 187
7.16 Learn: Bolt-on Data-ethics 188
7.17 Test: Data-Ethics and PGCE – interview 189
7.18 Learn: Data-Ethics is fundamental 190
7.19 Learn: Biometrics for data-ethics 191
7.20 Learn: Constraints 194
7.21 Learn: Constraints 194
8.1 AI-imagery Chapter header image 197
8.2 Study Design Increment 199
8.3 Chart: Computing Competencies 203
8.4 Test: Ballet Video 204
8.5 Learn: Alignment 206
8.6 Learn: Alignment 207
8.7 Learn: Alignment 207
8.8 Learn: Fear 208
8.9 Dancer Wearing Emotiv Headset 209
8.10 Test: EEG Brain Visualisation 210
8.11 Learn: Cross-curricular 211
8.12 Learn: Cross-curricular music 212

8.13 Learn: Cross-Curricular Music 213
8.14 Learn: EEG Coding Competency 215
8.15 Test: P5.js 216
8.16 Learn: Coding Competency 217
8.17 Feature/Conjecture Effectiveness 219
9.1 AI-imagery Chapter header image 221
9.2 Test: Protocols Video Feature 225
9.3 Learn: Precision 1 227
9.4 Learn: Precision 1I 228
9.5 Learn: Nonconventional Movement 230
9.6 Test: EEG and Neuroethics 232
9.7 Learn: EEG and Neuroethics 234
9.8 Learn: Digital Representation. 235
9.9 Learn Digital Representation II 236
9.10 Test: EEG Education Study China 238
9.11 Learn card theme legislation and control 239
9.12 Learn: Assessment 242
9.13 Feature/Conjecture Effectiveness 244
10.1 AI-imagery Chapter header image 245
10.2 Test: FrameVR 250
10.3 Learn: Access 252
10.4 Learn: Access II 253
10.5 Learn: Understanding the Brain 255
10.6 Learn: Body Becoming Data 257
10.7 Learn: Aesthetics & Complexity 259
10.8 Test: Microsoft Online Course 261
10.9 Test: Coded Bias 262
10.10 Learn: Surveillance 263
10.11 P5.js Facemesh code output 264
10.12 Learn: ML in the Classroom 266
10.13 Postpose-estimation Errors 268
10.14 Learn: Transdisciplinary confidence 269
10.15 Learn: Transdisciplinary confidence II 270
10.16 Feature/Conjecture Effectiveness 272
11.1 AI-imagery Chapter header image 274
11.2 Themes – Trello design implications 276
11.3 High-level Study Design Diagram 279
12.1 AI-imagery Chapter header image 294
12.2 Answering Research Questions 295

List of Tables

2.1 Literatures Relating to the Key Components and Link to my Study 23
2.2 Sample of Recent Studies 26
4.1 Studies showcasing DBR's flexibility, uncertainty, and theoretical 111
4.2: Design Principles and descriptions (adapted from Cremers et al., 2017) 120
4.3 Methodological synergies A. Modification of table by Bakker (2019:15) 125
5.1 Data Types 151
6.1 Fieldwork Grid in weeks 163
7.1 Features-Conjectures Design Phase 175
8.1 Features-Conjectures Design One 200
8.2 Time theme 218
9.1 Iteration Design principles 222
9.2 Features-Conjectures Design Two 224
10.1 Design principles 246
10.2 Features-Conjectures Design Three 249
11.1 Ryder Review Recommendation 277

List of abbreviations/acronyms

Acronym	Definition
AC	Acceptance Criteria
ACM	Associated for Computer Machinists
AI	Artificial Intelligence
AP	Advanced Placement
AQA	AQA, formerly the Assessment and Qualifications Alliance, UK.
AR	Augmented Reality
ARCS	Attention, Relevance, Confidence, and Satisfaction
BCI	Brain Computer Interface
BCS	British Computer Society
BERA	British Educational Research Association
BH	Benefits Hypothesis
BTEC	The Business and Technology Education Council
BVH	BioVision Motion Capture
CCTV	Closed Circuit Television
CEN	Centre for Educational Neuroscience
CLT	Cognitive Load Theory
CMT	Conceptual Metaphor Theory
CMTL	Cognitive Load Theory of Learning
COI	Conflict of Interest Categories
CPD	Continual Professional Development
CREST	The Council for Registered Ethical Security Testers
CS	Computer Science
CSEC	The Caribbean Examinations Council is an examination board in the Caribbean
CSIR	Case study intervention research
CSMS	Complex systems metaphor system
CSV	Comma-separated Values
CTML	Cognitive Theory of Multimedia Learning
DBR	Design-Based Research
DDD	DataDrivenDance
DfE	Department for Education, Gov.UK
DL	Digital Literacy
DP	Design Principles
DR	Design Research
EEG	Electroencephalogram
EH	Epic Hypothesis
EI	Ethics of Information
EYFS	Early Years Formal Schooling
FAB	Features & Benefits Hypothesis (FAB matrix)
FDD	Feature Driven Development

FPF	First Person Follow
FPS	Frames per second
GCHQ	UK Government Communications Headquarters
GCSE	General Certificate in Secondary Education
GDPR	General Data Protection Regulation
GET	Group Experiential Themes
GISP	Global Innovations and Science Project
GNU	GNU's Not Unix!
GPL	General Public License
GPT	Generative Pre-trained Transformer
GT	Grounded Theory
GV	Google Ventures
HCI	Human Computer Interaction
HE	Higher education
ICO	The Information Commissioner's Office is a non-departmental public body which reports directly to the Parliament of the United Kingdom and is sponsored by the Department for Digital, Culture, Media and Sport
ICT	Information Communication Technology
IDR	Interdisciplinary Design Research
INRIA	Institut national de recherche en sciences et technologies du numérique
IP	Increment Planning
IPA	Interpretative Phenomenological Analysis (not the beer)
IT	Information Technology
ITT	Initial Teacher Training
JS	JavaScript
JSON	JavaScript Object Notation
LED	Light Emitting Diode
LFR	Live Facial Recognition
MIT	The Massachusetts Institute of Technology
ML	Machine Learning
MMR	Mixed Methods Research
fMRI	Functional Magnetic Resonance Imaging
MS	Microsoft
MVP	A Minimum Viable Product
NCCE	National Centre for Computing Education
NCSC	National Cyber Security Centre
NLTK	Python package: Natural Language Toolkit
NPC	Non-Playable Characters
NPD	National Pupil Database
NPL	Natural Language Processing
NQT	Newly Qualified Teacher
NSF	National Science Foundation
NVQ	National Vocational Qualifications

OCR	Oxford, Cambridge, and RSA. A UK qualification awarding body
ODI	Open Data Institute
OECD	Organisation for Economic Co-operation and Development
OED	The Oxford English Dictionary
PE	Physical Education
PES	Personal Experiential Statement
PET	Personal Experiential Theme
PGCE	Post Graduate Certificate in Education
PHSE	Personal, Social, Health and Economic education
PI	Program Increment
POPM	Product Owner/Product Manager certification
PPE	Postpose Estimation
QTS	Qualified Teacher Status
RAD	Royal Academy of Dance
RCT	Randomised Control Trials
RE	Religious Education
RIAD	Rhythm Is A Dancer
RIMMS	Reduced Instructional Materials Motivation Survey
RQ	Research Question(s)
SAFe	Scaled Agile Framework
SDK	Software Development Kit
SEND	Special educational needs and disabilities
SKE	Subject Knowledge Enhancement
SMS	Short Messaging Service
STEAM	Science, Technology, Engineering, ARTs, & Maths
STEM	Science, Technology, Engineering, & Maths
TEF	Teaching Excellence Framework
TRACER	The Roehampton Annual Computing Education Report
UF	User Flow
UI	User Interface
UJ	User Journey
UX	User Experience
VCL	Virtual Computing Labs
VR	Virtual Reality
WIP	Work In Progress
XR	Extended Reality

Chapter One: Introduction

Data permeate our modern society (Livingstone, 2018), and a rise in data collection accompanies this omnipresence. The collection of data from many different sources and for a myriad of purposes has raised the thorny issues of user consent and the ethical use of data, as potentially private information is stored and shared rapidly and globally. To deal with this rising concern and operate a functioning, technologically progressive society, we need to establish an ethical awareness of personal data (RQ1) and how or where they are used. This may be achieved through widening the availability of computing education, ensuring that a larger proportion of the general public are aware of these issues and may participate in informed debates (RQ2). This aim aligns with the fourth aim of the Programme of Study for Computing in England (Department for Education (DfE), 2013, 2014) which emphasises the need to develop responsible, competent, confident, inventive, and ethical users of information and communication technology. This study aims to raise awareness of data-ethics using creative computing, biometrics, and ballet with/for trainee computing teachers. (RQ3) explores the potential of the methodological fusions, entanglements of Agile and Design-Based Research (DBR).

My training as a secondary computing educator and my current role as a university lecturer in Digital Media and Post-Graduate Certificate in Education (PGCE) computing have developed my extensive knowledge and experience of how to address the complex challenges and imbalances present within the computing classroom. My training as a ballet dancer inspired the subject of these large-scale, data-driven ballet performances centred on computing that underpin this study. This innovative combination produced [arra]stre ballet (made possible by Arts Council England funding) prior to the launch of the new programme of computing education across England in 2014. My project consisted of a mixture of ballet performances and educational workshops and contributed to my Google Rise Award for computing education in the same year.

This study examines the use of creative computing education to raise awareness of ethical concerns surrounding personal data collection and use. My research explores the potential of DataDrivenDance and biometric data as narrative and creative tools for teaching data-ethics and evaluating different design features that align with the pre-university computing curriculum in England. Rather than simply analysing the legal frameworks that control and preserve data, this study adopts a creative approach to explore these concerns in depth. My

findings critically evaluate computing education, highlighting how it may be used to enhance awareness of personal data-ethics and nurture a generation of responsible, competent, and ethical users of information and communication technology.

My study was guided by three main research questions:

RQ1: How can we raise awareness of data-ethics for trainee computing teachers?

RQ2: What new insights and unexplored approaches are there in combining classical ballet and biometric data to broaden participation in computing education?

RQ3: Is AgileDBR as an effective methodological approach for educational academic research? If so, how?

The first research question (RQ1) explores effective strategies for enhancing trainee computing teachers' awareness of data-ethics through biometrics and creative computing. RQ2 explores the potential for using ballet and biometrics as means to alternative pathways in computing education. Lastly, the third research question (RQ3) examines the effectiveness of AgileDBR as a methodological approach for educational academic research. This research seeks to advance our knowledge of computing education, offering insights into innovative and effective strategies for promoting data-ethics, enhancing participation, and adopting a robust methodology for educational research.

My study employs an AgileDBR methodology, an innovative entanglement of Design-based research (DBR) (Bakker 2018), blended with Agile (Pichler, 2010, 2020; Bland & Osterwalder, 2018; Scaled Agile Framework, SAFe 5, *2021*) processes and practices (discussed in Chapters Four and Five). The iterative nature of both Agile and DBR mean that the research cannot develop until each design iteration has been implemented. Although this written thesis follows a more traditional structure, it is organised and documented according to AgileDBR practices developed from this study. Many DBR studies struggle with the tension between theory and design, so I implemented Agile as a bridge between the two, an approach which aligns with Bakker's (2018) integration of design into research (theory generation). My study is organised into 12 chapters, detailed below.

Chapter One provides an introduction to this thesis, outlining my methodology and research questions/aims. Chapter Two presents a literature review in three parts, the first of which covers key components of data-ethics for the computing classroom, initial teacher training,

and an introduction to computing (Furber et al., 2012; Solomon, C., 1986; Kemp et al., 2018) and ballet (Balanchine, 1958; Babbage, 2011[1840s]; Noverre, 1783). The second part provides the context for the study, including creativity (Glăveanu, 2013, Chappell, 2018), STEM/STEAM (Colucci-Gray et al., 2017), and neuroscience (Farahany, 2012). Finally, I discuss theory and research ethics. Chapter Three explores the theoretical foundations of the study, drawing on posthumanism (Barad, 2007; Bayley, 2018), constructionism (Harel & Paper, 1991) and the ethics of information and data to offer different lenses through which to conduct my research. Chapter Four explores my methodology, and presents plausible methodological alternatives, including an overview of mixed methods research, DBR, Agile, and the fusion of the two as AgileDBR. Following on from this, Chapter Five provides a detailed description of the participants, materials, AgileDBR methods, and analysis approaches used in the study.

The next four chapters present the findings and analysis from each iteration of the study design. Chapter Six explains this design in detail, while Chapter Seven follows the development of the initial educational intervention design. Chapter Eight covers the implementation and testing of design iteration one, and Chapters Nine and Ten reflect design iteration two and three respectively.

The last two chapters conclude the study. Chapter Eleven discusses the findings and cross-iteration themes, exploring the implications of the findings with the research questions and methodological implications in mind. Chapter Twelve highlights the primary findings and contributions in biometrics for creative computing and ethics, motion capture (postpose-estimation (PPE), Machine Learning (ML)) for computing ethics, coding and classical ballet, and the methodological contribution of AgileDBR. The study promotes ethical considerations in computing through interactive, real-time generative programming, emphasising the importance of humanising data to raise awareness of data-ethics.

Note: All appendices are indexed by chapter therefore do not necessarily follow a chronological order. Some chapters have many and some have none.

Chapter Two: Literature Review

2.1 Prelude

This chapter is divided into three parts: key components, context, and theory. The literature review highlights previous research and works (performances, art works, etc.), situating this study in reference to current debates around data-ethics, computing education (including pre-service teacher training), and ballet, and provides additional background to inform the chapter/thesis. My study provides participants with the opportunity to experience creative practices when exploring the ethical and social justice implications of future technologies, focusing on pre-university computing education. The two main considerations that fuelled this research led to the RQs are as follows:

How could awareness of data-ethics, specifically biodigital ethics, be raised for/with PGCE Computing teachers? (RQ1)

How could we broaden participation in computing education at the pre-university level using Arts practice? (RQ2)

These questions guided my research, leading to the eventual adoption of the AgileDBR methodological route.

This literature review identifies both academic and grey literature (e.g., reports, blog posts, exam board specifications) related to data-ethics in computing education. My review was conducted using six digital libraries: IEEE Xplore, ACM Digital Library, Google Scholar, Science Direct, Springer Link, and Web of Science. The initial search terms used were ‘data-ethics’ and ‘computing education,’ to which I added ‘ballet’ and ‘computing’ for a more thorough overview. Search parameters were narrowed by year following the initial rounds (sprints) of the literature review.

Data, ethics, motivation, and creativity developed as prominent themes within this field, all of which are fundamental to understanding the current state of PGCE computing education, specifically data-ethics as a topic. These themes provided the main sections of the review, with central pieces of literature establishing each section as follows: the Data section uses the TRACER report (Kemp & Berry, 2018, 2019) that highlights decline in female students; Ethics draws on Farahany et al. (2018, 2020), Farahany (2012, 2023), and Floridi (2011–

2018); Motivation centres on Mishkin (2019); and Creativity focuses on Glăveanu (2013), Csikszentmihalyi (1988, 2014), and Chappell (et al., 2009, 2018, 2022).

2.1.1 Clarifying Scope

To understand the interactions, affordances, and gaps within computing education delivered via arts practices, I adopted a specific focus throughout my literature review. First, I define key terms in order to clarify my discussion of the foundational literature in this field. As with many new domains, there is sometimes a lack of clarity or coherence in defining 'computing education.' The wider field of Computer Science (CS) in its current form is also relatively recent, established by Alan Turing's work during the Second World War. CS courses were offered exclusively at A-Level and above in England until OCR launched the first GCSE course in 2012 (Dallaway, 2016, 2020, 2022). As my study focuses on trainee computing teachers, this timeline narrows the available literature.

The subtle differences in CS and computing are distinguished below to ensure that the reader understands the terms (a) computing education, (b) neuroethics, and (c) DataDrivenDance:

Computing education goes beyond CS theory to include digital literacy and Information Technology. Furber et al. (2012) define three core components of computing: (i) computer science, the rigorous academic discipline, encompassing programming languages, data structures, and algorithms; (ii) digital literacy, the general skills and ability to use computers; and (iii) Information Technology, the use of computers in industry, commerce, the arts, and elsewhere, using aspects of IT systems architecture, human factors, project management, and more (Furber et al., 2012).

Neuroethics refers to the ethical issues raised by our increased, constantly improving understanding of the brain (Salles et al., 2019).

DataDrivenDance (DDD) is a data-first approach to classical ballet productions using ballet as a narrative device to express computer science theories and concepts such as algorithms or data-ethics. This approach offers both challenges and opportunities for the computing classroom and the dance studio, and uses human movement data collection and brainwave data recording. The technical processes developed through this study were modified where necessary for classroom use, which took considerable time and required significant choreographic modification, but allowed participants to create processes that worked for them in their specific environments. Beyond the performances, both resources and workshops were

developed to share how we achieved the technologically enhanced performances and experiences. DDD is designed as an engaging tool to aid the understanding of computing, both technical and theoretical.

My review draws on van Laar et al.'s (2017) systematic literature review, which highlights key areas of digital skills and teaching, including: Collaboration, Creativity, Critical Thinking, Communication, Information Management, Technical, and Problem-Solving. These areas are instrumental to my interdisciplinary study, and inform current ethical debates in the field of creative computing education.

Part I Key Components

This section explores the broad range of existing literature on foundational areas of my research, including data-ethics, me++ see 3.3.4, computing, and dance/ballet. Table 2.1 outlines key studies of methodological or general significance to this study, and range from 2014 to the present day (with a few older texts included as context). This time span is appropriate to my research interests as it encompasses key legislative and educational advances in computing education.

Table 2.1 *Literatures Connecting to the Key Components and How They Link to my Study, Listed in Reverse Chronological Order*

Source: Author (year), title	*Connection to my study*
Reeve et al. (2022), Mapping Data ethics Curricula	The authors advocate for a more comprehensive and interdisciplinary approach to data-ethics education including both technical and societal perspectives.
Franzke (2021), An Exploratory Qualitative Analysis of AI Ethics Guidelines	This paper reinforces the need to ensure that data are ethically managed in terms of what and how data are collected, stored, and manipulated. Franzke examines AI ethics, but the same principles apply to data-ethics. The paper explains ethics in relation to AI, and outlines the importance of implementing AI ethical guidance.
Shapiro et al. (2020), Re-Shape: A Method to Teach Data Ethics for Data Science Education	Shaprio et al. state that there is 'little research on ethics education in computer science that explicitly addresses data-ethics.' Their study is aimed at HE and tailored to Human Computer Interaction (HCI) within computer science, and is thus highly relevant to my work.
Grosz et al. (2019), Embedded EthiCS: Integrating Ethics Broadly Across Computer Science Education	This HE study aimed to bring ethics, via philosophy, directly into the core of the CS curriculum. The paper takes an interdisciplinary approach to CS education, considering not only how innovative computer systems are built, but also how they should be built.

Source: Author (year), title	*Connection to my study*
Kemp et al. (2016, 2018, 2019), TRACER: The Roehampton Annual Computing Education Report	This report underlines the importance of involving more girls in this male-dominated field, an issue compounded by the removal of ICT from the curriculum in 2017. Further reports from Kemp and Berry have confirmed some of their negative predictions.
Banerjee et al. (1998), Modelling IT Ethics: A Study in Situational Ethics	Benerjee et al. consider IT Ethics within an industry context using ethical dilemmas, and how PGCE educators could use these specific examples in their own classrooms. Although this study is industry focused, it provides insights into situational ethics that could be modified for classroom use.
Solomon (1986), Computer Environments for Children	Solomon's work illuminates what computing is and could (should) be as a school subject. Although this is an older study, it provides important pedagogical approaches which could be implemented in the classroom.

Table 2.1 highlights the need for an interdisciplinary approach to data-ethics education, across sources. The topics relate to data-ethics and CS education, including the ethical management of data in AI, the integration of ethics across the computer science curriculum. Address situational ethics in IT, providing valuable insights that can be applied to the design and delivery in this study. Additionally, the pedagogical approaches presented in Solomon's (1986) work serve as an important reminder of the potential impact of CS education on students' learning experiences. These studies provide valuable insights into the various ways in which I could integrated data-ethics into my design, and highlighting the importance of using an interdisciplinary modality with my participants.

2.2.1 Data-ethics for the Computing Classroom

This section considers the role of data both in this study and in the classroom, and focuses on how data generated by this research have been created, processed, stored, and analysed. The use of biometric data makes these considerations all the more vital, as it invites debates around legislation and ethical/security issues, which I discuss alongside the processes and tools used in this study.

This study, owing to the fully online modality, adopted the 'privacy by design/default' approach to data protection, meaning that data protection requirements were fundamental to the systems and processes from their inception. This aligns with RQ: raising awareness of data-ethics.

The GDPR (*General Data Protection Regulation*, 2016) was of great relevance to my research, as it concerns setting out data protection and privacy guidelines, and indeed this privacy by design approach follows Article 25 of the GDPR. I focus particularly on Sections Two (Security of Personal Data) and Three (Data Protection Impact Assessment and Prior Consultation), as these are most relevant to my study. Additionally, the IEEE 2089–2021 Standard, also referred to as the Children's Code (*2089–2021—IEEE Standard for an Age-Appropriate Digital Services Framework Based on the 5Rights Principles for Children*, 2021) plays a role in initial teacher education and use of personal (including biometric) data in the classroom.

It is important to note here the difference between data collection and research data. Data collection refers to a wide range of methods and purposes of recording different types of information, and spans industry, personal use, and other fields outlined above. Research data are specific to academic contexts, and refers to information in digital, computer-readable, or paper-based format, defined by Berghmans et al., 2017 and the Research Data Team at Cambridge University as that which is:

i. Contained or presented in various ways, including notes, facts, figures, tables, images (still and moving), audio or visual recordings, and programming code.
ii. Collected, generated, or obtained during or because of undertaking research (which includes but is not limited to conducting field or laboratory experiments, conducting trials, surveys, interviews, focus groups, or analysis of data). This data is securely held in a repository, a data storage location (data-bucket), similar to folders where you store multiple files, that the University owns or controls and makes available to researchers for the storage of research data.
iii. Subsequently used by the researcher as a basis for making calculations or drawing conclusions to develop, support, or revise theories, practices, and findings. (Berghmans et al., 2017; Research Data Team, University of Cambridge, 2015, 2021).

It is necessary and beneficial to collect data within the classroom, but educators are seldom informed where these data are stored and for what purposes they are collected. What impact does data-ethics have on the computing classroom? Data-ethics considers how (personal) data should be collected, used, and shared, and outlines the potential risks and ethical principles that should inform and guide these activities (OECD, 2016, 2018, p. 14; *Good Practice Principles for Data-ethics in the Public Sector – OECD*, 2023; Brown & Wild, 2023, p. 24).

As we rely more and more on technology and the use of big data in contemporary life, the importance of an awareness of data-ethics becomes evermore paramount. This is a relatively new field, and as such there is much to learn about its implications for individuals, organisations, and society (see table 2.2).

2.2.2 Initial Teacher Training: A Lack of Data-ethics

The initial Qualified Teacher Status (QTS) guidance (DfE, updated June 2022) defines the minimum level of practice that trainee teachers must complete before they may be awarded the status. QTS can be broken down into a core competencies framework of eight standards: behaviour management is addressed in High Expectations (S1) and Managing Behaviour (S7); pedagogy is addressed in How Pupils Learn (S2), Classroom Practice (S4), and Adaptive Teaching (S5); and curriculum (S3) is covered in Assessment (S6) and Professional Behaviours (S8). Data are referred to only once throughout this document, in the Assessment section: 'use relevant data to monitor progress, set targets, and plan subsequent lessons' (DfE, 2022). There is no obligation or mandate to understand, or even show awareness of any data-ethics, data management, or data security concerns.

Curriculum design and content are impacted by many factors, including time and resource limitations, legislation, and government guidance (specifically in times of crisis like the recent global pandemic). Teachers' access to established computing educators is also limited by their own teaching, workload commitments, and the cost, time, and space dedicated to Continuous Professional Development (CPD). These factors impact both trainee teachers (Initial Teaching Training (ITT) in England) and New teachers, who are awarded Newly Qualified Teacher (NQT) status in England.

Several studies have focused on applications of ethics to STEM subjects, but these largely focus on undergraduate course content or higher education level teaching. Table 2.2 highlights a sample of studies on ethics specifically in computing or CS-related subjects and their relevance to my research. I was unable to find a study that examined data-ethics in computing education in the specific context of trainee computing (PGCE) teachers.

Table 2.2, below, illustrates the integration of ethics specifically within computer science education. Dean & Nourbakhsh's (2022) paper proposes a reformulation of a general ethics and robotics course to include ethical considerations. Chikukla et al.'s (pre-print 2022) paper identifies, analyses, and maps existing ethics-focused methods designed for ethical impact

within Human Computer Interaction (HCI). Although the paper doesn't specifically relate to educational studies, the findings can support the development of methods to integrate ethical decision-making which is important for this study (RQ1).

Table 2.2 *A Sample of Recent Studies Covering Ethics in Computing*

Study	*Commentary*
Dean & Nourbakhsh (2022), Teaching Ethics by Teaching Ethics Pedagogy: A Proposal for Structural Ethics Intervention	This paper presents a reformulation of a general ethics and robotics course by undergraduate Ethics students, who developed an ethics module and resources for 11 CS lecturers. Although the 'creative ideas for ethics pedagogy' are highlighted throughout the paper, the main focus is the adaptation of a robotics course to include ethical considerations. **The participatory design aligns with my study.**
Chikukula et al. (pre-print 2022), Surveying a Landscape of Ethics-Focused Design Methods	The paper identifies, analyses, and maps a collection of 63 existing ethics-focused methods intentionally designed for ethical impact within Human Computer Interaction (HCI). Not all of these 63 methods are related to educational studies, and the paper focuses on design knowledge—'design states'—methods/tools that 'support thinking, reflecting, and acting upon design activities' (p. 3). **This reflexivity is core to AgileDBR**.
Bullock et al. (2021), Computing Ethics Narratives: Teaching Computing Ethics and the Impact of Predictive Algorithms	This is a repository of computing ethics modules including a variety of narrative areas, developed as part of the Computing Ethics Narrative (CEN) project. The paper describes a pilot study with CS undergraduates and associated lecturers, and the preliminary results show that students deepened their critical thinking in relation to predictive algorithms as part of a 'predictive policing module' (p. 1024). Students examined their own roles, responsibilities, biases, and ethical reasoning skills. **Storytelling is at the heart of DDD to aid in computing and data-ethics awareness**.
Grosz et al. (2019), Embedded EthiCS: Integrating Ethics Across CS Education. Communications of the ACM	This study also in Table 2.1, and concerns the social justice and ethical threat of technology and computers. The paper outlines the threat to 'democracy through the spread of propaganda on online social networks, or to [...] privacy through the aggregation of datasets that include increasingly personal information' (p. 54). **Their aim aligns directly with my study, and emphasises that CS education can help meet these challenges by centralising ethical reasoning about computing technologies within the curriculum**.
Aitken and Briggs (2022), Engaging Children with AI Ethics. Raspberry Pi Foundation Research Seminars	This paper draws on the need to **engage young people in AI ethics**. Aitken and Briggs draw on UNICEF's nine child-centred principles to ensure young voices are central in AI lifecycles, and call for the participatory engagement of young people. However, they do not specifically discuss the role of teachers or schools in this engagement.

Bullock et al.'s (2021) repository of computing ethics modules emphasizes the importance of using storytelling to aid in computing and data-ethics awareness. Grosz et al.'s (2019) study

emphasizes the need to centralise ethical reasoning about computing technologies within the curriculum to meet the ethical threats of technology and computers to social justice and democracy. Finally, Aitken and Briggs (2022) argue for the need to engage young people in AI ethics, although they don't specifically address the role of teachers or schools in their paper. Collectively, these studies highlight the importance of integrating ethics into computing education which supports (RQ1) to prepare future creators and users of technology to engage with the ethical implications of their work (RQ1, 2).

Computing educators deal with many issues that stretch beyond the confines of the subject, specifically in relation to issues of online bullying and information bias. It is necessary, therefore, to incorporate within this education an exploration of the human-self and the data-self, which I refer to as ME++, a term borrowed and repurposed from Mitchell's 2003 book *ME++ The Cyborg Self and the Networked City*. In Chapter Three, Mitchell refers to the wireless biped when describing our (biometric) data selves, interconnected with the world (environment, city, room, street, personal devices) around us and sharing and transmitting our data selves. Interactions between humans and data (non-humans) create change and the exchange of data bits and bytes. I explore this duality and even the potential plurality of ME++ in Chapter 3, Section 3.4. In programming, the symbol ++ is used for iterations and incremental increases that are fundamental to computing as a whole, and also reflect the iterative design of this study.

In order to understand and protect our data-selves, we first need to consider the (current) data security principles and regulations designed to protect data and individuals by extension. How are the datasets that reflect our personal information, including biometric data, designed to be ethically and securely stored, used, and manipulated (altered or augmented) (Shaprio et al., 2020; Banerjee et al., 1998; Friedman, 1996)?

2.2.2.1 Data Security Principles and Regulations

It is essential to understand the role of data security within data-ethics for this study. As outlined above, data security has little coverage in the computing curriculum or the training of computing teachers, despite the datafied society in which we now live (Mascheroni et al., 2020; Livingstone, 2018). Studies concerning data/information security within education tend to be conducted at university level on undergraduate and postgraduate Computing (or related) courses. For example, Konak and Bartolacci's 2016 study uses 'a virtual computing laboratory to foster collaborative learning for information security and information

technology education,' focusing on collaborative learning outcomes to improve student learning and attitudes towards laboratory assessment (Konak & Bartlocci, 2016). In this study, virtual computing labs (VCLs) refer to virtual machine environments that enable students to run multiple 'emulations' of other system hardware and software without the need for many different sets of physical devices or applications. Mainly drawing on technical design literature, the study also includes the theory of computation via Hamada's 2008 Integrated Virtual Environment and Bayer's model of collaborative-apprenticeship learning for pedagogical contexts (Konak & Bartlocci, 2016, p. 4)

There are many different approaches (models) to data security (also referred to as information security), but largely the term refers to the security, protocols, and procedures of an organisation or individual that are validated by a computer to ensure the confidentiality, protection, access, and integrity of their data. Different data security models refer to the varied directions given to the operating system to carry out/comply with the security guidelines or goals, usually relating to confidentially, integrity, and even access to data/information. Examples of some of these models are described below.

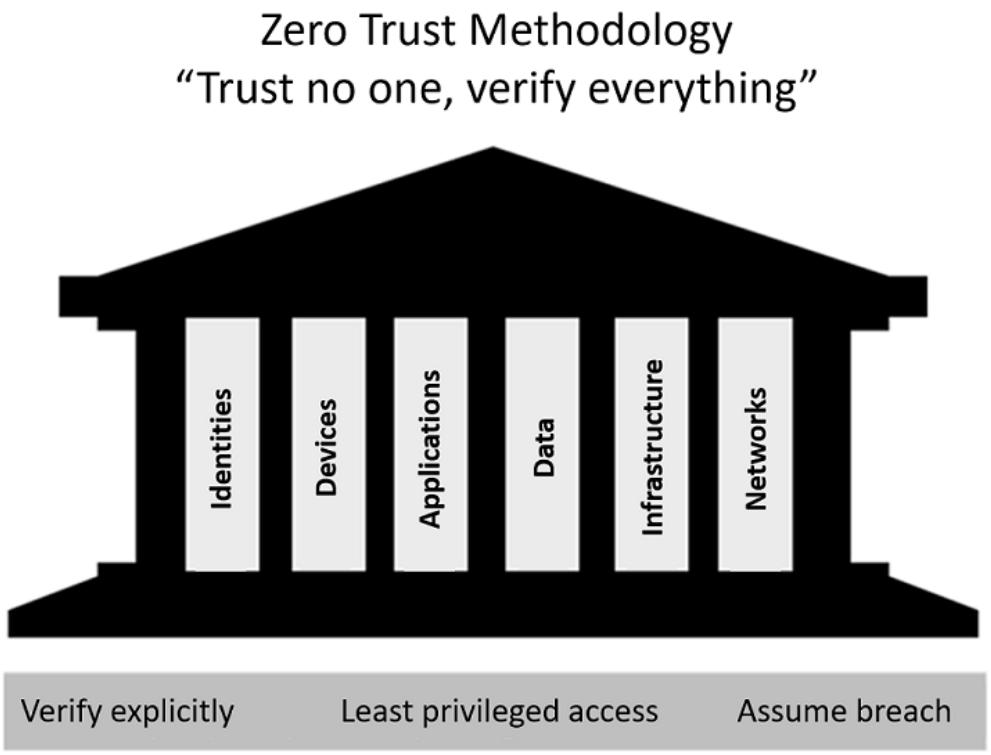
The **Brewer & Nash Model**, also referred to as the 'Chinese Wall Model,' prevents an individual, such as a consultant, from logging on to multiple systems or terminals, which Brewer and Nash term Conflicts Of Interest or COIs (Brewer & Nash, 1989). User behaviour determines how access control policies change: once an individual accesses information on one side, they are unable to access information on the other.

The **Clark Wilson Model** protects the integrity of commercial information by allowing only certified actions by explicitly authorised users (De Capitani di Vimercati & Samarati, 2011). This process ensures integrity as no resource (data or otherwise) can been changed, altered, or accessed in an unauthorised or 'improper' manner. To a certain degree, the system reflects the user's expectation of real-world representation of the stored data. This model aims to present data in their authentic form, ensuring that unauthorised changes are avoided.

Bell LaPauda's Model was originally developed by the US Department of Defence (DoD) in the 1950s, and explains the idea of a secure state and persistent, compulsory access methods. It is the initial mathematical model of a multilevel security policy and guarantees that data only move in a way that respects confidentiality and the system's policies (Bertino & Crampton, 2008).

The **Zero Trust Model** (Microsoft, 2021) provides a broader approach to security that starts with no—*zero*—trust given to all users on the system before repeatedly validating all digital interactions within that system, Fig 2.1.

Figure 2.1 *Zero Trust and Pillar of Trust—Microsoft Security Fundamentals (Microsoft, 2021)*



Zero Trust is the most appropriate for my study as it eliminates implicit trust in human and non-human actors on a system (RQ1). First, identity must be defined as the primary security perimeter. An identity in computing enables a user to be verified and authenticated as a trusted entity, and may refer to a person, an application, a device, or something else. There are four pillars of identity, defined through the four As: (i) administration, (ii) authentication, (iii) authorisation, and (iv) auditing. Administration creates and manages user, device, and service identities. An administrator manages how and when the characteristics of identities may change, be created, updated, or deleted. The level of authentication dictates how much assurance for a particular identity is needed to validate that identity, and often asks a user to provide legitimate credentials. Authorisation occurs after this initial identity data collection and assessment, and determines the level of access an authenticated user may have within the application or service that they seek to access. Auditing tracks this usage, when, where, and

how, and produces in-depth reports, alerts, and governance about the identities that interact with the application or service provided.

The GDPR update in December 2020 added a 'special category' designation for biometric data (GDPR, 2021), and there are now two obligations in relation to research data concerning the roles and responsibilities of the data controller and the data processor. In general, the data controller refers to the 'natural or legal person, public authority, agency, or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data,' and usually denotes the university sponsoring the PhD candidate or researcher, or any third party involved in the research. The data processor is the individual, agency, or other body that processes personal data on behalf of the controller (GDPR, 2016, p.10–articles 50, 51, & 53), and usually refers to the PhD candidate or researcher, following the ethical and data processing guidelines set out by their institution. All research data recordings in my study (see Chapter 5, Table 5.1) were stored on university servers.

Teaching data-ethics in schools could revolutionise the next generation's approach to computer use and data sharing, both as users and processors. Students could be made aware of the far-reaching consequences of their digital activities, and could be taught how best to handle sensitive information responsibly and protect themselves from potential harm (RQ1). As educators, it is our responsibility to ensure that students are aware of the ethical implications of data usage and are responsible when using information in their digital world (Dept for Education (DfE), 2014). To enable this progression, however, teachers must be equipped with the education and tools needed to successfully deliver this teaching which is the purpose of this study (RQ1, 2).

2.2.2.2 EthiCS: Ethics as a Taught Subject

Considering the possibility of teaching ethics (RQ1) as a subject through creative computing education (RQ2) unearths potential technical and content challenges for future education (OCED, 2023, 2018; Dean & Nourbakhsh, 2022, see table 2.2). Creative computing (data visualisation, data-art, data-sonification, and more) teaching would need to incorporate computational thinking, CS programming, and project-management skills alongside considerations of current ethical and philosophical debates such as immersive technologies, Artificial Intelligence (AI), Machine Learning (ML), and specifically personal biometric data. Although the term 'biometrics' is commonly known, biometric data are hard to visualise and are often thought of as 'hidden' data. This hidden aspect provides an interesting focus for my

discussion of data-ethics. Ethical dilemmas surrounding data ownership, control, and use of data both current and future can and should be explored in the computing classroom, as students must be made aware of the advantages and dangers of the world around them. Arts and creative practices are excellent mediums through which to express these current debates, as the use of dance as embodied learning and knowledge sharing creates shared spaces for dancers, creators, and audiences to converse both as a collective and individuals. The current literature concerning data-ethics curriculum development and creation is largely limited to Higher Education contexts. For example, Shapiro et al. (2020) use a feminist approach to ethics in their study 'Re-Shape: *A Method to Teach Data ethics for Data Science Education,*' engaging students with 'concepts of responsibility to the other, interdependence, and attentiveness to vulnerability and inequality in the socio-technical systems we design' (p. 4). Their model draws on creative approaches to teaching computing ethics, the ACM's Code of Ethics (Gotterbarn, *ACM Task Force*, 2018), game-based learning, and content case studies from computer vision and machine learning. Adapting computing courses to incorporate ethical concerns such as these could address the gender disparity in STEM and specifically CS fields (Barbeiri et al., 2020), and research could be conducted into why the majority of students do not currently opt to study computing as an examined subject at a pre-university level and beyond.

I define data-ethics (for computing education) as the broad and comprehensive topic concerning the ethical and appropriate gathering, management, use, and preservation of data that aims to protect privacy, security, and rights in data-related activities (Floridi, 2010-2013, see 3.3.4). Data-ethics requires a thorough understanding of the ethical implications and potential biases inherent in data use, as well as adherence to legal and regulatory frameworks. Developing principles for data-ethics is a challenging task, requiring both education and experience in the field, but it is an important one, leading to the protection of users and the creation of accurate information systems. Awareness of data-ethics is particularly important for computing educators, as it offers a way to negotiate the digitally mediated datafied society in which we live (RQ 1), and allows them to identify and assess the risks associated with working with data, develop policies and procedures for dealing with data ethically, educate others about data-ethics, and continue developing their own skills (RQ 1, 2).

2.2.3 What is Computing?

Computing was designed to encompass a broad range of areas, going beyond CS theories and concepts to include digital literacy (Glister, 1997) and IT (Furber et al., 2012). Integrating CS, digital literacy, and IT, the subject aims to extend understanding through interrogation and meaningful interactions with digital systems for specific purposes, and encompasses wider ethical and moral issues/questions (Serio et al., 2013). It is this combination of understanding and use which is so important in this study.

As previously explained, a distinction is made between computing and computer science in this literature review, as the former as a subject implies both the theoretical content and its application through creation and coding. CS has ancient roots, spanning from the first concept of 'zero' around 300–600 BCE, through to 1843, when Ada Lovelace became the first computer programmer (Carlucci Aiello, 2016), Shannon's 1948 mathematical theory of communication, Moore's Law (Shannon, 1948; Schaller, 1997), Berners-Lee's invention of the World Wide Web in 1987 (Berners-Lee et al., 2010), mapping the human genome in 2003 (Collins et al., 2003), to Simmons first single atom transistor in 2012 (Fuechsle et al., 2012). The field continues to develop at an incredible pace, and yet this innovative academic subject does not get the equivalent time and space in the classroom afforded to mathematics, physics, or English. This educational shortcoming is not only a UK phenomenon, and García-Cabrera (2017) found that US pre-university students are taught fewer 'computer skills than they were 10 years ago'(Garcia-Cabrera, 2017, p. 860). My study is one of many calling for action to address this imbalance.

In 2014, a new programme of study for computing was introduced in England, which was developed to address the problems with the existing ICT curriculum which had been labelled 'harmful,' and were considered to be boring and irrelevant (Gove, 2012). The withdrawal of the ICT curriculum in 2012 was intended to give teachers 'freedom' to teach how and what they thought necessary. This was not intended as a withdrawal of the subject (DfE, 2015), but rather as the possibility to redesign ICT alongside the introduction of CS. The move had good intentions, but lacked the financial, academic, and time support to help teachers through the massive transition, and opinions quickly turned sour (Vaughn, 2015).

Recruiting experienced computing teachers is also proving challenging, made evident by job adverts such as 'Appointment of a Purple Spotted Unicorn—Or Exceptional Computer Science Teacher' (TES Jobs, 2019). Humour aside, adverts like this highlight the current

challenges faced by teachers and schools. Furthermore, the change from ICT to computing has contributed to the decline in uptake of pre-university computing courses by all students. Curriculum content is often driven by the exam boards specification, and each board has similar content. Many have removed the assessed coursework component of the GCSE for this subject. CS in Higher Education and in industry are driven by projects that are often collaborative and iterative, enabling the application of academic knowledge. The removal of assessed coursework, therefore, fails to reflect this industry and academic future, and does not incentivise students to push their own knowledge, capabilities, and practices but to simply complete the requirements of an exam.

As an alternative to following traditional patterns, there are many possibilities to explore computing as a transdisciplinary subject. These possibilities do not mean a lack of rigour, but rather a wider application of the subject. There is a call to redefine and redesign computing courses informed by alternative, exciting methodologies and pedagogies that broaden our perceptions of computing in the classroom. The literature suggests (Kemp et al., 2018, 2019, OCED 2018, 2023) a definite need for a change of direction or approach to curriculum development owing to diminishing numbers in student recruitment at GCSE and A-Level, problems with experienced staff retention, and recruitment to CS specialist ITT programs. A project-driven approach reapplied to the examined component of pre-university assessment could instigate this positive revitalisation.

2.2.3.1 Computing Education

As outlined, CS is a very new subject area within the history of learning and education, and its history in pre-university education is even more recent, as CS was initially only taught at university level. Early pioneers' work in the subject, such as Solomon et al (Papert, 1980, Solomon, 1986) are still valid into today's digitally minded world, given the relatively recent instigation of the discipline.

Cynthia Solomon's work is instrumental to the development and progression of computing education and CS. Solomon worked closely with Seymour Papert in the 1970s and 1980s, and her work in 1976 on LOGO (a programming language) and turtle graphics for teaching children with computers was ground-breaking. Solomon's 1986 book *Computer Environments for Children*, which focuses on mathematical examples, poses some of the following questions in relation to setting up learning (research) centres for teacher education:

> What are the appropriate activities and what kind of knowledge do we expect to bring [..] and takeaway from the learning process [in computing education]? Do they [the learners] have to become skilled calculators or [..] is it sufficient to be able to intuit number relationships and use calculating devices for speed and precision? Will they be more aware, better prepared citizens?
>
> (Solomon, 1986, p. 162)

Mathematics examples permeate STEM computing literature. Examples include Fitzallen's (2016) 'What Does Mathematics Have to Offer STEM Education?' and Maaß et al.'s (2019) study on the role of mathematics within interdisciplinary STEM approaches, considering how mathematics is central to 21st century skills, including computing. However, mathematics and computing are not directly aligned at GCSE level, meaning that academic excellence or poor performance in one does not necessitate excellence or poor performance in the other. GeoGebra (Hohenwarter et al., 2008) is another example of the use of computing for mathematics but using coding examples in another subject does mean that this is computing education. However, there is a major lack of computing education specific studies illustrating a rationale for this study.

Computing should be a creative, collaborative, and cultural space open to all levels and abilities. Vedres (2022) relates this to computational social science and collaborative creativity. I argue that educators and learners are equal actors navigating the fundamental elements, the social, personal, and collective cultures involved in computing as subject, object, and space. This notion of computing as a creative, collaborative process is highlighted throughout Solomon's work.

Technological advances give rise to a more inclusive and accessible medium within computing education (Amiel & Reeves, 2008). These advances do not immediately present the widespread knowledge and understanding necessary for effective teaching and learning in a real-world classroom at pre-university level. Alongside the technical content of these computational subjects, educators must be taught the appropriate skills, competencies, and assessment processes to create appealing, engaging lessons which encourage students to thrive. Solomon asks the pertinent question 'How do I learn to use computers today in a way that will not be obsolete in five years?' (Solomon, 1986, p. 1), this resonates with contemporary educators, curriculum designers, and even learners. This question arises constantly as technology advances and continues to influence society, which is then reflected

by the curriculum. Before providing potential answers to this question, we must address the limiting factors of some institutions and learners who cannot participate in this innovative education due to limited access to technology, data, and/or space and time for learning and implementing knowledge. Alongside digital equity, learners need opportunities within the curriculum to question and interrogate the current and future limitations of computing as a subject (RQ2). Below, I briefly outline the issues and concerns of each stakeholder implicated in Solomon's question.

(i) Educators require competency before teaching any curriculum content with confidence.

The ever-increasing pace of technological advancement is a persistent challenge for computing educators. Timetable limitations add to this challenge, as many secondary schools allocate a maximum of one lesson/hour per week or less to computational education at Key Stage Three (Royal Society of Great Britain, 2017; Ofsted *Research review: Computing*, 2022).

(ii) Curriculum content and design is often influenced by final, terminal exam content and assessment criteria.

The Covid-19 pandemic has significantly disrupted the assessment process of examinations for pre-university courses. In place of the traditional two-hour, closed book, memory recall and knowledge application style exam courses (Cairns, 2021) now favour teacher assessment over a longer period with a slight reduction of curriculum content as dictated by the exam boards. All assessment outcomes depend upon the quality and access to the remote education delivered during the pandemic, and the educator plays a key role in learner engagement (Gray & DiLoreto, 2016; Martin & Bolliger, 2018). The variation in access to hardware, data allowance, and live synchronous teaching across England is still necessarily a new area of research. Still, initial reports indicate the existence of an inequitable digital divide, with limited access to technology, and the impact of external variables, including parental involvement, teacher proficiency, and the learning environment (Coleman, 2021).

This study was impacted by similar limitations arising from the pandemic, including limited or no access to research participants during lockdown and increased stress and workload for participants during this unusual period. Solomon's question resonates all the more through the

pandemic context, and provides the opportunity to review and re-imagine pre-university education during widespread disruption and innovation of teaching methods.

(iii) The learners' voices and opinions are infrequently called upon in the official external examination content or design.

Despite many prominent studies examining learners' opinions on methods of course design or assessment, which is by no means a new area of research, there are still very few opportunities for learners to voice these opinions. The following three studies highlight the possibilities of innovation that could radically improve the education sector: (i) Garashuk's (2022) study on the learning benefits of collaborative examination focuses on perception and performance in collaborative or group exams, but does not cover or consult learners when designing these exams; (ii) Ozdamli and Ozdal's (2018) study explored the development of an instructional design for the implementation and evaluation of infographics based on teacher and student opinions; and (iii) Starr (1970) analysed student teachers' opinions about methods of assessment used in one-year, post-graduate courses.

Solomon's question remains pertinent in today's society. Current computing education research takes many forms across many domains in answer to the proliferation of the personal computer and technological advancements. Computing is more than coding, engaging learners to 'being creative with technologies' (Sentence et al., 2018 p. 3). Guzdial's work on computing education spans the history of computing (Guzdial & Boulay, 2019), subgoal labelling (Margulieux et al., 2012), and the ACM post 'Disputing Dijkstra, and Birthdays in Base 2' (Guzdial & Adams, 2021). Guzdial advocates teaching computing through metaphors, describing his PhD student's work (Amber Solomon) on embodied metaphors for teaching CS. This practice of expressing computing knowledge and teaching through creative elements aligns well with this study, as I use embodied metaphor in ballet to explore the potentials and possibilities of/for broadening participation in computing (RQ2).

An effective computing classroom must make space for failure, a key element of CS education and practice where the 'fail fast—fail often' abounds (Babineaux & Krumboltz, 2013). Reframing failure as a positive approach to learning may be a hard task in a society based around perfection, but these 'tinkering' makerspaces can give agency back to the learner and allow them to fully appreciate the subject. This approach should not be gender-specific, though some literature exploring tinkering as a research method suggests that this

approach to problem-solving does 'seem' to benefit male students more than female students (Beckwith et al., 2006). Speiler et al.'s 2020 paper discusses the use of open makerspace settings for use in a gender-conscious approach to learning the basics of coding. Using makerspaces in the classroom positions students as facilitators, encourages open group work, and invites students to share and repurpose code together (Spieler et al., 2020), rather than the traditional, individual approach to learning content for an exam or assessment. Educational approaches/activities should focus on the different ways that individual students approach problem-solving, whether linear or comprehensive, and how the learning may best fit these varieties of thinking (Beckwith et al., 2006). The collaborative makerspace mimics the adult workplace environment, and allows each individual to work at their own pace and seek help or support when needed. At the Mozilla Foundation (Mozilla, 2023) annual MozFest, a kids' playground session/area is purposefully included, showcasing a non-traditional approach to computing and digital education with workshops for educators and learners to champion the makerspace approach to learning. These new and different approaches align with RQ2 on how delivery modalities explore the topic of data-ethics as a rationale for this study.

2.2.3.2 What Do the Data Say About Computing Education?

England's educational system is structured around key stages of learning and specified pre-university exams in Year 11 (GCSEs) and Year 13 (A-Levels). My study consults data collected within this system, focusing on the comprehensive TRACER report (The Roehampton Annual Computing Education Report by Kemp, Berry, & Wong, 2018 onwards), a statistical review of pre-university pupil data across England, using the DfE National Pupil Database (NPD) to provide a detailed data comparison of schools and subjects at GCSE and A-Level. This report tracks a progressing decline in students sitting GCSE and A-Level Computing (or computing-related) exams. Furthermore, Dr P. Kemp, TRACER's primary author, notes the lack of attention paid to the decline in 'girls and weaker students [who] will become disenfranchised from digital education over the next few years' in a BBC news article (Cellan-Jones, 2019).

TRACER shows a parallel decline in PGCE Computing applications as the number of students sitting computing exams drops (Kemp & Berry, 2019). This compounds the current teacher shortfall in secondary recruitment and retention (Foster et al., 2022). Subsection 3.12 of the Teacher Recruitment and Retention in England Report outlines the government's specific commitment to 'upskilling' 8000 CS teachers by the end of 2023 (or the end of the

current parliamentary period). Phased funding began in 2018–19, with £13 million provided to achieve this goal, then £21 million added in the subsequent two years, and a final £8 million in 2022–23. Provision for this training is run by a consortium of three independent organisations: STEM Learning, the Raspberry Pi Foundation, and the National Centre for Computing Education (NCCE).

These data represent only the state of English computing education, and a wider consideration of global trends and methods of education must be included in the development of curricula or training methods. England's focus on examination and assessment in learning allows the creation of reports such as TRACER, but is also symptomatic of the exclusionary practices embedded in our education system at present. TRACER carefully considers several key metrics, including the removal of the ICT GCSE and the long-term impacts of this choice for all pre-university students. The 2017 data indicate that female students constituted 38% of the ICT GCSE population, but only 20% of the CS GCSE after the removal of ICT. This significant difference warrants further investigation, as listed in the recommendations section of the TRACER report. Exam results from female CS students are typically higher in the A*–B grade range that male CS students (Kemp et al., 2018, p. 89), but this does not stem the decline in female students studying CS, and the gender imbalance grows as each education stage narrows the subject path selected by the student. The selection of GCSEs in Years Eight and Nine clearly impact subjects chosen at A-Level and future educational routes through university.

Owing to plagiarism concerns in 2018, a 20-hour programming project assessment was removed from the Computing GCSE (Robertson, 2018) which reduced the creative, practical aspects of the course, and meant that the GCSE relied entirely on a written, closed-book exam. Although the 20-hour programming project is still a requirement for the course, it 'will not count towards a student's final grade' as stated by the examboards (OCR.org, 2022; AQA.org, 2020In a pressurised environment with many assessments and deadlines for multiple subjects, removing the motivational aspect of this project seems to be a backwards step, and ensures that less effort and attention is given to this task by both students and teachers. This method of written, closed-book examination does not reflect the professional programming environment, which relies on collaboration and sharing communal code repositories (Robertson, 2018; Wu et al., 2019). The demanding and important work required

when learning the basics of coding is also not reflected in this assessment method, as this work has no impact on the final grade (Guzdial, 2010, Robertson, 2018).

2.2.3.3 Issue: Gender and Computing

Research undertaken in the 1990s examined the decline in the number of female CS students enrolled on undergraduate courses, and cited the common factors of motivation, negative stereotypes, social differences, and the lack of female role models that remain prevalent in today's research. One paper (Liu & Blanc, 1996) noted that only 16% of students enrolled on CS undergraduate courses were female, which represented an 8% drop from 1988 to 1996. Lui and Blanc's subheadings 'Computer as Toy or as Tool' and 'Teaching Applications vs Programming' still resonate current CS debates in this field. The effects of recommendations set out in this 1996 paper can be seen in England's recent computing programme of study (DfE, 2013), spanning from Early Years Foundation Stage (EYFS) through to Key Stage Four (students from four years of age up to 16). This programme has addressed the issue of students' lack of familiarity with computing terminology lexicon, and has implemented effective methods to address this decline in numbers. Dallaway's (2019) CREST (The Council for Registered Ethical Security Testers**)** on the gender gap in cybersecurity highlights the need for increased female computer science education at the school level. In a 2022 white paper, Dallaway shares narratives to inspire positive change for women in cybersecurity, promoting gender equity (Dallaway, 2022).

Mishkin (2019) builds on a substantial foundation of research—from Camp's (1997) 'The Incredible Shrinking Pipeline' to Whitley's (1997) 'Gender Differences in Computer-Related Attitudes and Behaviour'—to explore young women's motivations in the CS field, and calls for a psychological focus to the intervention that aims to change women's mindset and behaviour towards CS. Whitley's 1997 paper indicated that male CS students report higher self-efficacy than their female counterparts, and this statistic is still evident today after 20 years. Access to computing knowledge is vital for all individuals, given the accelerated advancements of the digital and technical world around us (Sentence, 2018b). Reduction in access for women, owing to any number of factors, strengthens the wider gender divide throughout society, and the decline in female CS students continues to accelerate as a result.

Mishkin's key recommendation to tackle this divide is the establishment of a 'sense of belonging' for women in CS, which increases motivation and reduces the feeling of otherness often experienced by women as minorities in a male-dominated environment. The male

confidence in their own ability in comparison to women's confidence, as shown in Whitley's paper, is in part attributable to this gender imbalance and sense of otherness that women feel in STEM environments. This anomaly creates a paradox, as without an existing body of female role models or colleagues in CS, fewer women are attracted to the field, and this key sense of belonging and solidarity becomes harder to achieve. Further research is required to develop psychologically supportive, inclusive CS education, but Mishkin's study does not mention creativity as a motivational factor in education.

Figure 2.2 *Cyber-First Advertising campaign (Batchelor, 2020)*

Figure 2.2 presents an example of the disastrous advertising campaign run by UK government in 2020. The tagline 'Rethink. Reskill. Reboot' highlights the lack of respect for the arts and the role of creativity within computing (Batchelor, 2020). The campaign was part of the Cyber First initiative, a government outreach and education programme run by the National Cyber Security Centre (NCSC), a part of GCHQ. This approach was condemned by the culture secretary, and exemplifies the campaign team's views on ballet as a career.

2.2.4 Ballet: Behind the Curtain

Classical ballet involves the systematic formalisation of movement and relative positions of the arms, feet, and body on the stage, which may be physical or digital. Ballet is usually performed to an audience through use of the fourth wall, and traditional ballet performances are made up of three main sections: the opening *pas de deux* or *adagio*; variations or individual performances by dancing partners, first male and then female; and the final *pas de deux*, or coda (Stuart & Kirstein, 1952; Rogers, 1998). I now trace two key moments in ballet history that highlight the important relationship between ballet and technology, which is vital to my study.

The history of ballet can be traced back to an assortment of vignettes—short pieces added to the middle of an opera, that served no purpose other than to demonstrate the dancers' skills (Garafole, 1985). A French choreographer and ballet master named Jean-Georges Noverre disliked this functionless display of ballet within opera, and sought the reformation of ballet into 'ballet d'action' ('ballet in motion'), a separate art form. This dislike of dance within opera being labelled as ballet is evident in his work *Lettres sur la Danse, et sur les Ballets* (Noverre, 1783, p. 122): 'fi la plupart des Danses de l'Opéra , quelques agréables qu'elles me paroissent, ne se présentent pas à mes yeux avec les traits distingués du Ballet,' which roughly translates as 'most of the opera dances, however pleasant they may seem [...], do not appear to [have the] distinguished features of the ballet.' Noverre's vision of ballet as an independent artform was realised in the first half of the 19th century.

2.2.4.1 Ballet and Technology

Charles Babbage, who is considered the father of the computer, had a keen love of opera and theatre, and even created his own ballet 'Rainbow Dance,' also called 'Alethes and Iris' (Hyamn, 1982) between 1845 and 1846. Babbage utilised technological advancements in his ballet to exhibit these 'splendid/superb' elements (Babbage, 2011 [1840s], p. 254), including coloured lights, and experimented with different substances and materials to create diverse colour effects. The ballet followed four groups of 15 dancers dressed in white moving between pools of different coloured lights. Benjamin Lumley, the 'lessee' of the Italian Opera house at the time, allowed Babbage access to the stage to perform these experiments, but, unfortunately, the ballet was only ever performed in rehearsal due to the fire risk posed by these new technologies. Babbage beautifully notes this as 'the combustion of genius' (Babbage, 2011 [1840s], p. 258).

Another example of the technological and artistic worlds colliding can be found in Merce Cunningham's innovative, mathematical choreography, supported by John Cage. Split Sides is a performance in which Cunningham decided the costumes, dance order, and music during the performance by rolling a dice (Clay et al., 2010, 2014). Technology, particularly immersive technology, continues to shape the teaching and learning processes that are foundational to dance and ballet specifically (Chan et al., 2010). Key uses include injury prevention (Kozaie et al., 2020), and digitally enhancing performances (Clay et al., 2010, 2014). Dance institutions are now increasingly incorporating new technologies into their

teaching methods, building on traditional uses of video recording for recall, correction, and rehearsal purposes (Parrish, 2016).

The choreographer George Balanchine characterised himself as a 'carpenter' in the 1958 Dance Magazine article 'A word from George Balanchine,' and likened the development of choreography to the construction of a cabinet. Balanchine evocatively described his famous 'Agon' as:

> Ballet is not a chest of draws. It is closer to an IBM electronic computer. A machine, but a machine that thinks [...] planned by Stravinsky and myself for twelve of our ablest technicians [...] a measured construction in space, demonstrated by moving bodies set to certain patterns or sequence in rhythm and melody with multiple ingenuities. (Balanchine, 1958, p. 35)

Balanchine's words demonstrate the crossover between art and computing, and recognise my use of DDD in this project. Pattern recognition, ordered/sequential movements, and algorithmic/choreographic design are elements of both computing and ballet, and work exceptionally well together. Jeyasingh draws attention to 'the internal logic of sequencing' (2000, p. 52), which is present both in choreography and coding. Within this dialogue of technology and art, we see the intertwining of the human and the non-human, the human-self with the data-self, the 'me ++.' Manufacturing, mastery of skill, and technology abound throughout ballet as an art form, from choreography to the pointe shoe itself.

Literature on this subject is often somewhat vague about dance as an art form. Publications often refer to the 'movement activities' or to dance in general terms without specific mention of the genres within dance. Named dance forms in the literature concerning dance as a tool for engagement in classroom learning include Zumba, freestyle, contemporary, and robot dancing, but not ballet. Ballet is only specifically listed when the study is conducted within a ballet context, but does not feature as a device for engaging students in an average classroom.

Movement is often used as a teaching device to engage students and redirect or focus attention, or in learning walks (Ferrington, 2010; Fisher & Frey, 2014). Ferrington (2010) describes the concept of a walking learning session, using movement and motion with discussion and conversation to nurture the learning 'journey' through the subject matter. The walk incorporates moments of silence in which to listen to the soundscape as a point of reference for recalling information.

This approach has been adapted and used for teaching algorithms with dance, sometimes in conjunction with PE (gymnastics). Typical examples include The Barefoot Computing Education resources (Barefoot.org) or using the video of Hungarian dancers performing a bubble sort (Bubble sort with Hungarian 'Csángó' folk dance, (Füzesi et al., 2011). This video is used as a way of clearly visualising the abstract and often complex nature algorithms (Alaman et al., 2016; Faria, 2017). The Drone Ballet is another video that highlights the beauty of movement, technology, and artistic practice as an artefact (SkyMagic, 2016). These videos demonstrate that the combination of dance and computing is not a new teaching device. Both the Hungarian dance and my first ballet [arra]stre (2014) include performances of the bubble sort, though the latter also adds checking and validating elements. In [arra]stre, the dancers face each other and curtsy, expressing the check process, answered with the validation of a *relevé* onto demi-pointe, which confirms the correct height order has been achieved. The use of data visualisation, wearables, and 'algorithmic' choreography in DDD allows dance, and specifically ballet, to be immersed in the computing classroom as more than just a video prompting discussion or as an aid to understanding. DDD presents ballet as a tool for interrogation, the development of key skills, and digital and media literacy through all aspect of computing—theory, IT, and digital literacy (Furber et al., 2012). Pavlik and Nordin-Bates (2016) conclude that a dance lacking imagery is inefficient, reductive in technique, and is a meaningless combinations of movements. The application of ballet as a pedagogical tool for algorithms, particularly when entangled with computing, serves as rationale for this study. The integration of ballet movements with computing infuses intention into the execution of the ballet as algorithmic, offering a clear rationale for the combination.

2.2.5 Part I Summary

This initial part of my literature review aims to provide background to the content of my study and to explain the key components of data-ethics within computing. The current lack or limitations of teaching, both at the training and educational levels, alongside the sparse coverage of data-ethics within the curriculum often insufficiently linked to online safety (FFT, 2022; Ofsted, 2022), is producing a national illiteracy in what may be the most crucial education one can receive in such a technologically focused world. Many factors contribute to the lack in pre-university data-ethics education and decline in CS examination at this level in general (Foster et al., 2022; Kemp et al., 2018-2019, Royal Society of Great Britain, 2017), including curriculum and exam content, core requirements for new teachers, the relatively new field of data-ethics, and the fact that institutional change takes time. Much research is

being undertaken into the closing gender gap in this sector (Sentence, 2018b), and the underappreciation of the possibility of implementing CS within the arts only adds to the marginalisation of both CS and arts education and appreciation. My study uses DDD, specifically incorporating ballet with future technologies to demonstrate how data-ethics can and should be a vital component of computing education (see design iterations 8.2.2, 9.2.1).

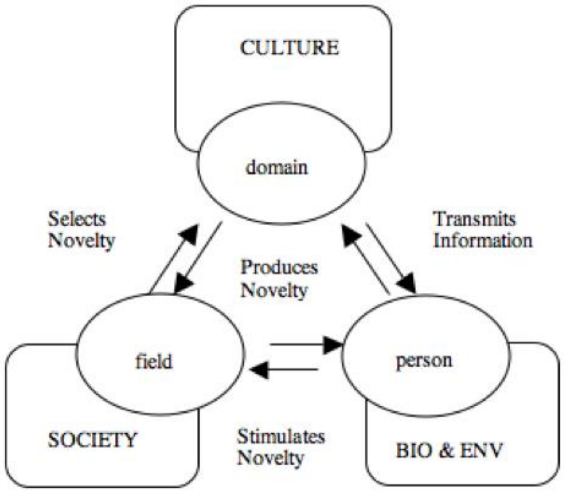
PART II Context

This section discusses value, creativity, STEM, STEAM, neuroscience, and ethics as they relate to my research, and examines the existing literature which has informed my work.

2.3.1 Creativity

Creativity takes many different forms within an education context, and it is important to consider the varying advantages of these different types of creative endeavour within the classroom. My study draws on Vlad Glăveanu's 'Five A's framework' (Glăveanu, 2013): actor, action, artefact, audience, and affordances. Additionally, Csikszentmihalyi proposed a generic systems model of creativity comprised of three elements, whose interactions reflect and generate the baseline of socially and culturally accepted creative contributions at any given time (Csikszentmihalyi, 1988).

Figure 2.3 *Systems of Creativity Model (recreated) or locus of creativity (Csikszentmihalyi 2014, p. 166)*



Csikszentmihalyi explored different metaphors to explain 'interrelations' within his model from fire, apples on trees, to Copernican model 'the person is not the centre of everything […] but part of a system' (Csikszentmihalyi, p. 336). He critiques Simon's (1985) notions of the

BACON program replicating solutions to 'creative problems' is an attribute of 'creativity' (p.326, cited in Csikszentmihalyi, 1998 p. 156; 2014). Csikszentmihalyi draws on equally technical and aesthetics paintings but 'cannot be consider equal in creativity' (p. 326) to illustrate the flaw Simon's argument. Stating replication of creative solutions is not creativity (Csikszentmihalyi, 1988).

Creativity's intersection with value is a fundamental discussion within my study, especially as the education context places a high value on grades and metrics, often at the expense of creativity in the classroom. While data may illuminate and inform many different stories within education, the generation of data should not be the focus of expanding and exploring creative computing education. The value of individual and communal human creativity must be the focus of this educational endeavour.

Chappell's 2018 chapter 'From Wise Humanising Creativity to (Posthumanising) Creativity' draws on her previous work, including a collaboration with Anna Craft's original work (2005) entitled *Wise Creativity Theory*, developed between 2005 and 2012. Chappell argues that *how* we create is of vital importance, not just who is creating or the product itself. This *how* occurs within a meshwork of the human and the non-human, and it is from within these 'enmeshed communal intra-action[s]' (Chappell, 2018, p. 151) that creativity emerges, these enmeshments and interactions also encourage ethics to emerge (p. 147). Chappell identifies two technological tensions in education: education as transmission versus education as a relationship (p. 148). The potential for cross-art work to challenge hierarchical structures and promote sustainability is discussed. The ethics arising from relational subjectivity are rooted in the agency and interconnectedness of embodied actants (p. 152), this aligns with RQ1.

Creativity demands space both physically and in an abstract sense in order to flourish. Given ample space and time, creativity has a boundless capacity to encourage individuals within a shared space to collaborate, reach their full potential, and go beyond the traditional, known forms of art and expression. Combining creativity with computing education is not merely method of beautification on a surface level, but is instead fundamental to the development of the process and practice of algorithm design and the act of programming itself.

'Updating Introductory Computer Science with Creative Computation' (Xu et al., 2018) aimed to redevelop the CS curriculum in order to bridge the gap between school and university through a creative practice approach. By strengthening formative/introductory CS education in high schools and colleges by providing teacher training through an art studio

practice, the study hoped to foster a sense of excitement and creativity in the teachers' pedagogic practices. The participating teachers were recruited from AP (Advanced Placement) programmes, and were therefore accustomed to teaching students who had shown an aptitude for more complex or taxing subjects/content. Computing, particularly the relatively new programming and coding aspects of the subject, fall into this category of complex and difficult subjects. Data reveal that certain groups such as girls and white working-class boys are underrepresented at this stage of education in this subject, so the study sought to address these imbalances. The study was adapted for first-year undergraduate students, and subsequently applied to a high school AP context. The findings demonstrated success in bridging the gap from high-school level to introductory college CS, while also meeting curriculum goals. Importantly, the qualitative nature of this research allowed teachers to voice their opinions on the process of implementing creative introductory computing courses.

2.3.1.1 Creativity and the STEM Classroom

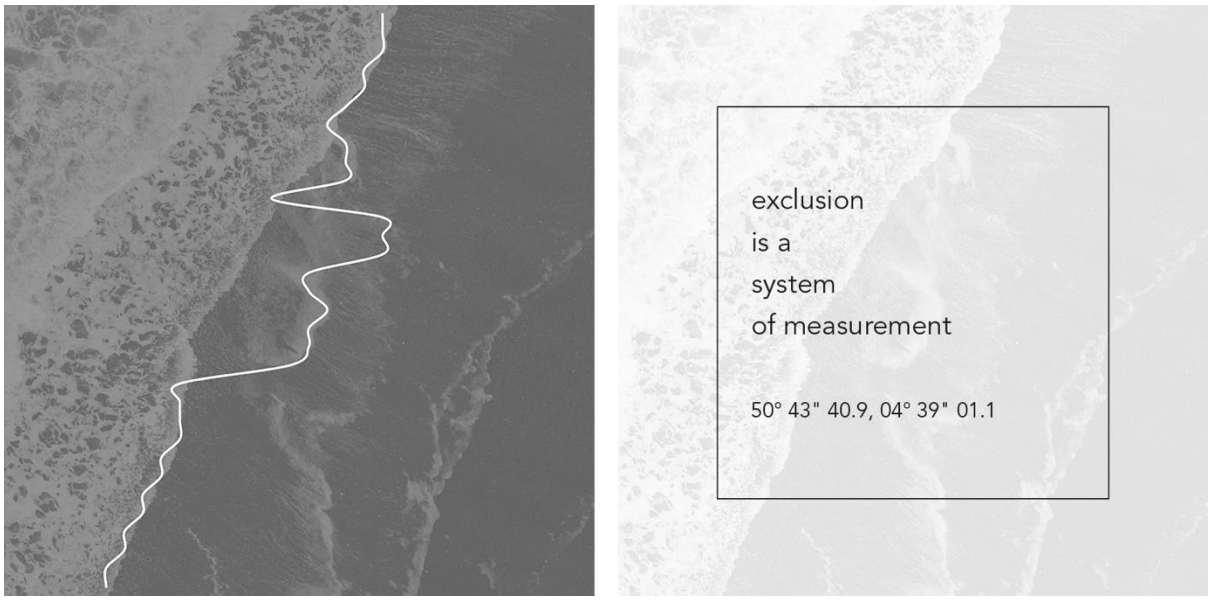
Despite being a fundamental element of computing education and the wider application of professional CS careers, creativity is largely absent from the examination process at pre-university level. Education motivated by examination presents significant challenges for the creative classroom, and this approach often limits opportunities for 'significant imaginative achievement' (Craft, 2008). Many studies in Higher Education examine the teaching process in Engineering, such as Peteranetz's (2018) study, which combines creative and computational thinking. Although this study concerns a higher level of education than my own research focus, the topics and general applications are very relevant to my own discussions and examinations of creativity within STEM teaching. Studies such as this use creativity as a tool to improve CS learning and problem-solving abilities by fostering computational creativity, and findings from this research are crucial for pre-university teacher education and continuing professional development in this area. See section 2.3.2 in this chapter.

2.3.1.2 Creative Technologists as inspiration

Waveform (Carter, 2018) is a creative project that combines art with computational methods, using drone technology, software, and photography (coastal shorelines) to create computationally generated poetry on themes concerning coast, changing climate, and the pursuit of scientific knowledge, Fig 2.4. This project is one example of the creative potential

of these two subjects coexisting and working together to raise awareness of prominent, global issues. Although opportunities to develop similar projects in the classroom are limited due to access to and the cost of drones, access to datasets, software, and expertise, similar approaches may be developed, such as those presented by Xu et al. (2018).

Figure 2.4 *WaveForm (2018) courtesy of Dr Carter*



2.3.1.3 Dance and Creativity

Because of its boundless nature, dance allows creative expression, construction, performance, and systems to flourish. Bishop & al-Rifaie's (2017) paper explores systems of dance and creative, iterative generative dance practices, and builds on their earlier work (al-Rifaie & Bishop, 2015), which reimagines autopoietic theory through dance. Autopoietic theory refers to a machine of network processes made and remade, and a regeneration of relations and components within the network (Maturana & Varela, 1980). Connections across a network and the development of a project through reflection and adaptation stages are key to both dance and software development. Leonard et al., (2020) even use dance and choreography practices to improve computational thinking and coding skills: dance motions are captured and reencoded into 3D avatars, enabling the physical manifestation of learning through the creative efforts of both dancers and programmers. Leonard and colleagues use 'body syntonicity' in dance to support CS knowledge and skill development (Leonard et al., 2020).

Another example is Associate Professor Alaoui's 2012 project entitled 'Double Skin/Double Mind,' an interactive dance installation and computer dance training workshop which sought to raise awareness of the dancer's inner body through technology (Alaoui, 2012). Alaoui's

work as part of INRIA (Institut national de recherche en sciences et technologies du numérique) covers interactive design, human/computer interaction, and dance, including an investigation into societal and technical constraints surrounding dance (Alaoui & Matos, 2021).

2.3.2 STEM

STEM denotes a group of similar academic disciplines—Science, Technology, Engineering, and Maths (Colucci-Gray et al., 2017). CS, a relatively new discipline in relation to these foundational subjects, has aspects of all of these areas, though it does not neatly fit into any one category. Many academics have questioned whether CS, as a burgeoning and ever-expanding field, should undergo some evolutionary changes that reflect the changing world in which it operates (Bares et al., 2018; Bares et al., 2019; Kemp et al., 2019). These fundamental questions arise as a result of the gender inequity and underrepresentation of minorities within CS, both in education and the professional/academic field. Such rebalance and parity on a substantial, lasting, and significant scale is unlikely for a century, according to Wang et al. (2019), which is a challenging and somewhat disheartening claim. CS and surrounding fields cannot afford this restriction and limitation of innovation, so creative solutions must be sought to tackle this inequality in a swift and lasting manner.

Studies show that over 50% of the population will not use computing education in their career paths, whether through academic study/research or professional applications (Anderson et al., 2008, p. 1309; Lasen, 2010, p. 1120). As new ethical debates arise from ongoing technical developments, the education sector struggles to keep pace with the world about which it seeks to instruct its students, and curricula remain driven by GCSE and A-Level targets, specifications, content, and results. Unfortunately, studies offering effective solutions to this rapid decline are also limited.

Many such studies draw attention to interest in STEM careers shown by young people, specifically girls, alongside the need to tackle low uptake of these subject after initial interest is shown (Gutica, 2021; Bares et al., 2019; Millen et al., 2019; Milgram, 2011; Rich et al., 2004). One solution to low female uptake has been to develop and integrate arts-based computing programmes into undergraduate courses (Weston et al., 2019; Barker et al., 2005). Boulder University's Bachelor of Science in Technology, Arts, and Media is an excellent example of the fusion of computing, arts, and digital media into a cohesive, rewarding, and educative programme of study.

2.3.2.1 From STEM to STEAM

Former National Science Foundation Division Director Judith Ramaley first coined the acronym STEM in 2001 (Breiner et al., 2012). Nowadays the understanding of the acronym has expanded to include Economics and Psychology alongside related disciplines. The term 'STEM-related' is becoming more common, and reflects the ever-changing landscape of technological and scientific advancements in which we live. Subject boundaries, once fixed, are now blurred, and many scientific disciplines require researchers to understand and have a competency of computational coding to perform research tasks, generate data, or results (Schrijvers et al., 2017).

STEAM is a relatively new advancement, adding the arts as a category within this consortium and thereby recognising the importance of the artistic and creative disciplines within scientific education and research. BERA 2017 reported the difficulty in defining STEAM (Colucci-Gray et al., 2017. p.29). Literature surrounding the interplay between science and arts subjects is prolific, so I have focused on the studies outlined below, which consider the use of dance within STEM subjects to enhance education. Literature examining both the theory and practice of all three aspects of my current study, CS, education, and dance, is similarly broad, so in order to refine my search I focused on literature published since 2014, as this was the year in which the initial programme of computing education was introduced in England at pre-university level and where possible not focussing on mathematics. Most existing studies use undergraduate students to create datasets and inform their findings, and limited research has been carried out in the pre-university category. Colucci-Gray et al, recommend in their 2017 BERA report that there should be the distinctive role of creativity and sustainability within STEM subjects (Colucci-Gray et al., 2017). An excellent example of transdisciplinary creative coding, music but not dance related, is SonicPi™, a live coding environment, originally designed to support both computing and music lessons in schools (Aaron et al., 2016). Similarly, Johnson (2019) MusE-XR musical experiences in XR to enhance learning and performance.

Using dance as a tool to promote and aid STEAM learning is the focus of the following studies: (i) dance and primary-aged learners (Bond, 1994; Bond & Stinson, 2000; Pugh-McCutchen, 2006; Sansom, 2011; Schiller & Meiners, 2003; Tortora, 2006); and (ii) 'dance and mathematics' at university level, also covering engineering (Watson, 2005; Conway, 2006). These studies focus on identifying cognitive functions within specific populations in

order to develop memory and store knowledge, rather than engaging learners in the content of the subject. Several papers that focus on the use of dance as a tool for engagement include Solomon et al.'s (2022) 'Embodies Physics,' which does not specify which form of dance is used to promote engagement in Physics education. Capocchiani et al.'s (2011) paper 'Physics in Dance and Dance to Represent Physical Processes' focuses on mechanics in Physics and specifically mentions ballet, but this is one of very few examples that specify the dance form used. This paper uses ballet as an external mechanism to inform and exemplify the observation, deconstruction, and analysis skills used in scientific contexts. Instead of using ballet as the driving force or an equal partner in education, it merely treats it as the object of scrutiny and analysis for scientific purposes. The paper has its advantages and is an important exploration of the possibilities of involving high-school students in scientific experimentation, but the choice of ballet is somewhat arbitrary: the dancer could have been replaced with a gymnast or ice dancer.

Despite this myriad of literature about using dance in computing education, it is surprisingly difficult to find studies that focus on ballet as a device as an additional pedagogical instrument, rather than for student engagement. This gap in the field exposes the shortfalls of the arts' integration into STEAM education. Despite efforts to reshape perceptions, it appears that dance continues to be used in a mechanistic way in science education.

2.3.2.2 Dancing with Computing

The annual surveys of arts participation, conducted by the Department for Digital, Culture, Media, and Sport, England (2020, 2022), According to the results, almost all children aged 5-15 years had engaged with the arts in the last 12 months, while adults aged 16-24 and 25-44 years had lower engagement in digital art than other age groups (Dept for Media, Culture, and Sports, 2022). Admittedly, these data were collected during a global pandemic and a series of national lockdowns, which prevented many people from accessing artistic venues or installations, and so it potentially misleading. The data concerning digital art interaction, however, should not have been too limited by physical access during this time period, however, but there is some ambiguity in the understanding of what constitutes 'digital art' inherent in the questionnaire used to collect these results. In contrast, these surveys demonstrated that participation in computing or dance in schools remains at a consistent level of around 13%. There is no mention in the survey of the data-ethics in relation to digitals arts demonstrating rationale for this study (RQ1).

CS is linked to an individual's enhanced spatial working memory abilities (Fincher et al., 2019; Ambrosio et al., 2014, cited in Kemp et al., 2019a), which 'requires the retention and manipulation of visuospatial information' (Cambridge Cognition, 2015). Spatial awareness and ability is also integral to dance, as the relationship between body orientation and body awareness is crucial to the cohesive, collaborative performance (Corsi-Cabrera & Gutierrez, 1991; Temple et al., 2020). Spatial working memory is also vital in processing and recalling movements, precise techniques, and sequences. Movement research encompasses many disciplines such as gymnastics (Schmidt et al., 2016), mixed sports (Lord & Garrison, 1998), surgical fields (Wanzel et al., 2003), and ballet (Corsi-Cabrera & Gutierrez, 1991; Jeyasingh, 2000; Ainsworth, 2009; Cortese & Rossi-Arnaud, 2010), which share this focus on intricate technique and complex, precise positioning of the body and limbs to achieve a required outcome. Jankovic and Bogaerts' (2021) paper notes that only 'one study examined ballet and various aspects of spatial skills', illustrating the limited use of ballet. Movement experts such as those studied above demonstrate a higher spatial working memory than non-movement experts (Barhorst-Cates, 2019).

Embodied and spatial working memory also has limited research attention within computing education. There are several examples of using videos of dance and/or skeleton tracking data to generate ballet poses with AI, which can then be used to develop new choreography using Deep Learning, as in Crnkovic-Friis' (2016) paper. LePrince-Ringuet (2018) uses Google's AI tool, along with video archive footage, to produce choreography in the style of Wayne Mcgregor. Beautiful contemporary dance performances are generated through 'body(input); //spin off' (Judova, 2014). Slayton's (2019) solo dance describes and explores a parasitic relationship between the physical body and technology entitled 'Formulae and fairytales.'

Of course, dance is not just a means of data generation, but rather a way of exploring knowledge, creation, and the recreation of understanding through practice and performance (RQ2). Tacit and explicit knowledge both play crucial roles in the interplay between dance and data. DataDrivenDance is concerned with the 'somatic tacit knowledge' inherent within the human body and brain (Collins, 2010). DataDrivenDance addresses knowledge from and as the expert, dance as learning and teaching, and the conceptual understanding of knowledge through non-traditional means (RQ2). Collins explains this beautifully: 'polimorphic actions are actions that can only be executed successfully by a person who understands the social context' (Collins, 2010, p. ix).

Learning and mastering ballet is a similar process to Polanyi's bicycle riding (Polanyi 1961, 1966), a core example in the tacit knowledge domain. With practice and training, the ability to balance on pointe or performed certain adagios 'becomes established in our neural pathways and muscles' (Collins, 2010), which is referred to as 'muscle memory' and similar phrases. The repetitive nature of ballet practice and learning to balance on a bike form stronger neural pathways and connections that are visible under high resolution brain imaging (Debaere et al., 2003).

Since 2013, using a DDD approach, I have found it useful to think of ballet as a kind of programming language. The form and function of ballet steps, motifs, and arm-leg-head position are constructed in similar ways to elements of coding—algorithmic choreography mimics the stage on the screen. Ballet can be used to recreate different patterns associated with CS theories and concepts. For example, from DDD the Data[storm] ballet emphasises patterns and concepts used in the development, choreography, and data visualisations of the live performance. The concepts of data transmission and signal processing are visualised through ballet choreography, wearables, and projections, which represent how information is transmitted over a network (Smith-Nunes et al., 2016). The use of node maps as a tool for dance notion highlights the hybrid nature of DDD through use of a CS tool repurposed for choreographic purposes (Smith-Nunes et al., 2018). Iterative development – (or re-development) choreography aligns with Design-Based Research (DBR). Current DDD works focus on the ethics of biodigital data within the sphere of computing, and use creative computing and ballet practices alongside EEG data to express these debates and dialogues. The technologies used in DDD are usually markerless, no attachments, or additional devices that would pose risk to the ballet dancers. Also, they are designed to work in computing classrooms with limited access to budget or high-end technologies. Each new ballet generated in this way adds to the research and development of educational resources in this area. Potentially illustrating how ballet can be compared to a programming language (RQ2) for developing various patterns associated to computer science theories and concepts..

2.3.3 Neuroscience

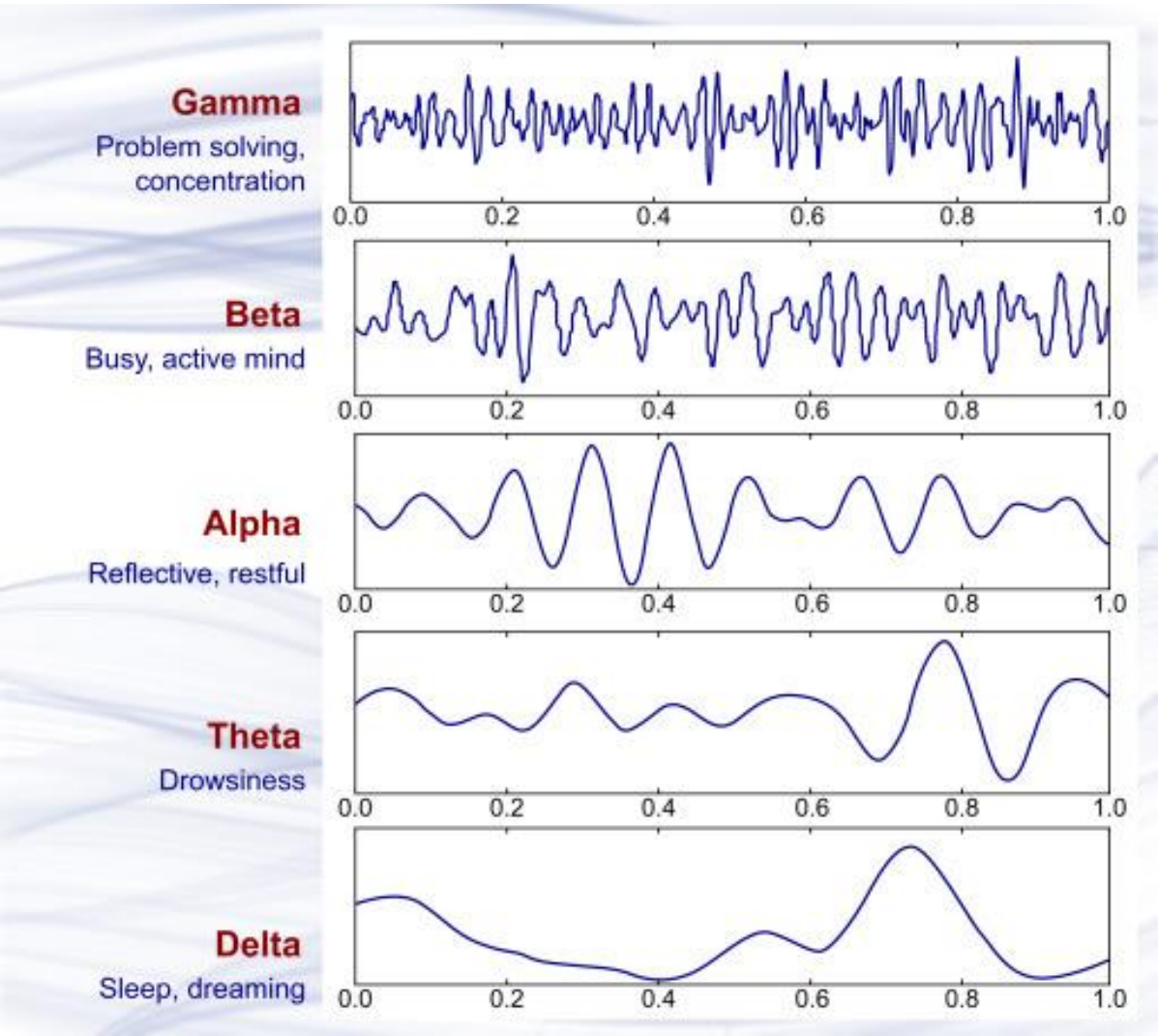
Historically, the study of the mind and the study of the brain were distinct disciplines with little overlap. This approach has changed and evolved through time, and neuroscience now encompasses interdisciplinary approaches to science, collaborating with other disciplines such as mathematics, linguistics, engineering, CS, chemistry, philosophy, psychology, medicine,

and education (Silva et al., 2013; Morse & Roskies, 2013). Neurosciences study a broad intersection of different topics to increase our understanding of the brain and issues concerning individual agency. Choudhury and Slaby's (2011) research is a key study in higher-level mental and behavioural phenomena in humans, and examines the individual brain's role in shaping collective behaviours. The study argues for transparency in the dissemination of information and for an open debate around the use of neuroscience in the examination of human behaviour and agency (Choudhury & Slaby, 2011).

Incriminating Thoughts (Farahany, 2012) examines an in-depth hypothetical scenario to explore 'cognitive liability' of police interrogation techniques through modern neuroscience methods. This hypothetical scenario provides a structured approach to current neuroethics debates that could be modified for the computing classroom. Four diverse digital techniques could be interrogated and explored equally on ethical and technical grounds. These specific techniques where data analysis could infer accurate results, within a neuroscience context: Brain imagery to look for evidence of trauma; EEG data to measure activity linked to questioning. Farahany's work form digital artefacts of the main study design.

While the neuroscience lab and the classroom have different ontological, epistemological, methodological, and axiological processes, Neuroscience within education is the focus of many studies devoted to a variety of topics from maths to dyslexia. Key studies include 'How People Learn' (De Smedt et al., 2010) and research into the application of neuroscience within maths education (De Smedt et al., 2011). Neuroscience research into dyslexia, such as Kaufmann's (2008) 'Dyscalculia' paper, highlights the challenges within education, and most neurofunction research is conducted among adults. Kaufmann argues that understanding 'numerical cognition' within the brains of children and young people will inform educational understanding and even classroom instructions/interventions (2008, p. 171). However, the paper states the limitations of 'brain imaging' within educational research, as well as the challenge of replicating reliable results given ongoing and fast-paced technological advances. Brain imaging often using EEG to detect brain activity, anywhere on the scale between five (commercial product) and 40 (medical/ research) channels that monitor changes. Each frequency band is associated with different brain activities that could be potentially used in the classroom. See Figure 2.5 below that summarises the different wave and frequency ranges and their associated functions.

Figure 2.5 *Summary of brainwave bands and functions (Abhang et al., 2016, p. 21)*



Kelly's (2018) paper on teacher training for English as an additional language is an interesting example of neuroscience applications in education, or the 'neurobiology of learning.' Kelly argues that an understanding of neuroscience is vital to understand the dynamics of a classroom, and that using neuroscience in this way can provide insights into findings already gleaned from other studies. Although Kelly's paper centres on language teaching, many of the insights can be applied to other educational areas.

Numerous publications highlight the challenges and 'problems' (Lindell & Kidd, 2011) of using neuroscience in education contexts. Generally, ethics are taught at university via four distinct lenses: biomedical ethics, utilitarian ethics, deontological ethics, and value ethics. There is a distinct lack of data-ethics both within the mainstream university context and in the computing curriculum/teacher education.

Current neuroscience research has a narrow focus due to both methodological and technical constraints, and 'experimental paradigms generally focus on islets of skills rather than learning processes and mechanisms' (Kaufman, 2008). Skills are only one part of education, however, and the learning processes and mechanisms currently underrepresented in this research are also vital for both learner and educator.

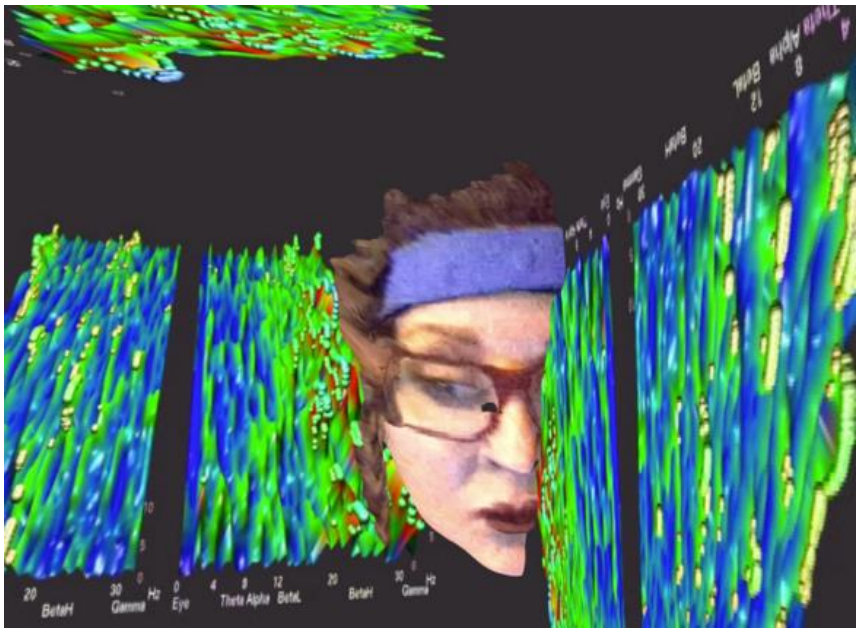
2.3.3.1 Dancing Brain

Neuroscience and dance are by no means new partners in research, but technological advancements widen the possibilities for both art and science. Dale, Hyatt, & Hofferman's (2007) paper 'The Neuroscience of Dance and the Dance of Neuroscience' focuses on the dancer rather than the audience. Cross & Ticini (2012) Nueroasthetics and Beyond applying brain sciences to the art of dance. Professor Karen Bradley's work on dance (as a general term) and neuroscience suggests that dancers are able to process complex choreography at great speed owing to what Professor Bradley refers to as 'cerebral synchronisation' and 'enchainment,' which enables dancers to remember chunks of steps and recognise patterns within them (Cruz-Garza et.al, 2014; Ruhren, 2017).

Luciana Haill is one of many artists working with brainwave data to create their art. Haill's work explores consciousness through the use of multimodal performances, drawings, installations, and immersive experiences, and focuses on sleep and lucid dreaming to bring about hypnagogia, the 'loosening of ego boundaries […] openness, sensitivity, internalisation-subjectification [of the] physical and mental environment' (Haill, 2014, November 4).

Haill's work examines the history of brainwave art, stretching beyond the 'vital or medical' use of this field to more experimental, artistic expressions, such as the use of Adrian and Matthew's (1934) sonification of brain waves in art. Mind the Gap (Guerrilla Zoo, 2019), Haill's work, is an exploration of the mind, the boundaries of science, and the spiritual, 'pushing the fringes of the human imagination and experience in new ways' (Haill, 2019, November 4). Mind the Gap, Fig. 2.6, is reminiscent of Nita A. Farahany's (2012) 'Incriminating Thoughts', which uses an in-depth, hypothetical scenario to explore the effect of interrogation techniques through modern neuroscience methods. Both are examples of innovative, alternative uses of real-time EEG data. Using neurofeedback to illuminate the hidden world and explore the nexus of science and art, Haill's work illuminates the possibilities that arise from the combination of neuroscience and ethics.

Figure 2.6 *The Mind Gap* (Haill, 2019)



The ‘Dancing Brain’ chapter (Tweney, 2005) discusses metaphorical comparison of science to dance through Hagedoorn’s (2003) bridging the gap between cognitive science and dance, entering into dialogue with Hagedoorn’s discourse on ‘biologization of dance,’ and using neuroimaging to understand dance through cognition, following the rules, steps, and systems at the core of ballet (Hegadoorn, 2003-5, 2012). Biologisation or ‘neuro-aesthetic’ analysis of dance, the neural mechanisms are the same in all human beings Hagedoor, 2005, p. 146. Connected with Hagedoorn’s biologisation concept are current techno-biological behaviours– *the entangled technological-biological-digital*–(Abbas et al., 2022), the entanglement between design elements, and the emergence of 'biometrics-as-a-service (BaaS)' (p. 79). This entanglement occurs across various levels: spanning from the foundational device level, progressing to the higher application tier, and extending to data manipulation. This has the potential to provide organisations/companies with detailed analytics, which can be harnessed and transformed into actionable information (Abbas et al., 2022, p. 79).

What I term ‘computational’ or ‘choreographic thinking’ is a blend of Wing’s (2006) foundational concept of computational thinking and Manning’s (2013) ‘Dancing the Virtual’ and ‘Ethics of Language Making.’ Tweney sought to demystify cognition, dance, behaviour, and the use of fMRI (Functional Magnetic Resonance Imaging) through the use of expert and non-expert dance participant. Since 2019, portable, wireless EEG (Electroencephalogram)

devices have enabled the rapid development of research, particularly in the neurobiology and neuroscience of dance.

Hagedoorn's investigation into emotional states in dance involves a fascination with choreography's philosophical examination of movements. By imagining EEG data recordings to examine dance movements, questions arise regarding the limitations and information conveyed by this data (Hagedoorn, 2005, p.148). While Hagedoorn does not directly address ethical implications in this field, the evaluation of perceptual and emotional effects of movement highlights the need for a holistic understanding of dance and science. However, the collection of real-time EEG data currently possible from both dancers and audiences raises ethical concerns that Hagedoorn (2005, 2012) could not address. Palk et al., (2020) study on ethical issues in global neuroimaging covers some of the issues could not covered in 2005.

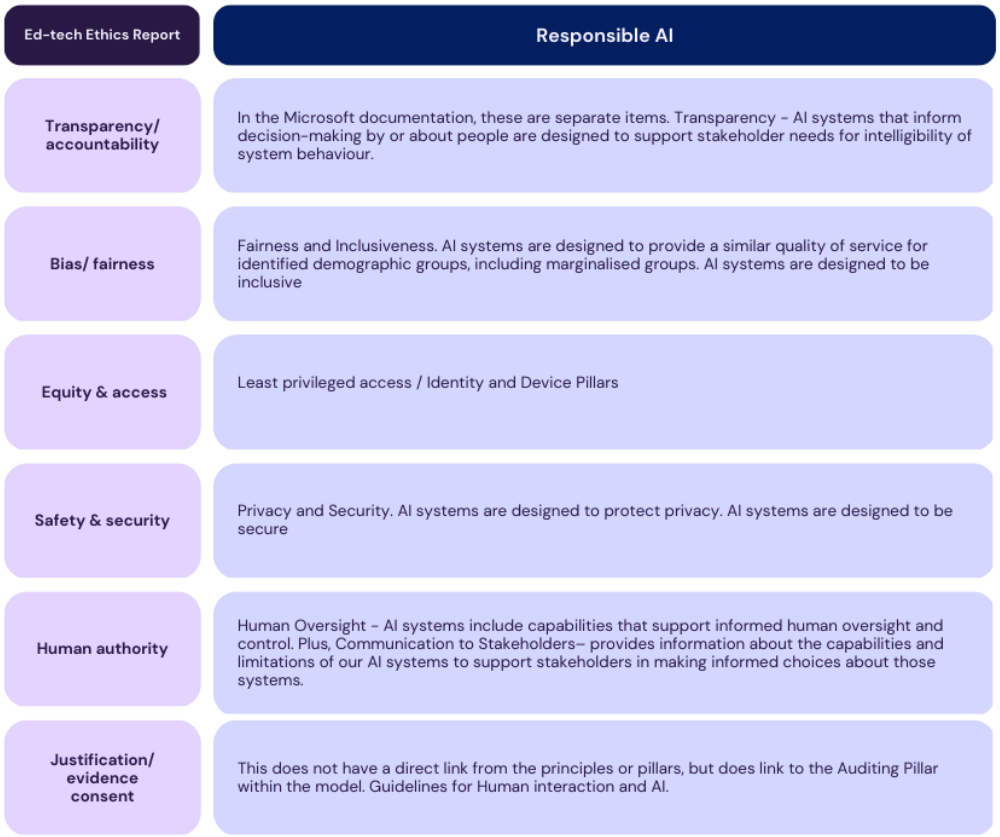
2.3.3.2 Ethics but not 'That Ethics'

This section presents a critical enquiry into the ethics of biodigital data, including neuroethics and decision-making for the computing classroom. Neuroethics concerns ethical issues raised by our increased and constantly improving understanding of the brain (Salles et al., 2019). There is a frustrating lack of attention paid to the future implications of storing, using, and sharing data generated through biometric devices, and debates about digital ethics offer many different ideas, difficulties, and challenges. Research in this area focuses on such topics as 'Information Ethics' (Capurro, 2006, 2009, 2018; Floridi, 2013), and digital media ethics (Kidd, 2019) neither specifically cover pre-university education.

Digital ethics is beginning to be a more prominent aspect of computing. A core topic in many GCSE and A-Level computing courses is now the 'consequences of uses of computing' (AQA, 2020), and examines the individual (moral), social (ethical), legal, and cultural issues and opportunities surrounding computing. The ACM Code of Ethics (Gotternbarn, 2018) was developed to accompany the development of software and technical advancements, and the IEEE 2089–2021 Standard for an Age-Appropriate Digital Services came into force in 2021 to regulate organisations that provide digital services to young people. As educators are responsible for the wellbeing of their students in the classroom, the latter regulations apply to the educational context. When developing this Standard, young people were consulted and involved in the design process, ensuring that the document is efficient and accessible to its target audience.

Other frameworks are being developed to regulate and track the use of biometric data, including EEG data, such as the IEEE Neuroethics Framework (IEEE Brain, summer 2023), which includes a specific section on Education. The recent Ryder Review (2022), an independent legal review of the governance of biometric data in England and Wales, has ten detailed recommendations for processing and working with biometric data. The Ed-Tech Ethics Report (Shum et al., 2022) details the design and processes involved in the development of draft ethics principles specifically 'for the use of technology, interactive tools using analytics or AI to make sense of student data' (Shum et al., 2022, p. 16). I illustrate the alignment between the principles of the Ed-tech ethics report and Microsoft's Responsible AI (Microsoft, 2022) in Figure 2.7, as I perceive them.

Figure 2.7 *Alignment of Ed-Tech Ethics Principles and Zero Trust Methodology*



EEG data have been used in studies seeking to examine our emotional responses, control of physical objects, reaction time in gaming, and in safety simulations. More recent educational studies focus on problem-solving in educational settings or contexts. The collection of EEG data involves pasting electrodes (small metal discs with thin wires attached) onto the scalp,

which then detect tiny electrical charges that signify brain activity in this study (NHS.UK, 2017). In this study EEG data are used as a 'digital artefact' for programming, data visualisation, and artistic activities, and requires an understanding of signal processing, which is also a key component of basic computing education.

Neuroethics constitutes a subsection of data-ethics, which in turn is part of the English Computing Programme of Study (PoS) at GCSE and A-Level. The aim of the PoS is for students to 'understand a range of ways to use technology safely, respectfully, responsibly, and securely, including protecting their online identity and privacy; recognise inappropriate content, contact, and conduct, and know how to report concerns' (DfE, 2014). The practical computing content of these courses is intertwined with data-ethics (Gov.UK, 2014; Önen & Tibet, 2020) via electroencephalogram (EEG) data, which is interpreted and understood through data transmission and signal processing concepts. EEG is a recording of the electrical activity of the brain, brainwaves (NHS.uk). Additionally, stimuli response using prompts from the crime scene; and review the suspect's biometric data to measure emotional and physiological responses.

My study aims to (RQ1) raise awareness about data-ethics through using biometric data (skeleton tracking and EEG data) (RQ2) explored through ballet to collectively explore with the trainee computing teachers. I rework existing theories discussed previously, 2.3.3, of cognitive liability (Farahany, 2012; Farahany et al., 2018; Farahany, 2018, 2020) and cognitive liberty (Sententia, 2004) to create and develop (RQ1) the neuroethics component of this research, see knowledge discussion 3.4; Cross-curricular EEG data 8.2.4; EEG education 9.2.2-3. The nature of this research brings to light the risks inherent in exposing hidden, personal biometric data, and naturally therefore joins the ongoing discussion surrounding biodigital/neuroethics. Questions abound about the level of personal or sensitive data that can be gleaned from brainwave activity, as well as concerns about the ownership, storage, and sharing of data (Farahany, 2012, 2020). My research focuses on the PGCE, trainee computing teachers with an informed space in which to debate the ethical and future implications of sharing their own hidden data, and in so doing to raise awareness of the data-ethics. Ethical frameworks are not new to education or digital learning (Andrews et al., 2015), but the swift change of focus onto AI and machine learning (ML) domains means that including data-ethics is vital for the future of education. Educators (PGCE) must have a grasp of how algorithms

function, their innate biases, the limitations of data, and the ethical implications of exclusively quantitative methods of thinking and operating within society.

Since 2012, commercial EEG hardware and software have advanced rapidly, and the cost of these devices has dramatically reduced, with devices from Emotiv.com, Muse.com, and OpenBCI.org, becoming readily available. Research concerning the use of EEG data often focuses on criminology rather than its applications within education. For example, Sajous-Turner et al., (2019) study maps the structural brain differences found in criminals The 800 voluntary participants were divided into three distinct categories based on the crimes that they had committed: 'homicide, violent offences that were not homicide, or non-violent or minimally violent transgressions' (Sajous-Turner et al., 2019, p. 2058). Grey matter differed across the three groups, and homicide offenders had 'reduced grey matter' than those in the other categories.

Neuroscience research has potential for improving education by studying brainwaves, associated data, and analysing student-teacher dynamics. However, its application in this age range is contentious and restricted. Despite research being conducted in both labs and classrooms, participants are selected or excluded based on specific criteria, which may distort or eliminate the natural diversity present in an average classroom. Consequently, this can lead to bias in the collected data and findings, making it challenging to apply the results to real classroom settings. This was also a concern for the education cohort see 10.2.2.

2.3.4 Part II Summary

Kaufman and Glăveanu (2019) discuss the 'vast' nature and history of creativity, and suggest that defining creativity 'is something both new and task-appropriate' (Kaufman & Glăveanu, 2019, p. 27). When attempting to define creativity, many cite Rhodes' '4 P's' framework that describes an architecture of creativity: Person, Product, Process, and Press (Rhodes, 1961). In a computing context, Rhodes' '4 P's' map well into Resnick's 'Four Ps of Creative Learning': Projects, Peers, Passion, and Play (Resnick, 2014). Both frameworks focus on the creator of 'this' creativity, whereas Glavenau (2013) goes beyond the creator to include the physical or material nature, and produces the 'Five A's': Actors, Audiences, Actions, Artifacts, and Affordances (Glavenau, 2013). Resnick and Glavenau both articulate the social component of creativity alongside its construction or material nature. The combination of social and constructive creativity is at the core of DDD, and therefore my own research.

This section traced the possible factors involved in the declining figures of pre-university students studying computing at GCSE/A-Level, including issues of lacking motivation, teacher training, roles models, the widening gender divide and other imbalances, the cessation of ICT as an examined subject, and many other reasons. It is clear from this brief survey that education that could equip students to handle future technologies is deeply underrepresented in current pre-university education. To combat these factors, systemic changes need to be implemented across STEM learning, extending not only across the classroom but also into examination and assessment methods too. Jenkins' (2002) findings prove that programming is a difficult skill to master, requiring both a dedicated educator and self-directed practice, which is supported by Guzdial's work (2010, 2021). Combining STEM education with arts and arts practices could prove vital in the development of key creative and functional skills for these subjects.

This section also covered the current state of ethics across both digital and neuroscience fields, particularly focusing on neuroethics and the lack of awareness of biometric data-ethics in an ever-evolving technological world.

PART III Theory and Research Ethics

Part III explores the role of theory visualised through a nodal map, highlighting each node's importance in the wider study in turn. I then discuss research ethics used throughout my work, including how I plan, collect, store, secure, process, use, and potentially share data within my study.

2.4.1 The Role of Theory

Figure 2.8, NODAL MAP, below, denotes the key theories used in this study and how they relate to each other. I discuss the following themes in some detail:

(i) Movement (Polanyi, 1961, 1966; Matthews, 1998; Collins, 2010; Green, 2002, 2015); (ii) The visual (Mayer, 2005, 2020, 2022; Sweller, 2005; Sorden, 2012); (iii) Abstraction and metaphor (Lakoff, 1980, 1993; Kövecses, 2020); (iv) Play, which I define as the collaboration between computing learn and teaching (Bruner, 1977, 2006, 2006b; Resnick, 2014, 2017); (v) Computing, including CS concepts of BCI; (vi) Neuroethics (Farahany, 2012, 2023); and (vii) The pedagogical computing practices used in this study.

Figure 2.8 *Role of Theory Nodal Map*

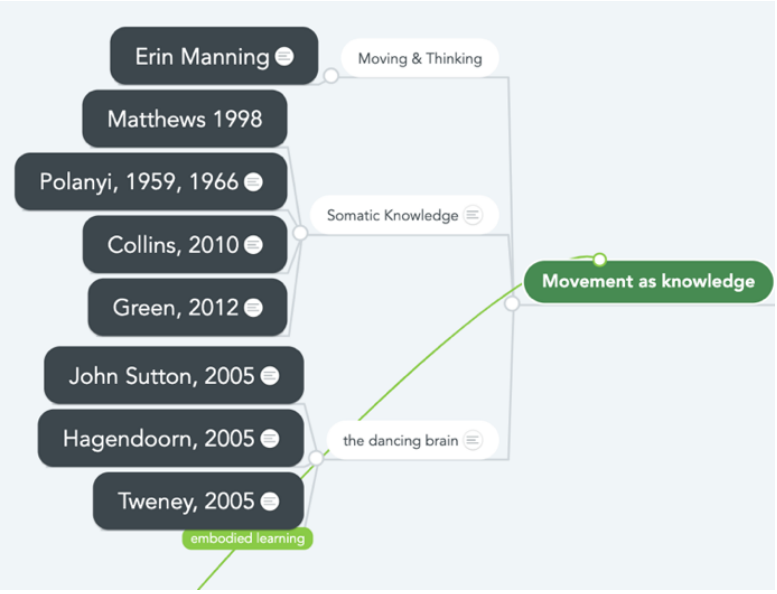
2.4.2 Explanation of the nodes

This section provides an overview and explanation of the theories discussed above, and the interactions between the categories, including key works on each area of research.

2.4.2.1 Movement as knowledge: dancing brain.

The body's self-awareness is developed through the repetition of learned movement. This can often become subconscious, such as when touch-typing (Collins, 2010, p. 104), balancing when riding a bike, or even balancing on pointe as a ballet dancer. Movement as knowledge feeds the embodied process of internal awareness and internal 'biofeedback' communication (Green, 2012).

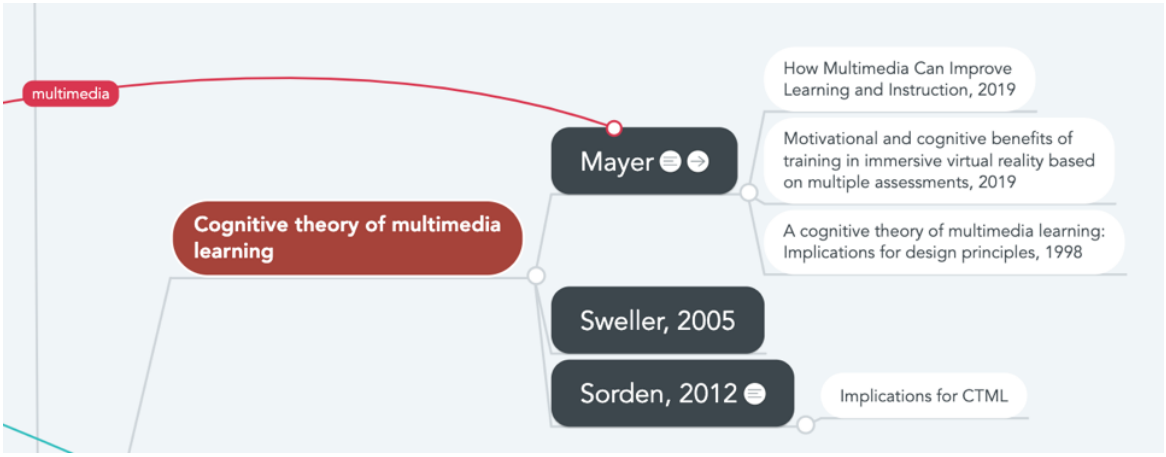
Figure 2.9 *Movement as Knowledge*



Somatic, tacit knowledge (Collins, 2010) emphasises the dualism of the body and brain, and is not Cartesian but an asymmetrical relationship which expands beyond Merlau-Ponty's (1945[2002]) analogy of the blind man's stick as an extension of himself. Attached to the man's body, the stick increases his reach beyond his natural limits, while remaining an object, separate but linked to the self. Merleau-Ponty's analogy is an example of this asymmetrical relationship: the human uses the stick as an extension of himself, but the stick cannot use the human in a similar manner (Collins, 2010). This analogy works too on pointe shoes, as the human and object move together, separate but part of the whole, and the human is augmented by the presence and use of the object (Sutton, 2005; Hagendoorn, 2005). This links to the notions of somatic surveillance explored later in this thesis, see 3.4.1.

2.4.2.2 The visual.

Figure 2.10 *Cognitive Theory of Multimedia Learning*



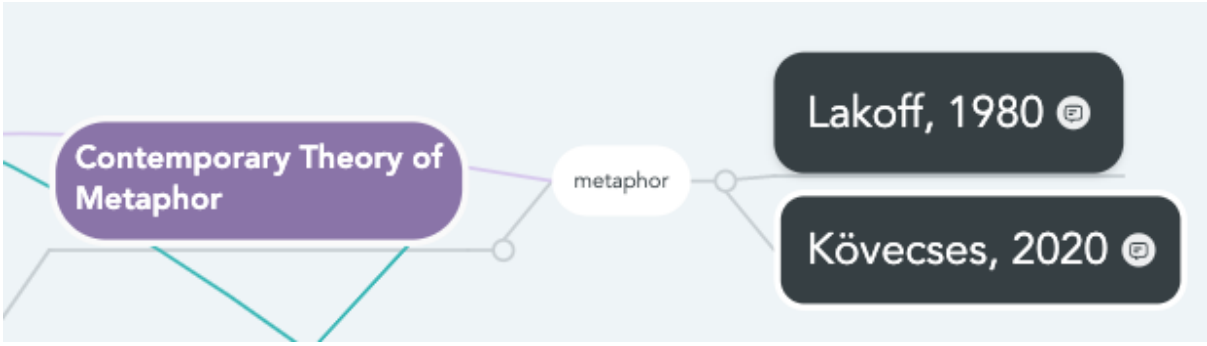
Mayer's Cognitive Theory of Multimedia Learning (CTML) is the principle that 'people learn more deeply from words and images than from words alone' (Mayer, 2005, p. 47). Mayer's

principle has become a foundation of educational theory, and developing his theory further to include three new principles (Mayer, 2020): embodiment – 'use of body to enhance instructional communication' (p.244). Immersion– 'creation of virtual environment using technology' (p. 358). Generative activity– 'learners must use the lesson rather than simple remember it' (p. 371) CMTL follows four guiding principles: theoretical plausibility, testability, empirical plausibility, and applicability. Underpinned by assumptions from cognitive neuroscience relating to memory storage, processing, and representation, this developed into 'dual channel' coding (Mayer & Mereno, 1998b, 2003). Example: dance a metaphor in the Metalurgy, Sir Prof. Bhadeshia compares atom displacement transmission in Steels to ballet dancers being 'highly constrained within the choreography' (Bhadeshia, 2023), as 'atoms are displaced into their positions in a coordinated motion' (Bhadeshia, 2021, p.6).

2.4.2.3 Abstraction as metaphor

Conceptual Metaphor Theory (CMT), as defined by Lakoff and Johnson (1980, 1980b), plays an integral role in this study, Figure 2.10. A conceptual metaphor enables and facilitates the understanding of one domain of experience (typically abstract) in terms of another (typically concrete). For example, dancers moving in patterns represent serial and parallel data streams. This two-fold nature of both process and product is key to developing an understanding and transferral of knowledge (Kövecses, 2020) from one domain through the medium of another. CMT originated in linguistics studies, which often refers to an internal linguistic mental lexicon (p. 2) reworking of the standard definition of CMT aligns with how ballet is used in this study in the notation of a systematic set of correspondences between domains of experience (Lakoff & Johnson, 1980; Kövecses, 2020).

Figure 2.11 *Conceptual Metaphor Theory*



Many subsets of CMT align with this study: (i) the State Metaphor System (Lakoff, 1992), which links directly to RQ1 data-ethics awareness and RQ2 widening participation ; (ii) the programming element of my study, specifically object-oriented programming (using objects as subsets of main classes that share attributes, characteristics, and methods, a class is often described as a blueprint for an 'object'); (iii) Complex Systems Metaphor System (CSMS)—Kövecses explains that 'abstract complex systems are complex physical systems' (Kövecses, 1995). Abstraction is core to DDD, not only because it is a key element of computational thinking (Wing, 2006), but also because it is possible to see ballet as a visual abstraction of CS theories through data transmission and signal processing within this study.

Similarly, Laban's dance notation (1928) or kinetography (Hutchinson et al., 1977) are symbolic representations of movement within a 3D space which present visual abstractions of choreography. Dabrowska and Giurchescu's work in the 1980s and 1990s on the analysis, structure, and classification of music and folk dance is also relevant as it constructs 'a system with a high degree of abstraction, which could later enable the use of computers; to present dance structure in graphic symbols' (Dabrowska, 1983, cited in Giurchescu & Torp, 1991).

2.4.2.4 Play

Figure 2.12 *Theory of Play*

Bruner's (2006, 2006b) educational learning theories are crucial to several areas of my own study. His modes of representation are active (enactive), image (iconic), language (symbolic), and the spiral curriculum, and use play as a means through which to construct the real. This engagement of students through play requires the 'reduction of the consequences of errors and failure' (Bruner, 2006, p.57) which directly corresponds with the 'tinkering' nature of computing and the use of ballet in DDD. Failure is built into Bruner's methodology, as well as the process of coding and learning ballet. Instead of using the term 'failure,' which holds such negative connotations, we need to consider the iterative development of these areas of creativity, in which errors are a crucial part of the process. Studies such as Bruner's show that

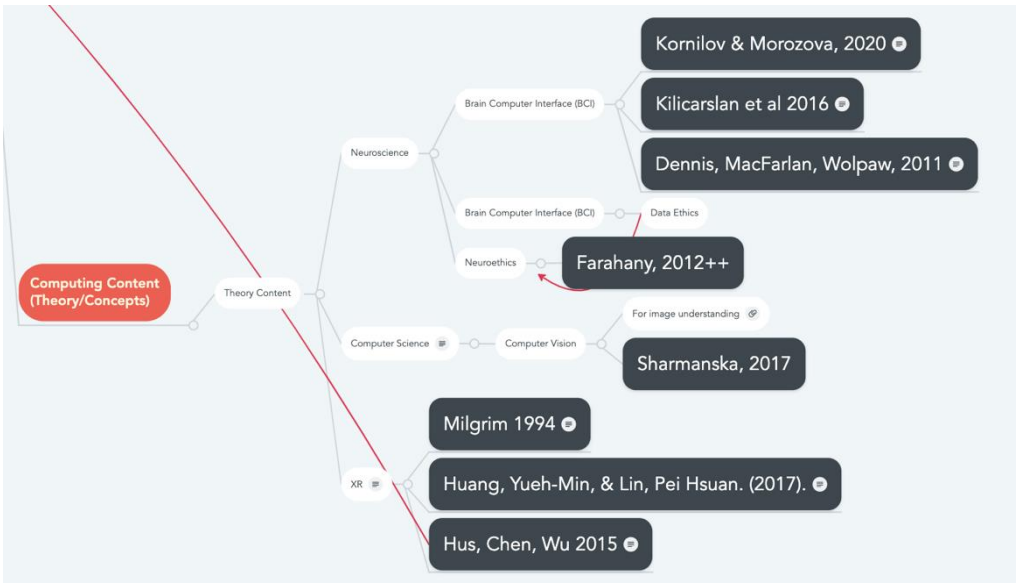
when tasks are perceived as extensions of play or are playful in nature, learners become less frustrated by errors or failures and are likely to continue to work on the task in a flexible and adaptable manner (Bruner, 2006). Although Bruner's work discusses young learners, the principles can equally be applied to different age ranges.

Resnick (2014) argues that play is a constructionist approach to learning, and involves experimentation—trying new things, tinkering with materials, testing boundaries, taking risks, and repetitive iterations of processes or methods of working. Resnick and his team, Scratch Foundation, state that 'students can develop the creativity, collaboration, communication, [and technical] skills that are needed to thrive in today's fast changing world.' (Resnick & Rusk, 2020, p. 127). It is important to note the wide variation of methods of play, and the varying value of implementing these in a classroom.

Bers (2012) work on 'Designing Digital Experiences for Positive Youth Development: From Playpen to Playground' use of metaphors, shopping malls and playgrounds, illuminates the role of new technologies for promoting core developmental milestone of each age group, often. Or Han et al., (2015) study on examining young children's perceptions of AR dramatic paly.

2.4.2.5 Computer Science concepts

Figure 2.13 *Computing Content*

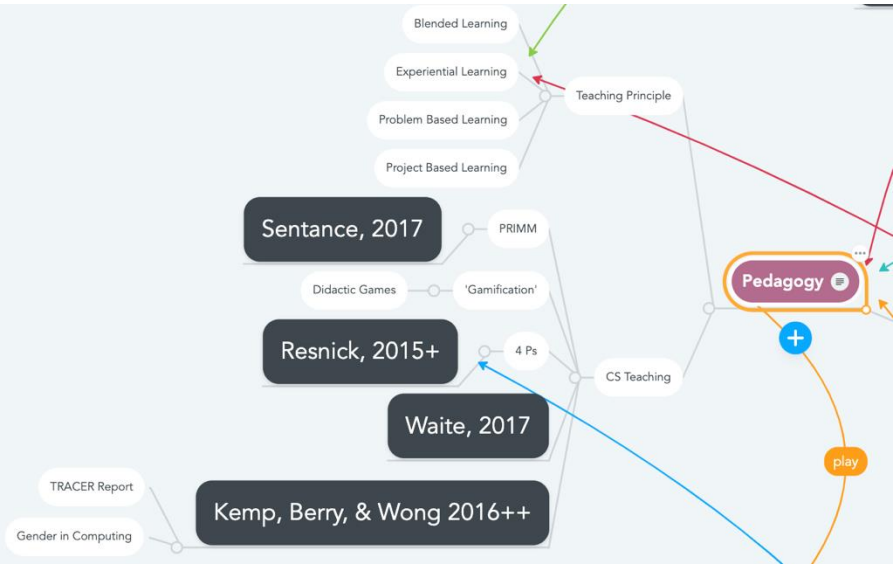


CS content and theory underpin the design of my study, particularly the neuroethics content, which is driven by Farahany's cognitive liberty work (2012, 2017, 2019) and linked with the

Cognitive Load Theory CLT (Thomas et al., 2023). I also consulted the hardware and software of Brain Computer Interfaces (BCI), EEG devices (Kilicarslan et al., 2016; McFarland & Wolpaw, 2011), computer vision (Sharmanska et al., 2014, Sharmanska & Quadrianto, 2017), XR, and technologies relating to immersive learning and development (Miligram & Kishino, 1994; Huang & Lin 2017; MacDowell, 2023).

2.4.2.6 Computing Pedagogy

Figure 2.14 *Pedagogy*



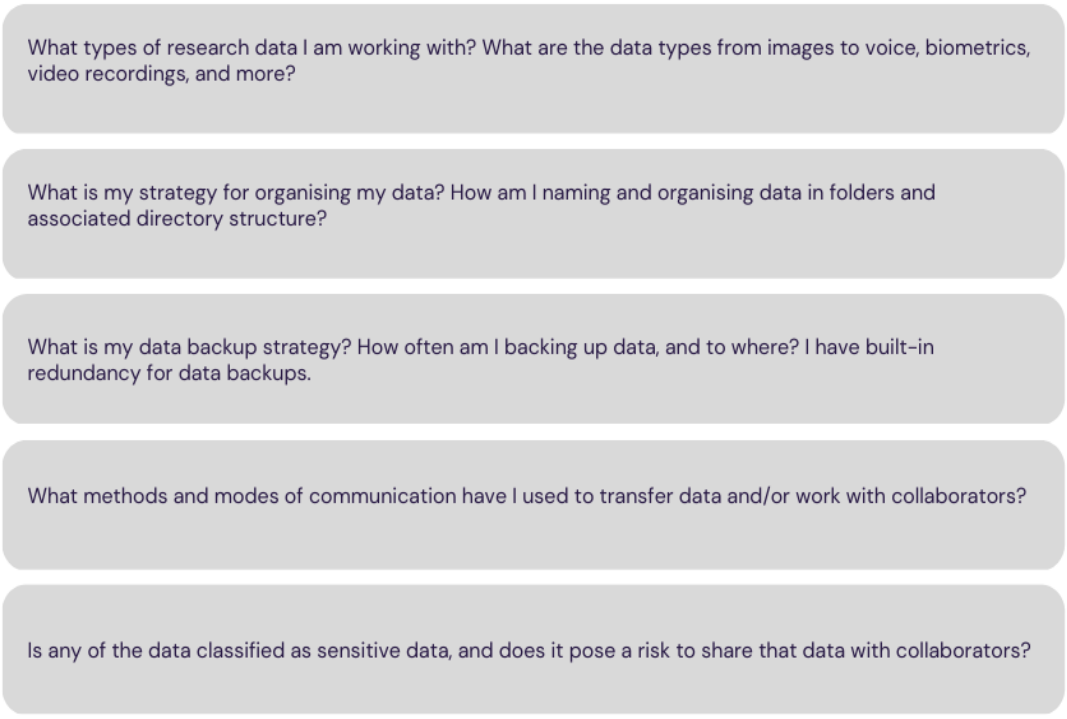
The pedagogy of teaching is split between computing teaching (Resnick, 2015; Waite, 2017; Sentence et al., 2018) and more general teaching principles that can be applied to computing education such as MacDowell (2023) study on teachers designing immersive experience for environmental and sustainability education.. This literature review does not cover all aspects of pre-university pedagogy, but instead focuses on those that directly related to computing and student data (Kemp et al., 2016++).

2.4.3 Research Ethics

Ethical considerations in any research study are vital to ensure that individuals, organisations, and any other involved parties are protected and that the research continues to work towards the positive progression of knowledge. Good research practice requires planning the collection, storage, security, processing, and use of research data, in accordance with university rules and compliance regulations (Teperek, 2015a,2015b; UKRI, 2022). In order to

adhere to these ethical guidelines, the researcher must consider the following questions, set out in Figure 2.15, at each stage of their research.

Figure 2.15 *Questions for Data Governance*



There is an important distinction to be made here between collected data (all the data collected throughout the research) and research data (specific data identified and used to inform the development of my thesis and results). All interactions with participants create a digital footprint or recording, which raises ethical considerations regarding the protection, storage, and ownership of these data.

2.4.4 Part III Summary

Part III of this literature review examines the role of foundational theories and approaches to research ethics that underpin my study. Figure 2.8 depicts the main theories used and the connections between them, such as embodied learning, knowledge transfer, multimedia, play, tinkering, metaphor, and abstraction. The size of a node has no bearing on the impact or importance in this study.

I discussed research ethics alongside the data-ethics that form an integral part of my research, particularly the ethical approaches and methods used to collect, store, and analyse personal, biometric data.

2.5 Conclusion

This literature review has provided a background and explanation of the key concepts, theories, and methodologies adopted throughout my research, and how these intertwine and inform each other. I explored how embodied movement, the agency of ballet, can provide a medium through which education experiences can flourish in both computing and dance, and how these two seemingly opposite fields of study are actually deeply similar and interlinked. My use of AgileDBR allows the synergy and hybridity of this study to develop and iterate over time, incorporating 'reflect and adapt' stages throughout. Fundamentally, 'the ability to remake knowledge for relevance in different contexts' (Fook, 2002, p. 156) is at the core of this study, DDD, and computing education.

Broadening participation in computing is an ongoing challenge, as data continue to illustrate the decline in numbers of female students and other underrepresented groups studying computing and computing-related disciplines across England. The gaps in the national curriculum both for training new computing teachers and in computing courses for students, particularly addressing data-ethics and related concerns, only adds to this issue. This review reaffirms the need for continued research in this area, and my study aims to contribute to changing perceptions of computing and its ethical implications in today's data-driven world.

Research has found that STEM subjects require a higher level of spatial working memory, which is also evident in dancers, and yet limited research exists comparing these two fields or commenting on how this similarity may be used. Hidi's (2016) study combines motivational research with neuroscience to demonstrate the lack of integration of neuroscience data into educational motivation research and challenge the gender imbalance in this area.

This study is an exploration of computing education which also seeks to raise awareness of data-ethics through computational and arts practices. I hope to demonstrate how ballet may be used as a pedagogical tool, through the collection and analysis of biometric data, which can inform data-ethics and rethink current educational practices in computing. Through using human bodies to collect data in this way, my study raises the issue of using the human body as a data artefact, and combining dancing with technology breaks down the perceived boundaries between computing and the arts. The participants are seen as co-constructors in this research study, which aims to engage participants and encourage active participation in their own education in order to inspire them to learn more about computing data-ethics. Through an integrated design combining qualitative and quantitative data collection and analysis, I hope

to provide a holistic understanding of my main areas of interest and further knowledge in this vital field of education (Hesse-Biber, 2010; Caracelli, 2006). The research questions born from this literature review:

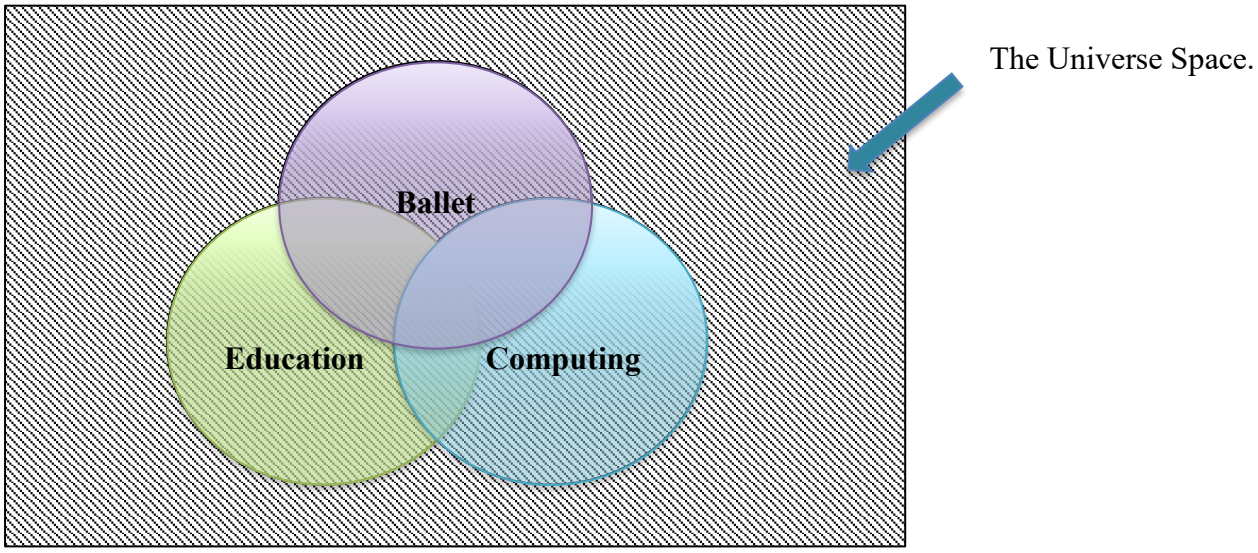
RQ1: How can we raise awareness of data-ethics for trainee computing teachers?

RQ2: What new insights and unexplored approaches are there in combining classical ballet and biometric data to broaden participation in computing education?

Chapter Three: Ontological Kaleidoscope, theoretical fusions

This chapter examines the convergence of the three main fields of my research (education, ballet, and computing), and how this illuminates the discussion, understanding, and awareness of data-ethics for computing through dance and immersive technologies as viewed through an ontological kaleidoscope.

Figure 3.1 *Venn Diagram of Domains Within a Universe*

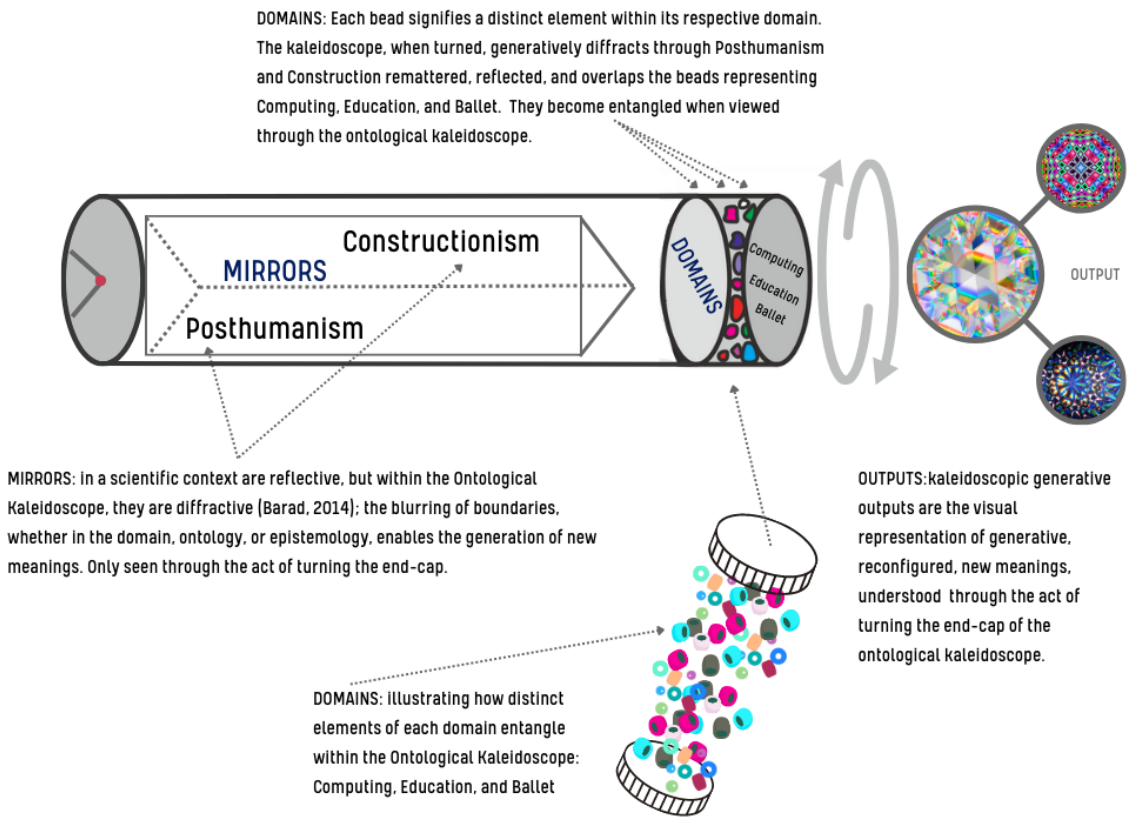


The Venn diagram in Figure 3.1 represents transdisciplinarity, beyond a domain's perceived boundaries (the constrained circles within Venn diagrams) into the universe space of a Venn diagram, to borrow a term from boolean algebra. The universe space is not everything in existence, but everything within the confines of this study– 'the totality of objects under consideration' (Ennes, 1980, p. 61)– ontological kaleidoscope is the methodologies, fields of research, and approaches utilised throughout my study. This chapter begins by defining my understanding of an ontological kaleidoscope, beyond and the relationship between the domains within this study, before explaining several aspects of this kaleidoscope in detail, including: (i) theoretical consideration of posthumanism and constructionism; (ii) concepts of entanglement, relationality, and diffraction; (iii) data-ethics in the context of the study, including computer ethics, subject silos, XR, and body data; and (iv) the ontological kaleidoscope as a whole.

3.1 What is the Ontological Kaleidoscope?

In its simplest form, the kaleidoscope is an optical device consisting of a tube with mirrors that reflect images of glass beads observed through rotating the endcap and watching the ever-changing patterns which result from the moving beads. Figure 3.2. takes the simple kaleidoscope diagram with the ontological kaleidoscope overlayed.

Figure 3.2 *Kaleidoscope Component Diagram mapped onto ontological kaleidoscope (inspired by* Sutar, Narlikar, and Tyagi (illustrator)*, 2022 p.170)*

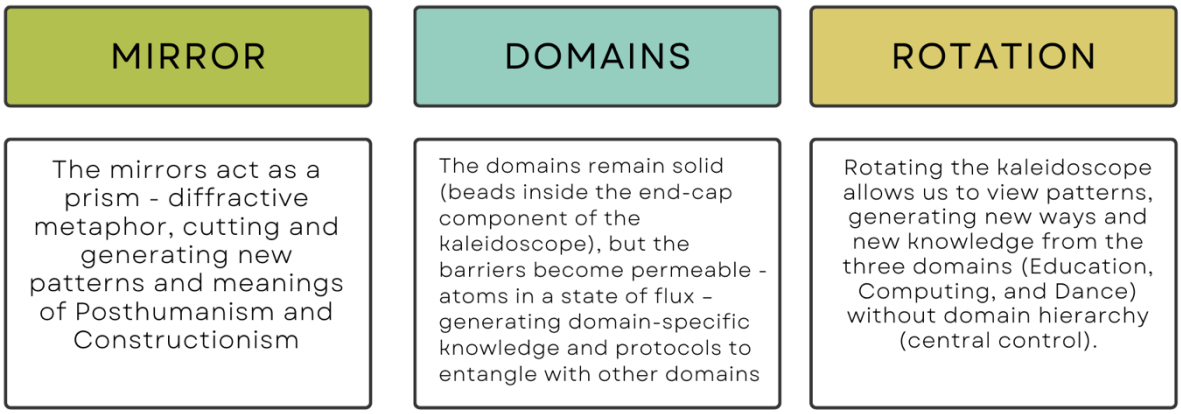


The kaleidoscope was created and patented in 1817 by Sir David Brewster, a scientist, inventor, author, and academic administrator working in experimental physical optics. In the patent, he beautifully describes a kaleidoscope as:

> An instrument for creating and exhibiting an infinite variety of beautiful forms, and is constructed in a manner as either to please the eye by an ever-varying succession of tints and symmetrical forms. (Brewster, 1817, p. 1)

Bringing together multiple concepts and theoretical schools of thought, the ontological kaleidoscope enables the generation of new meaning and understanding through the following states, as shown below Figure 3.3.

Figure 3.3 *States within the Ontological Kaleidoscope*



The domains of education, computing, and dance are often perceived as vastly different from each other, much like the different colours of beads in a kaleidoscope. Through entangling these disciplines with each other, however, patterns and similarities are generated, which then inform and inspire new modes and approaches to research and education practices. Turning the kaleidoscope is a mode of intra-action, the diffraction of iterative patterns (Barad, 2003, 2007, 2014), and represents this combination of disparate domains in my metaphor. The eyepiece, here the researcher, allows viewers to see these changing patterns and interpret them, while the beads themselves (here the different subjects) are refracted and rematterered (Barad, 2014, p. 147) into new forms and fields of research. I use this metaphor here to explain the ever-changing and expanding possibilities of this transdisciplinary approach, and the great value of such inclusive, diverse, and holistic research.

3.2 Consideration of Theories

In this section, I adopt posthumanism and constructionism as lenses/mirrors within the ontological kaleidoscope through which I conduct my research, and explore how these paradigms illuminate and apply to my work. The foundational authors consulted within this section include Barad, Bayley, and Papert, whose contributions shaped my considerations of these methodologies and theories.

3.2.1 Posthumanism

Posthumanism is a philosophical perspective that moves beyond the binary notion of human and non-human and involves the ethical interrogation of the complex connections of life with all forms and processes, whether human or non-human. Posthumanism draws upon and expands disciplinary boundaries as means of communication, research, and the creation of new knowledge and insights.

Barad, as an important author within this domain, questions the traditional boundaries and centralisation of human exceptionalism, arguing instead for a refusal of divisions between the human, non-human, natural, and cultural. Barad proposes a blurring of boundaries, how we may actively 'reconfigure and reconfiguring possibilities' of our place within the universe (Barad, 2017, p. 177), and posits posthumanism as a performative rather than a representational way of analysing phenomena beyond the binaries of substance/subject, human/non-human. Through agential realism, Barad argues that 'agency (doing or being) is a matter of intra-acting,' that is, enactment, not an innate attribute of something. The 'possibilities of change' can be seen through 'agential cuts materialising different phenomena' across the iterative nature of my study. Barad's work is full of ethics as an underlying principle in our intra-action with matter. Posthumanism encompasses ontology, epistemology, and axiology, and ethics appears again and again throughout these subjects and affects all stages of the research and generation of knowledge. Posthumanism within the ontological kaleidoscope draws on Barad's concept of 'ethico-onto-epistem-ology'—using scientific practices to engage in knowledge production, the world, and its inhabitants both human and non-human (Barad, 2003, p.824, 2007, p. 214). An understanding of Ethico-onto-epistem-ology requires an acknowledgement of the inseparable nature of ethics, ontology, and epistemology, which together create an ontological kaleidoscope.

Bayley's (2018) work on 'post human pedagogies' considers arts practices and processes in order to highlight the potential uses and implications of posthumanism within educational research. As with Barad, Bayley moves beyond the binaries of the human/non-human, specifically focusing on a pedagogy for the 21st century (Bayley, 2018, p. 6). Bayley highlights the pressing need for pedagogical change due to rapid technological, digital, and 'ontological blurriness' (p. 7), a disruption through an embedded and embodied approach, and to 're-imagine/ re-constitute' that which challenges our understandings of practice and 'the human'(p. 9) more broadly. Bayley combines posthumanism with new materialism and the

concept of deterritorialisation articulated in Barad, Braidotti, and other scholars' work. I read Braidotti's theory through Bayley's pedagogical lens throughout this research.

Bayley proposes 'new transdisciplinary ways of entangling the arts and social sciences to generate highly critical and complexity-aware pedagogies that work in practice to develop participatory thinking-strategies that recast teaching and learning' (Bayley, 2018, p.10). This entanglement is a firm foundation for my own inter/transdisciplinary work combining artistic and scientific methods in education and in raising awareness of data-ethics. Part II of Bayley's book *Entangling Practice with Concepts* is fundamental to the application of computing as a subject. This concept does not discount CS as a theoretical subject, but rather presents computing as more than theory, as defined in the Royal Society report (see Chapter Two, Section 2.2.3.1).

Criticism of posthumanism abounds, ranging from semantic uncertainties associated with 'post-isms' to fears that posthumanism will become inhuman(e) (Braidotti, 2013, p. 19). Barad posits other possible terms—trans-, anti-, or metahumanism—as ways of 'engaging with the limits of the human' (Barad, 2014, p. 428). These labels and semantic organisations of reality do not suggest that the posthuman is the next stage in evolution which discards the human entirely, however (see Barad's discussion of the 'death of the human,' 2014, p. 136). There is, however, a pressing need to rethink and reconceptualise research and education beyond boundaried requirements and methodologies, towards an open source, open governance, open data, and open science (Fernandes & Vos, 2017). Rather than providing an either/or choice of being, knowing, or valuing, posthumanism offers the mechanism within the ontological kaleidoscope to reveal new ways of knowledge and methodology creation and sharing across and through domains.

Generating an ontological kaleidoscope, therefore, provides space for the plurality of thought, practice, and knowledge connections through the mirrors of posthumanism and constructionism, iteratively reconfigured into patterns which offer diverse perspectives on computing education and data-ethics. Posthumanism and constructionism may not be considered natural partners but, in the context of this study, they are mutually entangled within the ontological kaleidoscope through mirrors and rotation, Fig 3.3, which these two perspectives interact and shape one another, much like how the kaleidoscope uses the interplay of light and mirrors to generate complex and dynamic patterns. The next section discusses constructionism through the work of Papert in the context of computing education.

3.2.2 Constructionism in Computing: an origin story

> Constructionism is that learning can happen most effectively when people are active in making tangible objects in the real world. (Harel & Papert, 1991 p. 1)

Constructionism in education is enacted practice of engaging children in constructive processes and methods of learning, encouraging them to physically create an object to aid their learning. This section engages with constructionism within computing education, and how the two have been intertwined even since the origin of computing itself. I examine Seymour Papert's theories and definitions of constructionism to inform these discussions and illuminate three main areas of inquiry: (i) what is understood by 'constructionism'; (ii) how constructionism is understood and applied within computing; (iii) the limits of constructivism according to Papert, and why these are important.

Constructionism focuses on 'producing knowledge through research practices rather than revealing knowledge' (Braun & Clark, 2022, p. 179). Outside the computing classroom, constructionism's main focus is in linguistics, where it informs and demonstrates theories about talking and writing. There are many branches of constructivism, including social constructivism, and this approach can be used throughout the curriculum to aid learning.

Seymour Papert developed constructionism within the computing education context alongside Jean Piaget, his doctoral supervisor, in the 1950s and 1960s as an extension of Papert's doctoral thesis. The work was granted four years of funding through MIT. This approach evolved through 1987–1991, the National Science Foundation (NSF) granted $1.5M to the development of future work in this vital area.

> Constructionism, according to Papert—the N word as opposed to the V word—shares constructivism's view of learning as 'building knowledge structures' through progressive internalization of action [...], whether it's a sand castle on the beach or a theory of the universe (Harel & Papert, 1991, p. 1).

Constructionism is more than simply learning by making. It is a multifaceted, richer method of building and developing sense through the process of construction. The learner is central to this process, and constructionism defines learning as the reconstruction rather than simply the transmission knowledge, and by engaging in 'construction of meaningful product' (Papert & Harel, 1991, p. 4), learners experience and understand knowledge on their own terms in their own specific contexts. The careful omission of 'a' in the quotation above demonstrates that

this ‘product’ is not one object created, but can encompass a process of creation too. The term ‘tinkering’ is often used to describe processes used in computing education and the wider computing domain, and is a method of exploration and knowledge discovery achieved ‘only by groping in our disorderly bags of tricks and tools for the wherewithal to build understandings’ (Papert & Harel, 1994, p. 5).

When defining constructionism in relation to computing, Papert acknowledges Claude Levi-Strauss’ concept of *bricolage*, a defining principle through combining whatever is at hand into something new. Papert notes that the *bricoleur* (the creator) in Levi-Strauss’ (Lévi-Strauss, 1962) theory does not necessarily follow a logical structure or argument when creating, but instead works with what is available to create something innovative from concrete and mismatched pieces. Papert likens this to LOGO, a programming language, and the act of programming as a means of creating and educating, rather than traditional uses of maths and small problem-solving activities (Harel & Papert, 1991). Papert compared the individuality of maths lessons, which compartmentalised learning into single lessons, with the expansive methods applied in art classes, which involved the creation of art over time in a continuously varied development of ideas. These observations informed Papert’s vision of the revolutionised maths classroom, and he imagined the possibilities of ‘soap-sculpture math’ (Harel &Papert, 1991, p. 11) using constructionist ideas learned in the art classroom to engage and adapt maths learning.

The sculpture in Papert’s constructionism becomes ‘*an object to think with*’ (Papert, 1980, p. 11; Harel & Papert, 1991, p. 13), and the learner becomes a creator of knowledge, rather than just a receiver. Learners engage with objects as they create them, and these creations act as physical manifestations of knowledge gained throughout this educative exercise, which is a more effective and long-lasting method of learning.

Constructionism can often be confused with constructivism, an approach which draws on Piaget’s work and focuses on sense-making (also key to other theories of learning), but shifts from knowledge acquisition to knowledge construction. Piaget’s constructivism observes the child through different developmental stages, providing a structured theory for understanding child interests, activities, and methods of action in each ‘fixed’ developmental phase. This approach is more collective, as ‘child’ is a group or category, rather than an individual with differences and personal preferences for learning, knowledge, and development as constructionism acknowledges. Piaget’s theory of constructivism does not consider the

context of this development of a child through developmental stages. In simple terms, constructionism argues that learning is achieved through the creation of concrete artefacts, whereas constructivism views learning as a purely cognitive process. This difference is a vital consideration in my examination of computing as an applied subject, not just as a theoretical approach.

The role of constructionism within applied computing is laid out in *Constructionism in Practice* (Kafai & Resnick, 1996). In this foundational work on the subject, Resnick constructs a three-threaded approach (*design fabric*) to developing a new paradigm for computing. The first thread, understanding 'how students construct new concepts and meaning through scaffolding the process through computational media,' explores how educators may provide computational tools to support learners' experimentation and exploration within computing (Kafai & Resnick, 1996, p. 225). The second thread constructs 'domain knowledge' through computational tools to 'recast knowledge,' not simply providing the same knowledge in 'new clothing,' (Kafai & Resnick, 1996, p. 225) but instead providing new ways of thinking (and exploring) domain concepts that were previously perceived as inaccessible. The third thread, which is intertwined with the first two, is a new paradigm with a central focus on 'parallelism,' which Resnick defines as 'providing new ways for programmers to model, control, and think about actions that actually happen in parallel' (Kafai & Resnick, 1996, p. 257). Running things simultaneously is a key component of programming and often involves localised or decentralised interactions which explore both concepts and real-world situations, all of which are vital considerations when constructing an effective computing education environment. Constructionism, as informed by Kafai and Resnick's work, incorporates design theories, going beyond the narrower constructivist focus on process to explore the role of artefact/product in constructing meaning within computing.

Papert and Turkle (1990) discuss epistemological pluralism as a crucial element of computing, as 'when we understand the computer as a projective screen for different approaches to knowledge, we can listen to these conversations in a new way' (Turkle & Papert, 1990, p. 154). The authors draw on Piaget's understanding of epistemology as the study of 'the diverse nature of different kinds of knowledge,' and argue that different approaches to knowledge are equally valid (p. 129). Papert and Turkle's 'projective screen' is akin to the ontological kaleidoscope I adopt throughout this study, which generates unbounded space for open conversations about being and knowing, and/or 'intellectual

alliances' (Turkle and Papert, 1990, p. 130) through ever-changing patterns of meaning and innovative understandings.

The theoretical frameworks discussed above are an important framework on which to build the concepts, methodologies, and practices of the rest of my study. Accordingly, the next section, 3.3, will discuss the central concepts of entanglement, relationality (over intersectionality), and diffraction.

3.3 Concepts

This section explores three principal concepts (entanglement, relationality, and diffraction) that underpin the ontological kaleidoscope used throughout my study. Entanglement is the interconnectedness beyond intersectionality of all different elements within this study, see 3.3.1. Rationality explores the complex and interconnected nature of knowledge and information, between distinct domain that can be connected through shared concepts and practices, see 3.3.2. Lastly, diffraction in context of knowledge and information allows for new meanings to develop through different perspectives and approaches to computing, see 3.3.3. I consider the role that each concept plays in the wider kaleidoscope, as well as how they fit together and the importance of each to my main areas of research

3.3.1 Entanglement

The ontological kaleidoscope used throughout this study demonstrates the omnipresence of entanglement, as the kaleidoscope continually rematters reality through interweaving different elements of the whole with each other. Entanglement comes in many forms, including rhizomes, meshes, networks, and tapestries, and spans across many subject areas and disciplines. This wide application of entanglement does not hinder our understanding of the concept, however, but instead allows the creation and interweaving of multiple perspectives, embodiments, incorporations, and reinterpretations of knowledge and understandings throughout my research.

Entanglement is a transdisciplinary phenomenon that reaches beyond intersectionality, beyond the crossovers of a Venn diagram, (Fig 3.1). I argue that the three domains (dance, education, and computer science) discussed in this study are inextricably entangled, and can be mutually beneficial when considered as a whole, cohesive entity. My background as a dancer informs my perspective on computing, just as my background in education enables me to understand dance from a different perspective, which all suggest the potential

entanglements of all three that surpass domain interrelationships or intersectionality. These different perspective, lenses, enable [me] a changing of roles throughout the research process. From educator-observer during the workshops to creator/artist with digital artefacts, and that of the role researcher when engaging with the data/information generated from each iteration, see chapters 7-10.

In a wider example, the pursuit of knowledge has become evermore entangled with the pursuit of self-definition as the real and near-real collide through social media. Online profiles present curated selves, and create or redefine personal information without producing substantial meaning, and these pieces of data are then rapidly transmitted across the globe. Cuts and re-cuts of data as knowledge does not produce meaning until transformed to information. The transmission bits of data without meaning, then reconfiguring data into meaning and the creation of information. Ethical considerations are weaved throughout this generative creation cycle, as product and thought are meshed together and the individual becomes the collective. Example: ethics of dancer body data is a key point in data governance which also aligns with discussions from Dancers and the body as a data artefact, see 10.2.2. The individual dancer's biometrics are our collective responsibility. As an educational researcher, an artistic producer, and a practitioner, I am aware of my ethical obligation to produce relevant, progressive research that seeks to improve the domain in which I work. Akkerman et al. talk of the relevance of educational research (Akkerman et al., 2021), using phrases such as 'meaningful movements in motion' movements through entangled domains, and 'multiple positions, purposes, and emergent potential' to define learning.

This rhizomatic structure of entanglement across a network, fits well with my own research, but the subterranean, hidden aspect of Gilles Deleuze and Felix Guattari's philosophy on entanglement using the rhizome analogy departs from my aim. For Deleuze & Guattari (1989) rhizome is relationship between materials and forces rather than between matter and form. This biological underground mapping with entry and exit points nourishing these hidden connections. This hidden nature of biometric data and hidden connections between curriculum subjects goes against my study that seeks to highlight and expose a network of entanglements above ground, and is therefore more akin to the 'meshwork' metaphor (Ingold, 2010). Meshwork, an entangled network with omnidirectional flow of data, is central to my ontological perspective in this study, as it brings information, insights, and knowledge to the

surface, using the ontological kaleidoscope to envision these multiple connections (Ingold, 2010; Ingold, 2011, Chapters Two and Four).

Ingold's meshwork is one of 'fluxes and flows,' (Ingold, 2010, p.3), and links to the lines, connections, and nodes of a computer network. Filipová (2019) uses the metaphor of mycelium, a network of fungal threads or hyphae which often grow underground but can also appear above ground (in rotting tree stumps, for example). The 'lines and flow' within these meshwork structures move and create new connections, much like a synapse firing and generating new connections in the meshwork of the brain.

In my computing context, meshwork, also connect to relationality, is used in the creation of 3D models of dancers for the Augmented Reality (AR) experience. In this 3D modelling context, a mesh is a collection of vertices, edges, and faces that describe the shape of a 3D object, and a vertex is a single point within this mesh, an edge is a straight line connecting two vertices, and a face is a flat surface enclosed by edges. Ingold's 'lines and flow' depart from Delueze and Guattari's (2004) 'matter flow,' as Ingold refers to matter flow as 'material,' and argues that we inhabit 'not a material world but a world of materials, of matter in flux' (Ingold, 2010, p. 8).

In this study, datasets and artefacts interact and entangle within a meshwork of various intertwined explorations, such as the computing classroom's learning activities that produce dance data (see 9.2.4), then materialised through digital virtual technologies into (AR) worlds and patterns viewed through the ontological kaleidoscope (see 3.4.3 below). Entanglement through meshwork establishes interconnected lines of potentiality and possibility, not just a network of interactions between domains or artefacts. The link between meshwork of entanglement aligns with Resnick's notion of computer networks as a medium for construction rather than information dissemination, allowing students to learn in new ways through construction activities (Resnick, 1996, p. 280).

3.3.2 Relationality

Relationality and connectedness are cultivated, experienced, and observed through the ebb and flow of knowledge transfers across domains (any group of users, devices, or servers that share data via a network). Domains are distinct from one another, but dematerialise in atoms, moving and rematterering into a diffractive pattern of differences both within and as part of an entangled state (Barad, 2007, p. 89). These spaces between, which reflect the different

components that make up a subject in an education context, are of great value to both learners and educators. I am using relationality and diffraction on two levels here: (i) to explain how DDD operates, and (ii) to explain how the relationship between education, dance, and computing functions. The 'particular configurations' (Haraway, 2016) that relationality and diffraction draw out enable narratives to unfold, and information is 'configured—reconfigured' (Haraway, 2016, p. 16) through space, time, and place to inform knowledge acquisition and development.

3.3.3 Diffraction

Each turn of the kaleidoscope, this blurring of boundaries, whether in the domain, ontology, or epistemology, enables the creation of new meanings. The elements within the kaleidoscope exist in a continuous fluid state, not fixed, and bounded by subject, ontology, or epistemology. Pattern recognition is central to computational thinking (Brennan & Resnick, 2012; Wing, 2006), and the diffraction of light through a kaleidoscope echoes the different perspectives and understandings that can develop from different methods and approaches to computing. Diffraction is not just a reflection, but the bending-blurring of knowing and meaning around the corners, through domains generating new perspectives.

Bayley (2018) explores posthuman pedagogies in practice, drawing on Barad (2007), Haraway (2016), and Braidotti (2013) to understand and explain the position of posthumanism within the concept of diffraction. Bayley posits diffraction as 'a prism via which we can appreciate the active processes of differing in action and […] multiplicity' (Bayley, 2018, p. 12).

Bergson and Andison (translated 1946) discuss the mediation of the entangled 'nature and function,' which is especially important within immersive spaces/experiences. Immersive worlds, such as Virbela™, are experienced through a customised avatar, usually in First Person Follow (FPF) view. An FPF perspective views an avatar from behind, and follows them as they (guided by the user) interact with the constructed world (Helsby, 2015). The avatar represents the user, and the user represents the avatar, and so the experience is entangled, a 'co-presence' (Shields, 2003, p. 63) or 'telepresence' (Boddington, 2021; Shields, 2003). This sense of others within the 'in-world,' the virtual digital medium, expands and potentially alters our embodied experience. Beyond the screen, a seemingly limitless expanse of constantly generated worlds create themselves as the avatar/human entanglement moves through them.

The iterative nature of my work complicates the notion of time as a singular, linear narrative in this context. By moving and working through kaleidoscopic diffractive timelines with all agents (human, non-human, matter, and virtual), I am able to develop new ways of creating, understanding, and mattering my research (Linstead & Mullarkey, 2003). With each rotation, see Figure 3.2, each part of my study reconfigures current and future elements, creating forces and pressures between increments and iterations, making and remaking theses and understandings of old and new concepts, see iteration summaries 8.3, 9.3, 10.3.

The next section considers data-ethics in the context of my research, focusing specifically on the philosophical, theoretical, and conceptual underpinnings needed in raising awareness of data-ethics for computing education.

3.4 Data-Ethics Context

I define data-ethics in this study as the principles and guidelines that govern the collection, management, use, and storage of data, with a focus on protecting individuals' privacy and security. It involves understanding and applying relevant legislation and practices, as well as considering ethical implications and potential biases related to the use of data (Michael et al., 2008; Farahany et al., 2018; Winfield et al., 2019; Farthing et al., 2021). Data-ethics also involves promoting responsible and ethical behaviour among individuals and organisations that handle data, including educators and educational institutions.

This study focuses on how the body as a data artefact can be used to raise awareness of data-ethics for participants. The complex, heterogeneous nature of the digital, the immersive, the human, and the technical nature of built environments (worlds), coupled with embodied interactions (physical and virtual) are not categorical or crystalline, but instead exist in an ever-expanding interplay of relationships, sensory responses, and technological devices. The role of ethics within this ever-expanding world is necessarily flexible and adaptable, but nevertheless, ethics is a vital consideration and component of these online/digital environments.

My exploration of data-ethics focuses on some critical areas of inquiry, such as the philosophy of information and how this relates to my research. A wider consideration of what constitutes information is then narrowed to my discussion of data, and how it may be considered as information that holds meaning, purpose, or direction.

In order to draw and build upon the Philosophy of Information (PoI) (Floridi, 2011a), we must first consider our understanding of it. PoI has two central tenets: (a) the critical investigation of the conceptual nature and basic principles of information, and (b) the elaboration and application of information-theoretic and computational methodologies to philosophical problems (Floridi, 2011a, p. 14). These two lenses are crucial to my research, both in terms of phenomena and practice. Both aspects of PoI are clarified in Floridi's (2011) book, but as only one edition was produced, and technology, approaches, and practices have undergone prolific change since 2011, this approach may seem somewhat outdated. Floridi's more recent work focuses primarily on digital ethics, AI, and the future of this technological society.

PoI is not a unified singularity, but rather a collection of theoretical lenses through which to analyse, evaluate, and explain information, and context and interconnectivity are essential to this understanding. PoI reaches beyond computation and algorithmic processes to explore information processing and rapid technology development, providing a cohesive framework on which to base theories and understandings of the many branches of specialised information: cognitive, immersive, ethical, and digital (Floridi, 2011b). From a constructionist, epistemological perspective, knowledge drawn through and from information is more than discoverable and inventive, but exists as a way of modelling and designing features and behaviours into meaningful worlds of experience. Using Agile to design experiences (systems, products, and services), my approach seeks to bridge the gap between ontological/epistemological academia and industry, observing and exploring the core alignment of features and behaviours across these two domains. Studying the PoI allows us to consider definitions of data and information, both through the ontological kaleidoscope metaphor and through the study's methodological approach.

Floridi depicts information as the well-formed structure (syntax) and meaning (semantics) of data (Floridi, 2016). Data themselves, according to Floridi, are a pre-informational state, initially without understanding attached. Floridi offers a non-reductionist approach to PoI, seeking only to suggest a re-lensing, re-seeing, or re-thinking of what we know (syntax) and what we understand (semantics), through which to create a new map of PoI. This approach replaces the traditional reductive, hierarchical model with a distributed network of mutual and dynamic, interconnected concepts. This ties into Barad's 'agential cuts' and the Ingold's 'entanglement' discussed earlier in 3.2. Floridi explores the 'points of intersection of

philosophical investigations' (Floridi, 2016, p. 2), and so each diffraction has ontological and/or epistemological potential.

The interrelational nature of information within a system is a continuous, iterative rhythm, providing incremental change and improvement. Data are generated both qualitatively and quantitatively in this study, approaches which are both important in research and industry as they offer different understandings, vantage points within the kaleidoscope, of information. Collections of data (datasets), information, and classifications (in an AI modelling sense), are vital groupings of the singular datum elements, as 'effective difference denotes demarcation, a line of classification, and all classification is hierarchic' (Bateson, 2015).

As connections are drawn between sections and bodies of data to produce useable information, the need to consider data-ethics becomes clear. Crucially, research of this kind must protect participants both now and in the future, and store this information as appropriate. Both Floridi and Barad provide new ways of viewing the multiplicity of understanding information through entanglement and the coexistence of different models. I entangle Floridi and Barad's different perspectives here in order to create a new understanding of information and data-ethics without requiring these theories to intersect, like beads in a kaleidoscope. Reading these perspectives together (particularly Barad, 2007, 2014, and Floridi, 2011, 2013, 2016) has enabled me to dematerialise the barriers between disciplines, cutting together knowledge and information to present a holistic view of data-ethics and its implications in my domain of study.

Having established the entanglement of data and information, it is vital to investigate this study's ethical dimensions further, in order to raise awareness of data-ethics and its importance within the computing classroom. My notions of meaning come into play when domain knowledge is bound by unseen disciplinary lines, drawing on Floridi's ideas of syntax and semantics. The blurring of disciplinary boundaries through sharing and using terminology, tools, and processes across cohorts, leading to transdisciplinary confidence, see findings 10.2.1.

3.4.1 Ethics of Computing

The ethics of computing concerns the ethical/moral standards that (should) govern the use, creation, and interaction between computers in terms of both hardware and software. These considerations include privacy, intellectual property, and the effects of computing in the wider

societal context. These ethical guidelines or standards should reflect the inherent diversity and variation within society, while ensuring that computing works towards implementing positive change. Rather than laws, these standards act as a kind of code of practice that many domains utilise. Floridi refers to this as 'Information Ethics,' which 'should clarify and solve ethical issues arising in the infosphere' (Floridi, 2013, p. 19), but recognises the challenges posed by different understandings of the boundaries of this concept. To tackle this problem, de Bruin and Floridi employ the idea of interlucency, the epistemic virtue governing ethically effective communication (de Bruin & Floridi, 2017, p.30). Interlucency describes the occurrence of interactions between specific entities and agents, adapting to 'establish common knowledge' (de Bruin, 2015, p. 161) and establish successful communication e.g., the ease with which dance participants used computing (transdisciplinary) terminology and processes, see 10.2.5. The transmission of information between these 'agents' (the human and the non-human) is transparent, open, and tracks the audience's understanding of communication. Though de Bruin coined the term when writing about the financial crisis, this idea can also apply to this research.

Ethical communication is vital to data-ethics and effective computing more generally. Literature in this area often deals with specific domains of computing, such as the ethics of cloud computing (de Bruin & Floridi, 2017), biomedical ethics (Beauchamp & Childress, 2019, Chapters Eight and Nine; Christen et al., 2014), and AI ethics (Dubber et al., 2020; Floridi, 2018; Rességuier & Rodrigues, 2020). The communication and transmission of data and information is integral to the collective process and output of this study.

In 'A Defence of Constructionism: Philosophy as Conceptual Engineering,' Floridi (2011) elevates the concept of constructionism by explicitly referencing Papert's work and applying it to engineering (computing) philosophy. This paper is not beyond critique, however, as Floridi uses the terms 'maker' and 'user' somewhat simplistically in his explanation of 'constructionism.' Floridi proposes a 'unified model of information ethics,' employing three microethical approaches with one macroethical approach (Floridi, 2013, 2016). The unified model consists of four stages: (i) resources, (ii) products, (iii) environment, and (iv) macroethics. Floridi defined the focus of each stage as an 'information vector' (Floridi, 2013, p. 21). Stage One explores information as a resource through effective, efficient, and fair management, treating the resource as valuable, constituting an input. The system requires information to be available, accessible, and accurate (where possible) to function correctly.

Stage Two concerns the ethics of informational products in the context of misinformation, liability, accountability, and agents are information consumers and information producers, constituting an output. Stage Three, the environment, concerns the location of information, privacy, and access to information. It is at this stage in the 1990s that information and computer ethics converge. Finally, Stage Four encompasses a macro view of ethics of computing, incorporating all the previous stages to understand problems beyond domains and agents in the Ethics of Information (EI). It should be noted that Floridi's PoI was written in 2013, and given the recent advancements of technology including deep fakes, drone technology, and biomedical devices, there is an increasing call towards reshaping and reforming data-ethics debates to fit these rapid advancements. Policies such as the Children's Code (2021) and the IEEE standard 2089 (2021) have begun to address this need for data-ethics awareness.

The protection of data and information on an individual level is a difficult task on account of distributed computing, cloud storage, biometrics, and the longevity of information. Floridi addresses some of these future concerns in 'The Ethics of Cloud Computing' (de Bruin & Floridi, 2017), outlining the need for industry to draw upon important CS research that has until recently largely been ignored. Early papers like Michael et al., (2008) 'Ethics in the emerging age of überveillance' talk of 'exaggerated omnipresent surveillance' with the need for debate around the socio-ethical implications (p. 1198). The employment of biometric and individual-specific data, coupled with the tracking of bodily motion, links to a concept sometimes referred to as 'somatic surveillance' see 10.2.4 surveillance subsection. Monahan and Wall (2007) paper 'Somatic Surveillance: Corporeal Control through Information Networks' presents this concept in an accessible and understandable way for a non-expert reader. They define 'somatic surveillance' as 'the increasingly invasive technical monitoring of and intervention of bodily functions' (p.154). While the paper focuses primarily on military examples, it is transferrable to other settings, such as education.

Additionally, current codes-of-practice: The 2018 ACM Code of Ethics and Professional Conduct, ACM Code TaskForce (Gotterbarn, 2018), answered this call, and was created to tackle this problem for computing and technology sector. The ACM code consists of four main sections: (i) general ethical principles—the fundamental principles as the foundation of the code; (ii) professional responsibilities—specific considerations of computing professionals' actions that could 'change the world'; (iii) professional leadership principles—

guidance for leaders and individuals with leadership responsibilities; and (iv) compliance with the code—a commitment to ethical conduct required of all ACM members. The code covers new ideas, inventions, creative works, and artefacts alongside existing products and services. The responsibilities cover the core principles of privacy, fairness, and avoiding harm to confidentiality. The code is designed to 'serve as a basis for ethical decision-making' (Gotterbarn, 2018, p. 1), these principles formed part of the data-ethics educational features for designs two and three.

3.4.2 Destroying Subject (Domain) Silos

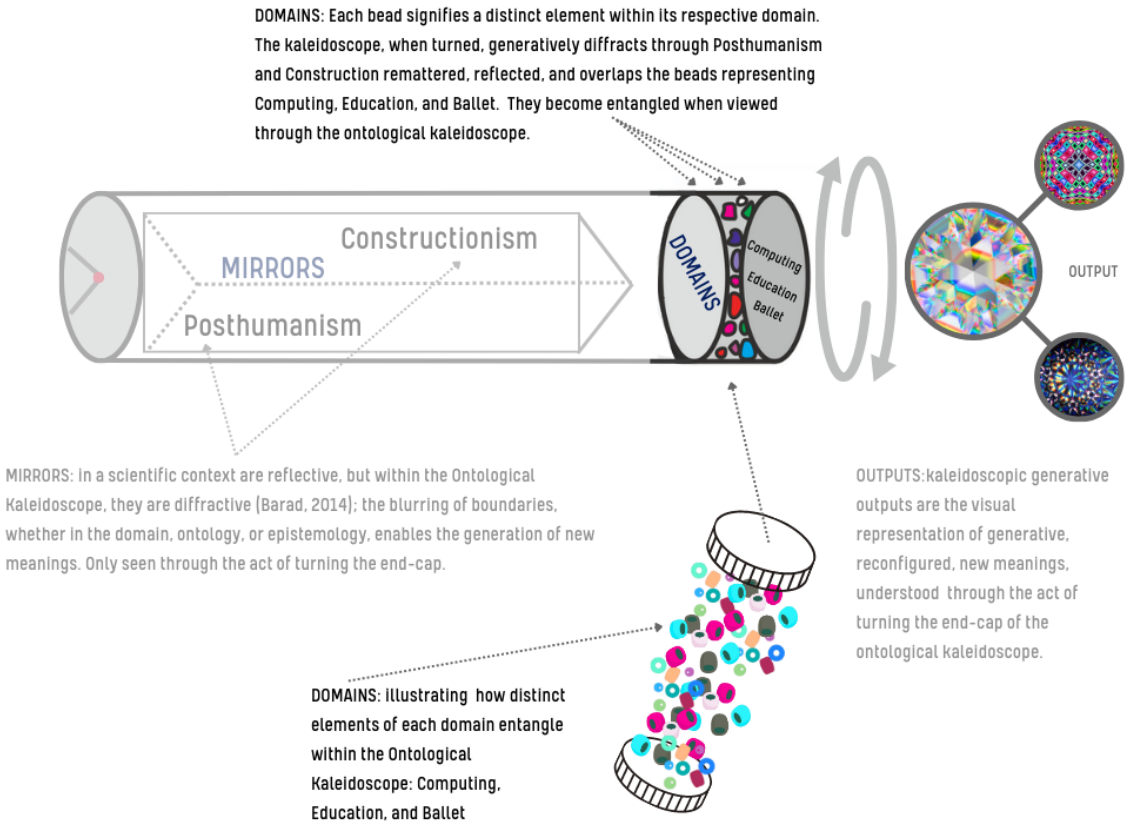
Computer science, ballet, and education could be viewed as distinct domains or separate silos. Domain silos exist in the real world, but not in a world viewed through the ontological kaleidoscope. Pierre Bourdieu describes 'multiple forms of capital' as a destructive perspective on reality. According to Bourdieu, if we reduce things or domains to their production of value (however we may define that), such as the production of financial capital, then reality becomes imbalanced, and in this example the arts have no value (Bourdieu, 1986). Similarly, if one focused only on intellectual capital, E-Sports could be considered as unrelated to computing education, or thought to have no or little value in this domain, which is misleading. In another example, using culture as capital, ballet would be rated higher than computer science and education. These examples illustrate the difficulties and reductivity of considering different silos or isolated disciplines, which create disjunctions and barriers, and inhibit the movement, ability, and potential of human and non-human development and progression. The ontological kaleidoscope employed here aims to unbind these domains from their categories and isolated states, and thereby to unlock their potential combined value.

Value, both current and potential, is achieved across networks of domains through breaking down subject barriers and hierarchies. Silos are not just subjects or domains, but also teams, communities, and groups. To break down such hierarchies and create value, Agile uses empowerment and the agency of the individuals within a team to achieve value for the whole (Mergel et al., 2021). Teams in Agile organisations are cross-functional, and value all forms of capital across all disciplines. These mesh-worked connections within and across teams use ritual and ceremony to achieve kinship and relationships, and this social capital then enables effective and transformative problem-solving.

The timetabling blocks of a school environment encourage this categorisation of learning into distinct silos, and set subjects at GCSE reinforce this distinction (Abrahams, 2018). At

present, no official documentation exists highlighting the cross-curricular potential or opportunities from the (DfE) in England. Consequently, this compartmentalisation of learning into subjects can be seen as a limiting factor in education, which fails to realise the potential of combining different subjects together. One example of a successful combination of subject is 'truth tables,' which incorporates elements of both the computing and mathematics curriculum. This combination is cross-curricular, as truth tables taught in GCSE Computing are not taught within mathematics until A-Level (Exam board syllabi: AQA.org; OCR.org). Combinations such as this, however, could create a multitude of possibilities to enhance education and share knowledge across the curriculum.

Figure 3.2 *reposted–Ontological Kaleidoscope–Domain focus*



The ontological kaleidoscope is not bound by imaginary barriers such as content or delivery, non-cross-curricular communication, and specific assessments, see Figure 3.2 above. Baudrillard draws upon Bourdieu in his argument that 'the essence of every relation of force is to dissimulate itself' from the idea (Baudrillard, 1994, p.14). Baudrillard notes that Bourdieu views the relation of force as truth: an ideology and a reality. The hyperreal in education already exists in various forms, from immersive learning through web technologies or tools such as FrameVR.com, to the more functional tools such as Zoom© and Microsoft

Teams™. Learners can find like-minded communities or develop their computational skills through the creative environments of Scratch™, Minecraft©, and Fortnite creator™. These technology-driven creative environments are also silos, but the learners incorporate multiple communities and additional practices which expand the 'traditional' silo of learning in educational institutions.

Baudrillard's work has received limited attention in the study of philosophy of education, although some more recent studies are beginning to embrace or critique his work about postmodernism and 'the loss of the real' (van Kessel & Kline, 2019), engage with his critiques of capitalism and the commercialisation of the education system (Norris, 2018), or speculate about the Teaching Excellence Framework (TEF) as an illustration of hyperreality (Canning, 2019). This last example suggests that teaching and learning, through constant assessment and scrutiny, have become unreal concepts, mere ghosts in the educational machine. The real and simulation are separated by outcome: the metric of the National Student Survey and post-degree employment trajectories have become the ultimate determination of the quality of teaching and learning. Instead of considering the actual learning, pedagogical, or educational aspects of teaching and learning, modern education, according to this perspective, has been reduced to its value as determined by a metric of assessment and outcome.

Baudrillard's system of objects (1996) is relevant here. Baudrillard argues that there are 'lines of development' that can be traced through objects' relationship with each other and the wider system in which they exist. These lines include (i) the technical function of the object, and (ii) the interrelated, materialising worlds that result from the concurrency of object and system, here learning and education. Baudrillard defines this concurrency as 'parallel structuring' (p. 137). The notions of categorisation and commodification within an educational context create and maintain boundaries between subjects and phases of education. GCSE exams are written by exam boards, and these impact not just GCSE educational instruction, but the whole system of secondary education, as exam specification requirements determine subject content, curriculum development, and even methods of teaching. The student's future study at A-Level and beyond is then further limited by their GCSE subject choices, which continues to perpetuate the isolation of subjects into discrete categories.

To understand this interconnection between seemingly disparate silos of knowledge—the codified nature of ballet choreography to the complexity of computer programming—one

must draw on concepts of relationality and diffraction, and also appreciate the hidden nature of data that control many aspects of our daily lives through the utilisation of motion capture and visualising brainwave data. In EEG data, the live electrical activity of neurons are brought to life through code and data sets. Through a deeper understanding of Haraway's (2016, 2018) work (see Appendix 3A), there is potential to re-explore what computing education could and should be for learners. This is embodied through my lived experience of dancer, educator, researcher, and more. Access to these relational lenses provide insight into the complexities of each domain acting as enablers not inhibitors for the research.

Lewis' thesis 'Education for Sustainability at a Primary School: From Silos to Systems Thinking' (2012) draws upon longitudinal data, coupled with a case study, to highlight Australia's sustainable education system. Lewis's study notes that the traditional siloed approach to education is 'fragmentary with focus on narrow specialisations,' and consequently students are unaware of the interrelationships that make up the whole system, both at subject level and throughout the wider curriculum as a whole. This is also evident at other key stages, as GCSE Maths and Maths for Computing are not of equivalent content or complexity. Technology and application are used across subjects, but students are unable to break the 'lesson' silos and draw upon knowledge and skills from other subjects.

From the medical domain, McGinn's (2015) response to Järhult's (2015) 'One Health' paper argues that we must 'recognise we are in a silo, climb out of it and talk to others first' (p. 419). Though McGinn's paper discusses medical education, these considerations are widely applicable across other domains. Järhult has three areas of interest: (i) an integrated education, incorporating perspectives of current and future professionals in general, specifically medics; (ii) the problem of limitations placed on learning through perceptions of what falls within the scope of 'their subject' and what does not; (iii) the challenge of publishing interdisciplinary health research, as this domain is entrenched within the siloed approach to subjects. This last point is also a significant challenge within the domain of education.

Billingsley and Hazeldine's (2020) work draws on the OECD's (2018) report to highlight the need for the curriculum to be more than examinable content, and should focus instead on 'substantive knowledge' (p. 1), as well as 'disciplinary knowledge,' (p. 1) that is, the epistemic knowledge about a discipline. The subject silos, 'the entrenched subject compartmentalisation' that create barriers to transdisciplinary modes of teaching, learning, and creating, must be broken down to create environments that foster respect and understand

the opportunity inherent in failure. Understanding how different subjects function and could work together develops students' curiosity, imagination, and resilience (OECD). The OECD report focuses on digital transformation in light of big data and the essential need for education regarding digital literacy and data literacy, as well as physical health and mental well-being. This (OCED, 2018) and other OECD reports (2016, 2023) aim to move beyond subject-specific knowledge towards providing holistic, interdisciplinary education that prepares students for new data frontiers.

3.4.3 XR Immersive, Simulation

XR (often refer to as Extended Reality) is a relatively new term which groups together Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) technologies in order to easily identify the exponential and rapid change in technology development. Nick Whiting of Epic Games and the Khronos OpenXR Standards Group argues that the 'X' in XR is a placeholder or a mathematical X encompassing all future iterations of VR and AR technologies (Whiting, 2018).

The immersive nature of XR enables access to and transmission of information through these virtual spaces: (XR worlds) such as Snapchat©, Instagram™, Spatial.io™, FrameVR™, Hololens™, Virbela™, as well as immersive caves and digital spaces such as Zoom. AR provides ease of access, as it does not require the creation of a whole new world, whereas VR requires hardware to create a different reality. This ease of access for AR is a significant positive factor in its widespread use within education contexts, as it can be accessed through existing devices and allows the restriction and regulation of content.

Immersive world experiences are commonly associated with film, theatre, and music, but their use in gaming adds an extra dimension, as a user controls their avatar's motions, and interactions, and can change camera angles and perspectives. Charlie Brooker's 'Bandersnatch' episode of the hit TV show *Black Mirror* (Reynolds, 2018) mimics this game-specific approach , as the episode follows a 'choose your own adventure' format, and the plot changes based on each viewer's choice at certain points during the episode. Whilst not as granular or wide-ranging as the gaming experience of an immersive world, Brooker's episode does provide an insight into this style of entertainment, and widens the scope of AR within TV and film.

XR experiences give the user a much greater sense of choice. At the other end of the spectrum is Spot, the Boston Dynamic 'dancing' robot, that has programmable moves (such as *bourrée*) and uses software aptly named 'Choreography.' A *bourrée* is described in the documentation as a 'tippy-toe, ballet-like movement,' and demonstrates the intermingling of dance with robotics (Spot Choreography SDK [software], 2021).

In order to create these immersive worlds, we need to simulate existing worlds, objects, and characters to provide the materials or foundations of the XR experience. This study aims to mimic the hyper-reality of some experiences in VR through the prototype creation of an AR episodic ballet see 5.5.3.1. Through this creation, both the process and product become simulacra, a replication, mimicry, or simulation of the real before becoming real themselves (example Figures 3.6-7 p. 97). The simulation of the ballet dancers is achieved through skeleton tracking, AI models, transformation software, and world-building tools such as Unity or Unreal Engine. This dancer data become a simulation of the dancers themselves, representing both data and meaning. There is a need in computing education to provide opportunities for content creation, not just content use. Although Baudrillard's 1981 is far-removed from today's content creation context, his words are still relevant, as he notes that 'Information devours its own content […] exhausts itself in the staging of communication rather than producing meaning' (Baudrillard, 1994, p. 80). The AR dancer data simulations are not the curated images on social media platforms, but are instead a simulacrum of self to be remattered into new forms or avatars.

The scholarly discourse regarding immersion and philosophy that pertains to education encompasses several notable works. These include An and Oliver's 2021 publication; The Transcendent Mind by Sullins (2000) which explores the use of technology to design and develop XR experiences; and *techné* by Flyvbjerg (2001). The data collected in this study could be considered artificial, as dance is an artificial construction of movement, and I create choreography though the use of technology. The blurring of self and avatar in my study is echoed, bizarrely, in the horror game genre. Perron (2009) notes the blurred distinction between human (player) and avatar (character) as the self or as an extension of the self. Immersive worlds blur these two seemingly distinct entities to create a horrifying experience as the real flows into the unreal and the physical body often reacts to stimulate within the XR (Rodríguez-Ardura & Meseguer-Artola, 2019).

Plato saw two types of representation—faithful and intentionally distorted (simulacrum). Baudrillard, however, sees four: (i) basic reflections of reality; (ii) the perversion of reality; (iii) the pretence of reality (where there is no model); and (iv) simulacrum, which 'bears no relation to any reality whatsoever' (Baudrillard, 1994, p.6). Avatars (dancer data in my context) may become faithful representations or simulacrum of our collective imaginations during the building process using (ii), (iii), and (iv) of Baudrillard's reflections. This is also evident in Boston Dynamics 'Spot's On It' ballet (Ackerman, 2021), in which each step is completely codified and lacks the improvisation of working with humans. Eric Whitman explains this a 'disadvantage that you have to tell them [the robots] every little detail. They don't improvise at all' (Hennick, 2021, June 29). The 'Spot's On It' ballet is a combination of reflections (i) and (ii), as the robots are able to move in ways we perceive as human, but are in fact merely robotic movements based on the abilities and restrictions of mechanical anatomy.

Education is discussed in Baudrillard's *Simulacra and Simulation*, in which he explains that education is a (complex) system of practices encompassing not only teaching and learning but also often hidden elements of funding, policy, media, or the marketisation of education (Roderick, 2010). When crossing over into hyperreality (through marketing and advertising), the commodification and separation of the real from the hyperreal is highlighted. This line between the real and the hyperreal (Baudrillard, 1994) is more than a philosophical question, and is a constant consideration, especially in an educational context. The use and exchange value of education is discussed in Baudrillard's work, and is also central to the Agile mindset and methodology. Baudrillard does not offer solutions to these issues raised, but rather observations on the contemporary human condition within our understanding of reality and how this develops when reality becomes a simulation in part or in full.

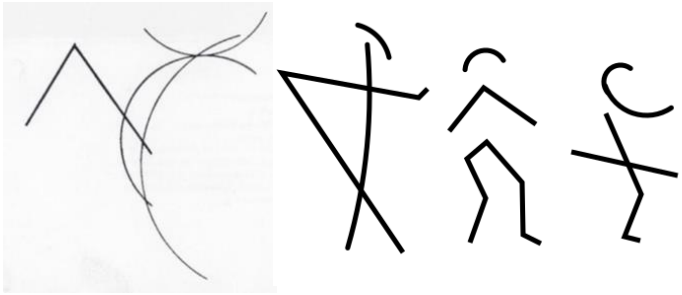
The different aspects of the built environment of the XR experience, including the aesthetics of the immersive environment, skyboxes, terrains, buildings, and the structure and textures, are meshed together to form representations of known objects. The look of these XR worlds is vital, as they must create a believable, understandable, yet significantly different world for the audience (the user) to inhabit. An immersive world is generated in real-time, moving, and recreating just beyond the user's field of view. Our viewport through XR is an act of choice that mimics human vision, and provides our window into the experience. 'La clef des songes' (Magritte, 1935) is a powerful art piece which exemplifies our constant vision which precedes

even our processing of words, and explores the relationship between what we see and what we know about the world around us (Berger, 2008).

Biometric data remain neutral and inert until human interaction and processing occurs. Viewing such data through the kaleidoscope, however, allows us to gain a deeper understanding of patterns of information, and to understand the meaning behind data. My study uses biometric data to produce a 3D rendering of a 3D AR ballet dancer prototype, see Figures 3-6-3.8. To produce these data, we used MocapNet ML model (Qammaz & Argyros, 2019) and a custom BVH software, see 5.5.3, to generate the functional 3D model capable of simulating human movement. 3D models or avatars as representations of both the data and dancer become information experienced by the audience through viewing the 3D prototype in FrameVR, see 5.4.1, 10.2.1.

Wassily Kandinsky's (1926) *Point and Line to Plane* could be viewed as a visualisation of meshwork, although this may limit the intention of Ingold's meshwork to a 2D static plane of thinking. Through the development of 3D avatars and AR, my 3D experience of ballet intends to capture the essence of Ingold's meshwork across multiple planes. Kandinsky believed that 'phenomena can be experience in two ways' (Kandinsky et al., 1947, p. 17) externally and internally, which aligns with the ontological kaleidoscope I use throughout this study. Movement and lines 'envelop' the viewer (of Kandinsky's paintings or an artist in the act of painting) through the motion 'of horizontal and vertical lines bending in different directions' (p. 17). These ideas were used for discussion in the prototype development of the visual aesthetics for the AR. Kandinsky point-line-plane movement evokes the mesh of entanglement, experience, understanding, and information central to both the ontological kaleidoscope and the study itself. Additionally, Kandinsky's 'Dance Curves' (Figure 3.4) is used to explore the connectedness and entanglement of body data within computing education, data-ethics, and dance (see 8.2.7, 9.2.1, 9.2.4, 10.2.1, 10.2.4-5)

Figure 3.4 *Curves Kandinsky's Dance Curves (left), Computer Generated Dance (right)*

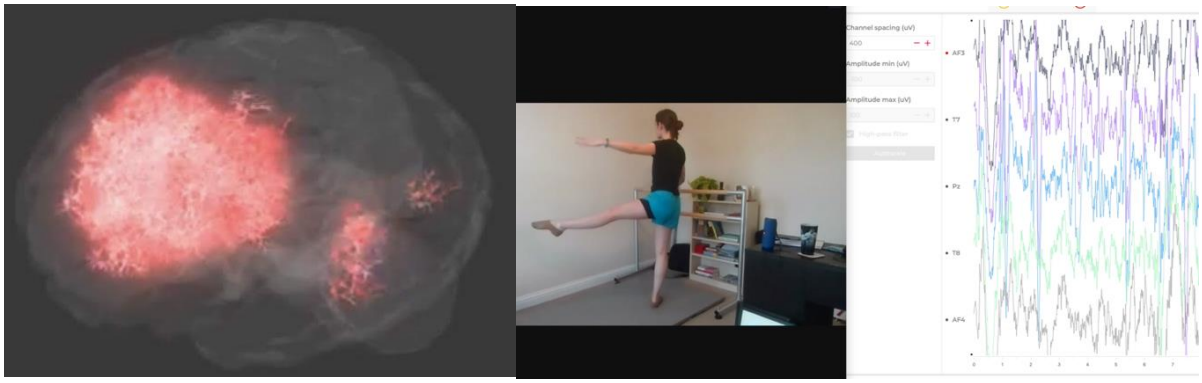


3.4.4 Body Data as an Artefact

The body may be viewed as a data artefact, an ontological kaleidoscope of data with semantics and meaning. The role of education in this research is to raise awareness of data-ethics in computer science classrooms and beyond. The importance of body data, the data self, and how these are interpreted in research is significant in this study. Biometric data generated through real-time skeleton tracking and EEG recording provide a dataset through which created the AR ballet prototype and also serves as a resource for my discussion of the ethics of body data. This discourse then weaves its way through the possibilities presented by this approach in creative computing education and dance studio practices for both research participants and audiences as consumers/users of the experience.

The question of the value of biometric data is unavoidable in this study. To be observed, the body data (simulacra) must be seen (Berger, 2008), a stimulus remattered into form. The biometric data (Figure 3.5) collected in this study is anonymised but not analysed in a neuroscientific context, but is instead used to generate new means of storytelling and knowledge, as the 3D avatar narrates an immersive/augmented world.

Figure 3.5 *My Brainwaves and Ballet*



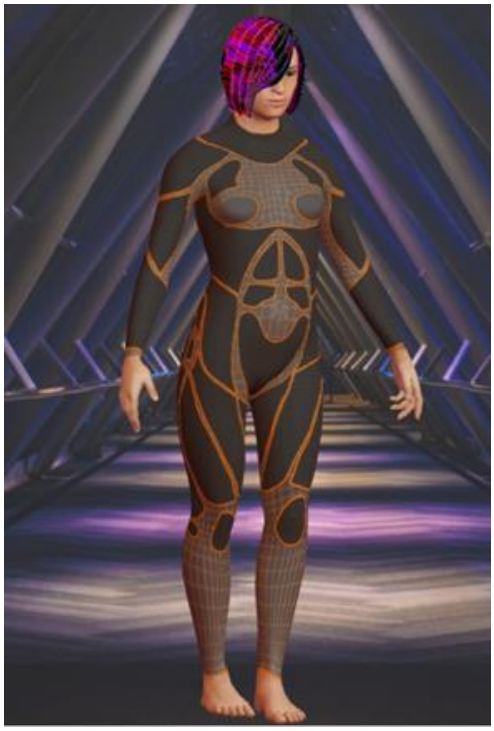
The virtual 'telepresence' of an individual is comprised of the real-time reception and transmission of audio-visual across virtual time and space (Boddington, 2021), recording, transmitting, and then recreating the digital body and voice. On our many Zoom calls during lockdown, we transmitted these digital, virtual selves to others, using image (or a chosen avatar) and audio. S.F. Alaoui, an Interaction Associate Professor, and choreographer at Université Paris Sarclay, is an expert in this field and has produced 'ROC' (Alaoui & Matou, 2021), a project that includes participatory dance and technology interaction, and earlier 'double skin' (Alaoui, 2015), which involves telepresence and choreography. My own study

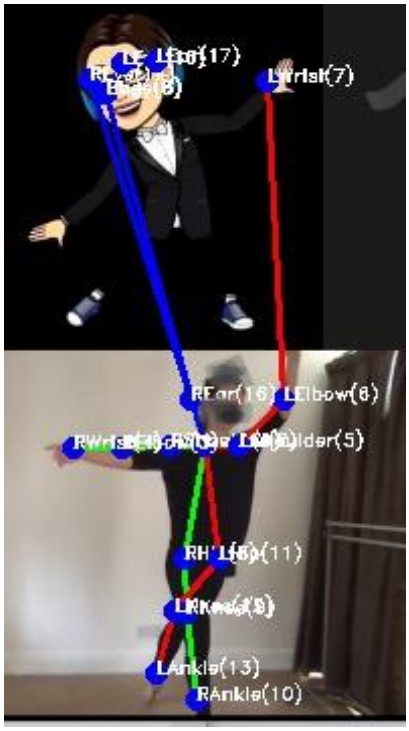
makes copious use of these technologies to create, innovate, and collaborate, see 5.4 material, as part of the DataDrivenDance process owing to the disparate nature of the team with whom I work, 5.4.1,

Considering the ethics of body data is a steppingstone which then allows us to conceptualise, generate, store, modify, repurpose, and create new immersive entities or experiences with foundational ethical conduct set firmly in place. For example, having considered how best to protect the individual and anonymise the data, receive the individual's permission for its use, I was able to explore the use of Kandinsky's dance curves in relation to data latency and throughput in the AR prototyping. Using biometric data allowed me to consider the visualisation of the body, and how data transmission and data loss over space and time distort reality and produce a near-human form, the simulacra of human in a 3D avatar, which then followed the lines and curves choreographed for it, which were inspired by Kandinsky's dance curves. Figure 3.4, p.95, shows the similarities and differences between Kandinsky's artwork and the computer-generated inspired artefacts.

Figure 3.6 *(left) 3D character with 'skin and hair' textured meshes applied*

Figure 3.7 *(Right) Live Skeleton Tracking (with errors) using MocapNet2 and (custom) BVH software*





Empathy with Non-Playable Characters (NPCs) in gaming is a multifaceted encounter for the human player which reaches beyond the immediate physiological to broader, more profound

effects on the ethical, cognitive, and philosophical choices that players make in the game (Pointon, 2015). Immersive spaces such as this trigger accurate physical and ethical responses which reflect how each individual would react to similar scenarios in the real world. Likewise, the sensory and conceptual aspects of the game are experienced through controlled lighting, digital textured meshes (Figures 3.6 and 3.7), (RQ1) and soundscapes which are designed to evoke specific responses (RQ2).

Questions about how one conceptualises the self–the human, and data-self, that distinguishes them from others–(RQ1) arise when considering the immersive spaces of computer games and other similar environments. Fitzgerald's 2023 thesis 'Turning Pointe: lived experience of embodied occupational identity in professional ballet dancers' also draws similar distinctions between the self and the dancer self 'distinction between her objective body and herself' (p173). When controlling an avatar in a game, the internal and external are experienced at a distance, which takes the individual out of their usual bodily experience. The duality of kinaesthetic space, the immersive experience of being in the world while also being in the 'real world' comes via interactions through a microphone, mouse, trackpad, or VR tools which extend or merge into the real world. Data create this AR world, building avatars and objects out of the developers' perceptions and reimaginations of our physical reality. AR tools, allow simulation to extend into the real world, which reimagines data and brings in the storytelling aspect of recreating our perceptions of physical space in order to imagine a different reality painted over this one. The use of biometric data in these virtual or augmented reality settings invites consideration of our data selves and how these are altered or affected by this manipulation of perception and reality. This immersive, all-encompassing experience also heightens the need to understand the risks and to protect these personal data both now and in future work.

3.5 The Ontological Kaleidoscope

This chapter has explored the metaphor of the ontological kaleidoscope in depth, drawing upon Barad's concept of 'ethico-onto-epistem-ology' (2007, p.90) –for this study is the inseparability of ethics, ontology of domain, and epistemology– how new knowledge is generated through the entangled of theory and the three domains: education, computing, and ballet. I examined the traditional siloed perceptions of these domains as separate, isolated subjects of study, and offered avenues of thought to counteract these perceptions, considering crossovers and interweaving threads between the three that inextricably tie them together. I

explained how data can be formed into meaning or used to tell a story, and how ethical considerations are inextricable from our use of data in every aspect of today's technological world. Finally, considered how the self is dispersed through virtual and augmented reality in the gaming world, and how this alters or manipulates our concepts of self, which only adds to the need to provide a firm foundation of data-ethics from which to work.

These many different considerations and subjects are represented by different coloured beads within my ontological kaleidoscope, and as our perceptions widen and alter throughout this work and through different technological advancements as a society, the different patterns that generate time and again reflect the omnipresent role of ethics in domains that have any consideration of data or information. The entanglements of experience and process were drawn up through the ontological roots of this analogy to generate epistemological branches which informed my understanding and approach to the theories and methodologies used in this study. Another rotation of the kaleidoscope forms the interweaving pattern of practice, axiology, and (re)new(ed) knowledge and practice.

Each domain considered in this study has its distinct areas of inquiry and certain terminology that is specific to its processes and understandings, but there are ways of making meaning and collective understanding that unite these subjects outside these specific, isolated domains. Countering this individuality of subject does not involve creating a singular, reductive understanding that poorly fits all three, but rather a collective understanding of domain terminology, concepts, and approaches that unite the three in different ways. Transdisciplinary vantage points may be created through which one may understand domain-specific terminology through the perspective of another domain. It is these vantage points, a kaleidoscope of syntax and semantics, tat create an ever-changing, entangled view of the world around us.

Information is data with meaning and purpose, and must be treated with the utmost care and consideration. It is vital to understand this when dealing with biometric data, as the body as a data artefact is more than a dataset—it is personal, part-human, belonging to one, and shared with others. Instead of passively observing the world, the human instinct is to create stories and interpret data or information that we find around us (Brocki & Wearden, 2006). Creating datasets from human data, then requires more than an ethics checklist of storage, use, and manipulation. We must understand in this context that the data artefact is human. These data can then be repurposed and rematttered into 3D avatars (see Figures 3.6 and 3.7), virtual or

simulated environments can be created as a collaborative co-creation between the individual and the researcher/developer.

Figure 3.8 *3D Model of Dancer (Smith-Nunes, 2021) FrameVR still*

The blue 'dancer 3D model,' seen in Figure 3.8 above, was created using custom software (Shaw, 2022) to generate motion capture data (see Figure 3.5) via a video-only recording of me during a ballet class. This motion capture dataset rematters the real self into a new, virtual form when applied to a 3D model and rendered as an animated, rigged character (the blue dancer here). This demonstrates the recutting of the self into a texture mesh, which dictates the appearance of the character, or the 'skin,' as it is known in gaming. The web VR environment is also seen in Figure 3.8.

Simulated worlds offer new modalities through which to explore hidden data, and provide an immersive space for discourse and creativity to thrive, not just in terms of building, coding, and creating these alternate realities, but also bringing space, time, and a sense of presence—telepresence (Boddington, 2021)—to an audience, user, or developer. AR provides access to new worlds within the comfort of the familiar. Pixels, virtual particles viewed and sensed through (ever-advancing) technology, can be experienced both individually and collectively. AR acquiesces to the collective experience, reducing friction and barriers to entry, whereas VR, although arguably a more immersive experience, sometimes creates boundaries because of its technological requirements.

This chapter presents the conceptual metaphor of the ontological kaleidoscope to illustrate the advantages of integrating and merging diverse schools of thought in order to gain new

insights into the ontological, epistemological, theoretical, and practical dimensions of the subject domains under investigation. This approach entails blending different perspectives, thereby creating a complex and multifaceted picture of the research subject. The ontological kaleidoscope, metaphorical framework promotes a more iterative and inclusive approach to inquiry that encourages researchers to embrace a multiplicity of perspectives and to challenge traditional boundaries between different schools of thought. This perspective underscores the value of incorporating multiple lenses and perspectives to expand the scope and richness of our understanding, which can ultimately lead to more insightful and impactful research outcomes. An ontological understanding of data gives strength to the next increment through epistemological and methodological approaches and processes. Understanding the axiological lens of data-ethics as a crucial part of the research is integral to my process of conducting research. Patterns in the data change with each new rotation or iteration in the research process. A move towards the blurring of possibilities and boundaries, to borrow Dr Bayley's excellent phrasing 'lean into the blur' (Bayley, 2023).

The next chapter explores the methodology used in this study, blending DBR (Design-Based Research) and Agile (an industry methodology) into AgileDBR, which was developed through the ontological kaleidoscope discussed above.

Chapter Four: Methodological Musings

The purpose of this chapter is to provide an introduction and rationale of the research methodology, framing this mixed-method AgileDBR study. Agile is an iterative approach to project management which usually (but not always) incorporates software development to enable 'work' to be delivered in small increments. All elements of a project—requirements, plans, output, and results—are evaluated continuously, providing a built mechanism for rapidly responding to change (Cohn, 2004-5; Cockburn, 2006). DBR has a similar approach and aligns with Agile's iterative, continuously evaluative, and reflexive nature. Blending the Design-Based Research and Agile frameworks, I developed a new way to conduct research that focused on metrics and deliverables. DDD is transdisciplinary, and blurs methodological boundaries by incorporating the necessary skills and understanding from across computing, education, and ballet to complete this research study. An explanation of DBR and Agile follow, highlighting the alignment between these two disciplines and the advantages of this hybrid for future research studies

4.1 Introduction

The literature review, chapter two, explored the need to raise awareness of data-ethics within computing and the use of personal or biometric data collection in the arts and more generally. Two key areas to consider developed from this study: (i) how participation in computing education may be widened so that underrepresented groups can share their talents, and (ii) the need to raise awareness of data-ethics in processes such as data capture, storage, privacy, the use of data, and ownership, see 2.2.2.1. These considerations arose alongside a consideration of the diminishing uptake of computing students at GCSE and A-Level in England. The TRACER report (Kemp & Berry, 2019; Kemp et al., 2018) reflects this decline as well as the gender and class imbalances that continue to widen in computer education. These two areas of consideration drove the methodology of my study, as DBR needed to be grounded in a real-world application (Agile) in order to be relevant and create lasting change. The three domains—computing education, computer science, and the arts— provided the framework for this methodology, as all three were combined to achieve a common goal but also consulted individually in order to inform and deepen the research.

This chapter aims to demonstrate how my innovative development of the AgileDBR approach informed the use of DataDrivenDance to successfully complete my research aims. To explore

how computing and data-ethics may be taught (RQ1) through incorporating classical ballet (DataDrivenDance) and biometric data (RQ2). I discuss the ethics of my research design, involving the use of personal, biometric data collected from participants, alongside the possibility of teaching neuroethics as part of computing education. I discuss the impact of these specific methods and approaches, as well as the limitations of my study, in order to aid the teaching of computing theory and to explore the ethical and social justice implications of future technologies. The entangled nature of this study requires a creative and developmental methodology that has the capacity to accommodate uncertainty. Chapter Five details the study design itself.

4.1.1 AgileDBR origins

> You shall no longer take things at second or third hand, nor look through the eyes of the dead, nor feed on the spectres in books, You shall not look through my eyes either, nor take things from me, You shall listen to all sides and filter them from your self…
>
> Not I, not any one else can travel that road for you, You must travel it for yourself.
>
> It is not far, it is within reach, Perhaps you have been on it since you were born and did not know… (Walt Whitman: From Song of Myself, 1855 [2004])

Whitman here depicts a journey of self-discovery and knowledge, not relying on passive knowledge acquisition through other sources but instead on an active, exploratory revelation of the world and our place within it. Through the self-exploration of being, doing (practice), and knowing—involving our internal theoretical frameworks and the cyclic nature of doing through knowledge and knowledge through doing—we create the entangled, interconnected feedback loop of applied education practice and research. The nature of the knowledge journey and its methodology are vital components in the generation of new knowledge or the improvement of existing knowledge. These cycles or iterations of learning are core foundations to DBR and Agile, creating a synergy that is crucial to my research. My fusion of the two that serves the purpose of my research, to use Whitman's, *I shall listen to all sides* (DBR and Agile) and *filter them from yourself*, an iterative reconfiguring of possibilities (Barad, 2007) that will become AgileDBR.

4.2 General Methodological Discussion

Methodological foundations, including (i) practice-based research (RQ2), (ii) research-oriented design (RQ1,2), (iii) research-through-design (RQ1), and (iv) interaction criticism (RQ1,2) all played a role in the selection of mixed methods for this research. Just as the natural sciences seek to analyse phenomena to determine how designed artefacts (e.g., aeroplanes, robots, concert halls, interstellar radio telescopes) behave under different conditions, Simon (1996, 2019) and Collins et al. (2004) argued that we need to develop a 'design science of education where we investigate how different learning-environment designs affect dependent variables in teaching and learning' (Collins et al., 2004, p. 17).

The nature of AgileDBR enables a creative approach which includes teaching computing through dance, the use of wearables, data visualisation of brainwaves, and the creation of 3D avatars for augmented reality experiences and externally accessible datasets. In order to demonstrate the power of creativity across the computing domain, I have used creative methods both across the study itself and to conducting this research (Burgess, 1984).

Burgess (1984) describes togetherness embodied in multi-domain, transdisciplinary research. The epistemological and methodological opportunities and provocations exist in the space between disciplinary boundaries, and a transdisciplinary methodology requires the researcher to cross these blurred boundaries, incorporating key skills and understandings from each to augment the whole. A kaleidoscope of ontological, methodological, and practical perspectives was used to answer the research enquiry set forth at the beginning of my research. Computing—and particularly this study—relies on Human-Computer Interaction (HCI), and so this interdisciplinary, cross-boundary approach was vital to my research.

Bertelsen et al. (2019) argue that HCI is a complex and multi-transdisciplinary field that requires a particular approach to research. They emphasise the importance of understanding the context, purpose, and situation of the research, rather than generalising findings. The authors suggest that impactful research can be scaled through a pluralistic approach that captures the nuanced complexities of a particular research user or situation. In educational research settings, multiple methods, and ways of knowing or understanding are needed to generate and disseminate new knowledge.

4.2.1 Mixed Methods

Along with Agile and DBR, Mixed Methods Research (MMR) has multiple definitions. Creswell and Clark use an MMR methodology to develop better, more context-specific instruments with which to conduct their research, and argue that the purpose of mixing is to give richer and more reliable understanding than a single approach would offer (Creswell & Clark, 2017, p. 132). MMR is often linked with phases of research, such as with interventions, and presents a way to explore first, through scoping or piloting, in order to determine if an intervention will work (Creswell, 2009). MMR is not necessarily fixed to all phases of the research, and may only occur within one phase (a research cycle or sprint) or across all phases.

Tensions created through this cross-disciplinary approach create a space in which to rupture the traditional research trajectory (Hesse-Biber, 2015). My study diverges from the traditional, linear approach, preferring instead an iterative, transdisciplinary, and multidimensional strategy, see Agile alignment 4.6.1 and Chapter Six. The benefits of collaboration are clear, as new pathways are forged (Hesse-Biber, 2015) and new ground is broken on which to develop new, blended, philosophical, theoretical, and methodological strategies.

'De-disciplining' as Richardson (1997) describes it, refers to the amalgamation of mixed methods. Richardson's (1997) article 'Skirting a Pleated Text: De-Disciplining and Academic Life' explores the 'fields of play […] intertwined to create new ways of reading and writing' (p. 296). This intertwined mesh of interconnected nodes and methodological approaches taken from multiple domains was not traditional or favoured in Richardson's time, but was seen as divergent and limited. This approach has slowly been recognised as a step forward in education, however. Rice and Mundel—from the Re-Vision Centre for Art and Social Justice—have produced fascinating work on 'Story-Making as Methodology' (2018), and posit 'storytelling as a method for working and reworking the material of our lives' (p. 219). They investigate the power of the arts, and especially the story, in positively influencing decision-makers and practitioners across diverse sectors (Rice & Mundel, 2018).

Mertens and Hesse-Biber (2013) both note that using mixed methods presents problems because a particular methodology will often be associated with a specific paradigm. They do, however, accept the use of mixed methods for evaluation, and provide examples such as 'dialectical pluralism seen as a philosophical stance that allows evaluators to engage in mixed

methods inquiries while experiencing the tension between the assumptions of the post-positivist and constructivist paradigms' (p. 10). Mertens & Hesse-Bieber consider this as a transformative paradigm that stresses the ethics of social justice and human rights, which aligns well with the research aim, design, and implementation used in my own study.

A significant challenge for mixed methods approaches to research is 'poor quality research masquerading as mixed methods' (de Lisle, 2018, p. 90), in which researchers merely mix or confuse methods of research rather than integrating methodological approaches, presenting this patchwork as mixed methods rather than multiple methods (Gidding & Grant, 2007). Gidding and Grant's paper 'A Trojan Horse for Positivism?' critiques this mixing of methods, arguing that such studies fail to illustrate their methodological positionality that acknowledges the differences and alignments of 'slurring' worldviews (p. 59). They do acknowledge, however, that some 'slurring' of worldviews is important for fields such as critical ethnography, in which theoretical assumptions and values align. The useful phrase 'mixed-up methods,' (Maudsley, 2011, p.92) which distinguishes the legitimate mixed-methods approach from this counterfeit approach, originated in a paper that addressed the 'thing-ness' problem of mixed methods research (Hesse-Biber, 2014; Hesse-Biber, 2015, p. 786)

4.2.3 Ethics of MMR

While one may consider ethics to be central to research as a whole, MMR poses its own specific challenges. The different values, axioms, and paradigms affect the researcher's ethical stance. Green (2012) discusses this through Human Resource Management (HRM), emphasising the ethical pluralism within this field. Considerations of ethics involve defining 'what is good and what is bad' (Thompson, 2008, p. 13), and so widening the area of implementation of right or good (as MMR does) complicates such definitions (Illes, 2010). The next section suggests alternative methodological approaches that could have been adopted in this study.

4.3 Plausible Alternatives

My research aimed to tackle two main fields of inquiry: (i) the importance of raising awareness of data-ethics for trainee computing teachers, and (ii) how disciplinary boundaries between education, computer science, and dance/ballet may be transcended to augment the final product of the research. These areas required an in-depth study of intervention education

research, creative practice as a tool for learning, and how to structure effective, innovative teaching methods to utilise the findings from my study.

I considered several alternative methodologies including: (i) action research, (ii) case study, (iii) grounded theory, and (iv) *bricolage*. I discuss these alternatives in detail below, along with my reasons for not adopting these methodologies in my research.

4.3.1 Action Research

Action research is a practical approach that encourages researchers to investigate and evaluate their own work. It is a research practice created by and for practitioners, enabling them to improve and understand their methods (Winter, 1996). Winter discusses six principles for action research:

- Reflexive critique, which involves an awareness of one's own biases.
- Dialectical critique, in which a researcher understands the various connected elements that make up a particular phon.
- Collaboration, which encourages a collective perspective and different contributions to the same situation.
- Risking disturbance, which involves individual submission to critique and understanding thereof.
- Plural structures, which create multiple perspectives and accounts rather than a single, authoritarian view.
- Internalised theory and practice, which entangles complementary parts of research.

Though interesting, this approach was not appropriate to my research as I was not seeking to research my own practice as an educator or artist but explore an intervention with participants.

4.3.2 Case Study.

The case study approach has many benefits, and is actively used across many research fields both to advance knowledge and to tackle human problems. The development of the Case Study Intervention Research (CSIR) enabled the transferable, replicable, and rigours methodology used in Randomised Control Trials (RCT) (Kratochwill & Levin, 2014). CSIR

is rooted in quasi-experimental applied behaviour analysis research conducted in the 1960s (Sidman, 1960; Campbell & Stanley, 1963, cited in Kratochwill et al., 2014, p. 4).

CSIR developed the traditional case study research methods of its time, incorporating the use of statistical tools and analysis techniques that went beyond the narrative and limited data uses (Creswell, 2014). CSIR was useful for examining data patterns at the micro or individual level (Barton et al., 2016), but differed from traditional case study methods as it included quantitative data analysis, providing an objective analysis of the research data. Characteristics of CSIR include: a single case study, the use of quantitative data to compare cases, the use of systematic and reliable formative and summative evaluation of the data, and the ability to replicate the study (Kratochwill & Levin, 2014). It is defined as 'research that allows for systematic, iterative development processes while maintaining experimental control that is suited to the identification of feasible evidence-based practices' (Barton et al., 2016, p. 13).

Core to CSIR is a logical model and the notation of credibility through the use of statistical data to infer outcomes of the collected observable data (Kratochwill & Levin, 2014; Barton et al., 2016). This study used an integrated design approach that combines qualitative and quantitative data analysis to provide more insightful understanding of the data (Hesse Biber, 2002; Caracelli et al., 2006). Although each part of my study could be formulated as a case study (the dancers as one case study, the trainee computing teachers as another), this would detract from the overall aim of the study, which is explore RQ1 how to raise awareness of the data-ethics using biometrics RQ1 through collaborative and connected methods/data RQ2. Thus were the main reasons for not adopting this methodological approach.

4.3.3 Grounded Theory

Grounded Theory (GT) is the use of systematic data generation and analysis as the basis for theory evolution. It has a two-fold purpose of generating theory alongside the implementation of social research (Strauss & Corbin, 1994, 1997). This aligns with DBR, which applies theoretical principles to real-world educational settings. The main emphasis of GT is on theory generation, and is a way of thinking about and conceptualising data (Strauss & Corbin, 1994). Chun Tie, Birks, & Francis, in their article (2019) 'Grounded theory research: A design framework for novice researchers' explain methodological genres spanning across the traditional —Glaser and Strauss (1967), and Corbin and Strauss (1990)—to Charmaz' (2014) constructivist, GT approach (Chun Tie et al., 2019).

Analysis techniques used in open coding are informed by GT approaches, as the researcher often labels a piece of text (or in my case an element of brainwave data) in order to describe and categorise it ready for inclusion in a wider dataset or analysis framework (Moore & Price, 2009; Cohen et al., 2018, p. 671). Each code or category may have multiple properties, and this may expand as each research iteration brings in different categories and considerations.

As the ballet component of my research takes time to develop, perform, and interpret as a form of art, this methodology was not appropriate for my research. The Dance continued to develop throughout the fieldwork, meaning data were continually generating. GT uses data to understand a situation or research question, and disregards the process, but the process of my research was integral to the wider project, the development of AgileDBR.

4.3.4 Bricolage.

Bricolage is a multi-layered, critical, and systematic approach to research. Coined by Levi-Strauss (1962), this method uses the tools at hand to tackle any given challenge, creating innovation from objects or 'artefacts' in the vicinity. *Bricolage* as research was further conceptualised by Denzin and Lincoln (1995, 2017), whose work enabled other researchers to 'make meaning' through and within the complex world of the lived experience. Often described as a mixed method process (Yardley, 2019), many *bricolage* publications rely on qualitative methodological tools to conduct their research. Two examples which emphasise this qualitative focus are Markham's (2019) critical pedagogy as a response to datafication and Kincheloe's (2001) paper 'Bricolage: Conceptualising a New Rigor in Qualitative Research.' *Bricolage* is an emergent research field that encourages the researcher to focus on individual meaning through small 'bricks' of knowledge that are then reassembled to create holistic meaning.

Bricolage begins with an initial artefact or text which then leads to several other texts connected in an intricate network of points or themes. As a methodology, *bricolage* is more than the product or outcome of the research process, but instead fully engages with the process of creating and uncovering knowledge, connections, and understanding. This process starts with a single point of entry, usually in the form of a document, which in my study would be the computing programme of study for England (DfE, Gov.Uk, 2014). This starting point is then used to visit several different points '*as they are needed in the unfolding context* of the re*search situation'* through a matrix of text (Kincheloe et al., 2018, p. 244) Each point in this matrix should then reveal further, more complex information which traces back to the

initial point of entry text, allowing the researcher to witness these connections and understand what information there is alongside what is not there (Denzin & Lincoln, 1995; Kincheloe, 2001).

This is a new and rapidly developing methodology which aligns well with DDD, but unfortunately does not map well onto Agile processes which are vital for this study. The embodied biometric and EEG data used as the artefacts in my research fix the data to a certain point within the research matrix, which does not allow for this divergence and flow that are central to the *Bricolage* approach. Therefore, this methodology was not selected for my study.

4.4 DBR the What and the Why?

Design-Based Research (DBR) methodology can be summarised as a systematic, yet flexible methodology designed to improve educational practices through iterative analysis, design, development, and implementation. DBR is based on collaboration among researchers and practitioners in real-world settings, leading to contextually sensitive design principles and theories (Wang & Hannafin, 2005). This approach has been used in multiple ways and in various research settings.

The use of DBR In education is founded in Design Research (Bakker, 2018), the 'scholarly focus' on methods used to improve practice (Margolin, 2010, cited in Christensen & West, 2018). DBR presents its own challenges, and no concrete, unified definition exists (Dede, 2004). Philip Bell (2004) combats this 'messiness,' explaining that this challenging element of DBR is attributable to the 'cultivation of each microculture as a unique [research focus],' and suggesting that the literature does not recognise that varying studies have methodological coherence.

The foundations of contemporary DBR can be traced back to the Design Research work within the marketing domain (Dede, 2004, 2005; Rogers & Yee, 2014; West, 2018), which initially related only to practice or instructional design, with limited attention centred on research and theory generation. Christensen & West (2018) refers to this 'focus shift' from 'research for design' to 'research on design' (p.323). This shift goes beyond the pragmatic and practical nature of 'product' (instructional resources and outcomes) towards a clear understanding through a systematic discourse on the methods of DBR. Bell (2004) argues that DBR should strive to go beyond the development of design experiments or design-based

research as singular traditions, and should reach towards a high-level methodological orientation that can be applied through, across, and within theoretical perspectives and research design traditions.

Table 4.1 *Sample of Studies Showcasing DBR's Flexibility, Uncertainty, & Theoretical Uses*

Studies	*Flexible*	*Uncertainty*	*Theoretical*
Hoadley (2004), 'Methodological Alignment in Design-Based Research'	DBR can be useful for creating and testing theories in situations, such as complex educational technology innovations, where little is fixed.	The very nature of design (rather than problem-solving or deduction) invites reasoning under uncertainty, in under-constrained problem spaces.	DBR can build theoretical, empirical propositions about learning with technology. DBR allowed me to refine the implementation of my theory, helping to increase the alignment between theoretical notions.
Li & Chu (2018), 'Using Design-Based Research Methodology to Develop a Pedagogy for the Teaching and Learning of Chinese Writing with Wiki Among Chinese Upper-Primary School Students'	Based on the results of the observations and interviews in the second research phase, students still encountered several learning difficulties. The design was subsequently improved for the next iteration.	Open-minded sharing and reciprocity. Children aged 7–11 become less egocentric and were able to consider other people's views.	This innovative approach suggests pedagogical strategies for individual Chinese language teachers in primary schools.
Wolcott et al. (2019), 'DBR: Connecting Theory and Practice in Pharmacy Educational Intervention Research'	DBR processes can sometimes appear chaotic or disorganised as they often include rapid prototyping and troubleshooting using new ideas that may not be fully formed.	This approach invites participants to embrace creativity and have fun. Scholars must think of creative approaches to bring together groups and engage them in meaningful learning activities and creative problem-solving processes to help.	DBR's goal is to create interventions aligned with our understanding of learning theories as well as using the results to support, derive, or refine theories as they are applied in the setting of interest. We can use DBR to test the theory and determine which components are salient or should be modified based on the findings.

Table 4.1 compares the different aspects of several iterations and definitions of DBR across key research studies. Many of these studies offer practical implementations of the theories they present, rather than limiting these ideas to theoretical fields only. Robinson argues for the importance of both practice and theoretical research in education, which should not be detached from each other as theory alone. The 'willingness on the part of researchers to recognize the rationality of those practices they seek to alter and to treat the search for a revised theory of practice as a test of the validity and utility of their critique' (Robinson, 1998, p. 290).

4.4.1 History of DBR

Archer (1969) first began to develop a systematic approach to research designed to generate theory—named ‘design science’ (p. 81). In 1970, Jones advocated for the method as it enabled transparency within research. Archer et al. are examples of the many researchers who have influenced the multiple origins of DBR. Hoadley (2004) notes that ‘design-based research is strong at helping connect interventions to outcomes through mechanisms and can lead to better alignment between theory, treatments, and measurement’ (p. 204).

The term ‘design experiments’ is used to describe experiments that test education theories in their natural setting. The term was coined by Cobb in 1990 and Brown built upon it in 1992 (Collins et al., 2004). This methodology was developed from theories spanning back to the 1960s, in which Herb Simon delivered the Karl Taylor Compton lectures at MIT (Simon, 1969). Simon distinguished between subjects which he called ‘natural sciences’—mathematics, biology, chemistry—and ‘sciences of the artificial’—subjects involving a design element, such as architecture, engineering, computer science, and education (Collins et al., 2004; Simon, 1969, p. 5). Simon argued that these ‘design sciences’ initially lacked the rigorous theoretical underpinning utilised in natural science research.

Since Simon’s criticism, the theoretical foundations of many of these ‘artificial sciences’ have developed. Papert et al. undertook vital work in the 1980s that developed CS education, using experiments, new technologies, and what would now be defined as DBR approaches to ground this subject in factual, evidential theory and practice.

Since then, the term has developed into DBR, and there is now a healthy body of work which argues that it is an established (Bakker, 2019) and rigorous (Hoadley, 2004) approach to educational research. The terms ‘Design Research’ and ‘Design-Based Research’ are used interchangeably within the literature. For clarity, I use the term DBR in order to align my work with that of the Design-Based Research Collective and Arthur Bakker (2019).

4.4.2 Rationale for Selecting DBR

I selected a DBR approach to my research for three reasons: (i) DBR offers flexibility, (ii) DBR has the capacity to accommodate uncertainty, and (iii) DBR enables the implementation of fit-for-purpose theory. Hammersley and Atkinson (2007) highlight the benefits of using DBR in their work as an iterative process in which ideas are used to make sense of data, and data are used to change our ideas.

Epistemological reasons for selecting a DBR methodology are complex, and include notions such as: (i) experiential knowledge, (ii) practical knowing, (iii) knowing-in-action, and (iii) artefacts-as-knowledge (Krippendorf, 2006). This epistemological complexity may be viewed through: (i) human interaction and agency; (ii) relations of the research participants with each other, and the associated communities and entangled nature of the individual and collective; (iii) the twofold nature of ethics in this study as both educational resource and research method; (iv) research involving humans being vastly different from the natural sciences, which study phenomena such as electrons, cells, or dinosaur bones—humans are not passive objects being studied but individuals with agency (Griffiths, 1998) who form and reform their own subjective views of the world. This last consideration is of particular significance, as an individual's experience can inform and shape their understanding, nature, perception, and ways of learning/knowing information (Chalmers, 2013).

Working in a human environment also means that inevitable entanglements of community and commonality will be formed, and different ontological and epistemological experiences are shared and developed through this community. Research (Griffith, 1998) suggests that an individual's perception of the world is vastly altered and expanded when part of a community. As humans are all individual, and the communities and connections made between them rely on these individual traits and perceptions, the scientific gold standard of repeatable results are unobtainable in this context. We can replicate educational research experiments, but they cannot be repeated in the exact same way, because humans will not react exactly the same as they previously did, and other individuals may have different reactions to situations that cannot be predicted. Similarly in computing, and specifically with software that involves interaction with a user (usually human), these iterations become emulations rather than simulations (McGregor, 2002). A simulation is defined as directly 'repeating' the behaviour of a system, starting from a conceptual model through to end results (law & Kelton 1991; Robinson, 2008). Emulation replicates how the original system worked, considering each function and its relation to others, but using different inputs or other factors (McGregor, 2002).

These elements and foundations of DBR align well with my doctoral research. DDD likens the systematic nature of ballet in both rehearsal/training and performance to that of a programming language. In ballet, one can recreate different patterns associated with computer science theories and concepts. The ballet acts as an R&D platform for the development of

computing education resources and practices. DDD highlights the implications for knowledge representation, and communication.

DBR allowed me to adopt an iterative approach to my research. Bakker (2019) details the design cycles of a DBR research project, quoting Latour's (2008) famous phrase: 'to design is to redesign' (Bakker, 2019, p. 59). This concept captures the fundamental approach of DBR, as well as its focus on both the macro and the micro simultaneously. The macro is approached through preparation, design, implementation/intervention, and retrospective analysis of the whole, while the micro is addressed through constant sprints that make up the process. DBR's ability to create a feedback loop across preparation, implementation, and redesign strengthens the relationship between design activity and research activity (Rodgers & Yee, 2014).

4.4.3 Building and Generating Theory through DBR.

According to Hoadley (2005), DBR methods help generate theory in four ways: induction, orientation, constraints, and manipulation. Induction involves data collection and generation, and is a significant part of DBR studies owing to the iterative nature of the method. Dede (2004) critiques this as the 'temptation to produce designs […] that lend themselves to easy collection and analysis (p. 5), but Hoadley argues that this is a benefit to creating solid hypotheses, or 'conjectures' in Bakker's terminology (Bakker, 2019). The orientation of the data aids in theory generation as it 'focus[es] on the design' (Bakker, 2019 p. 3), and the iterative improvements or changes with each cycle readjust the theory to fit with what works, working towards a near-perfect end product. Bell's (2004, 2004b) 'On the Theoretical Breadth of DBR in Education' reveals that educational research is complex and goes beyond one discipline, theory, or research design.

Typical DBR studies focus on several areas of inquiry: (i) how a learner's education experience changes from their point of entry into the learning experience to their exit; (ii) how learners interact with the materials and information presented to them; (iii) how the learning process may be optimised, modified, or improved; and (iv) how the findings build on current understandings of learning in this context (Wolcott et al., 2019).

DBR adds a layer of systematic data analysis, which provides room for the falsification of data (Popper, 1963, 1995). Popper notes that 'every genuine test of a theory is an attempt to falsify it or to refute it. […]Some theories are more testable, more exposed to refutation than others; they take […] more significant risks' (Popper, 1962, p. 36). Hoadley addresses this

risk, incorporating the use of constraints which adds rigour to the approach and enhances the appeal of using DBR in my research study.

The uncertainty that is central to DBR presents not just problem-solving but problem-exploration through its systematic design, which is akin to laboratory experiments with variables and controls. The relationship between conjectures, interventions, and feedback (output as value from each iteration) is made clearer by the iterative process, and the manipulation of each iteration and reformulation provides the opportunity to expand an individual study out of its context and into a more general setting (Hoadley, 2004). Popper argues that the rigour of a theory or its scientific status is tested by its ability to be falsified, refuted, or tested. While these are important considerations in any scientific method, Popper's work has often been criticised as an extreme of strict, logical thought that is somewhat reductive in its adherence to logic. Johansson & Johansson (2016) eloquently explains Popper's argument that a scientist should abandon a hypothesis if the consequences conflict with the initial observation, as this is clearly misleading. Theory generation through DBR occupies a healthy middle ground, incorporating Popper's notion of falsification or 'critical rationalism' as well as Hoadley iterative method which uses DBR to generate conjectures and potentially more general theories in the field.

4.5 DBR according to Bakker

Arthur Bakker, a mathematician, researcher, and Associate Professor at the University of Utrecht, refers to this approach as 'design research (in education),' with education set in brackets as this is not included when engaging with the education community. Design research provides a systematic framework through which to answer questions that are also relevant to this study.

Design research goes beyond 'describe and compare' methodologies and incorporates the 'advisory function' of giving theoretical insights into how particular teaching benefits learning. DBR is a journey of 'actionable knowledge and theories related to the research study' (Bakker, 2019, p. 47). In the case of DataDrivenDance, actionable knowledge of the computing education content of data transmission, signal processing, and digital ethics is taught and understood through experiential learning via ballet and XR technologies. Theories and conjectures are generated and collected through theory-informed experiences that link to the design and context of the setting. Design research—the simultaneous and iterative

development and testing of 'theory'—is designed to 'promote learning or an educational problem' (Bakker, 2019, p. 15).

DBR balances theory and practice in education, providing a mixed-methods approach to educational research, using theory-driven design to produce and enhance learning interventions, see 4.4.3, 4.5.2. DBR is an advantageous methodology for understanding how, when, and why educational innovations work in practice, see 4.6.1. Additionally, DBR methods aim to reveal the relationships and tensions between educational theory, designed artefact, and practice, see 4.6.3. Many experts on DBR have written extensively on the subject, such as Collins (1992), and Brown, (1992), but I focus here on Bakker's explanation of and advocation for DBR as it closely aligns with my own research practices.

The coining of the term DBR is attributed to the design experiments of Collins (1992) and Brown (1992), but this fails to account for the ground-breaking earlier computer science education work of Papert and Solomon in the 1970s. 'Programming Languages as a Conceptual Framework for Teaching Mathematics' (Feurzeig et al., 1970), for example, along with the development of the programming language LOGO, which was specifically designed to help children understand and learn programming languages, were vast and unprecedented advancements in the field. Papert's (1980) *Mindstorms: Children, Computers, and Powerful Ideas* has over 14700 citations, and depicts children as epistemologists—'actively building their own intellectual structures […] learning to think articulately about thinking' (p. 19). This ground-breaking work in computing education had iterative, reflexive designs (Papert et al., 1971; Solomon & Papert, 1976; Harel & Papert, 1991) which sought to improve education through the use of and interaction with computers. Papert's theories and iterative, real-world experiment design align with current descriptions of DBR. Experiments through interaction and exploration of the 'turtle' computer could now be classed as DBR in authentic classroom settings, generating new theory through specific classroom experiences.

There is a high level of focus on education within many DBR studies, but other fields are given significant attention, including: health professions education (Kartoglu et al., 2017); STEM education (Ketelhut et al., 2010); and higher education faculty training (Shattuck & Anderson, 2013). The transdisciplinary nature of my research creates conflicts with some of the wide-ranging definitions of DBR and their applications in certain contexts. Most studies assume the use of a traditional classroom education, whereas my study dissolves the

boundaries of this classroom, mixing computing education with data, dance, and ethics in a performance space.

The interplay between my three domains leads to a methodological interest in Interdisciplinary Design Research (IDR), which is closely related to DBR through design research and the underlying approach. This interplay between IDR and DBR enhances the transdisciplinary nature of my research and informs the creation of AgileDBR as an approach to research.

4.5.1 Design Based Research: Conjectures and Principles

This section explores the theories and principles of DBR design before the next chapter examines the specific methods used in this study. The development of AgileDBR was informed by critiques of DBR, including the following: (i) the approach lacks rigour or standards (Dede, 2005); (ii) it does not live up to the claim of simultaneous theory generation and education design evaluation (Phillip & Dolle, 2006); (iii) DBR lacks argumentative grammar (Kelly, 2004, cited in Sandoval, 2014, p. 118); and (iv) that it involves vague descriptions in research proposals (Dede, 2005).

DBR seeks to go beyond improving intervention design and implementation. It addresses the need for a deeper understanding of not only what works in any given learning environment, but also why these approaches work towards producing the desired learning outcomes. The inherent ability to generalise this approach is akin to the scalability of the research design, as both can be scaled beyond the particular context of any given DBR study to the larger population (Bakker, 2018).

The ability to generalise a study is often challenging in educational research: each classroom has a different ecosystem, culture, and mode of communication, even with the same educator, and research provides only ‘thin evidence’ that this may be possible (Dede, 2005, p. 7). However, the attention given to how and why an intervention works at the implementation stage is beneficial for practitioners and professional educators in their classrooms, both real and virtual. There is an additional need to support practitioners in implementing the theoretical and practical outcomes of studies in their real-world classrooms, as the individuality of the classroom context differs from the theoretical model; this is the challenge for scalability or generalisability in DBR (Ercikan & Roth, 2009). Bielaczyc (2013) refers to ‘implementation paths’ (p. 261), the practice of supporting educators to enact and navigate the

intervention for use in the classroom. Other tools similar to implementation paths are Sandoval's 'conjecture maps' (Sandoval, 2014) which represent the interactions and influences of the research questions with the invention design and materials.

Dixon's (2019) explores Dewey and pragmatism through DBR to bridge the gap between the pragmatic, practical, and the theoretical dimensions of research in any domain. Dixon referred to the methodological vagueness between the value of practice-based research and the knowledge generation of traditional research. He notes that 'design-process-as-method becomes something akin to a self-justifying mode of operation not requir[ing] argument or epistemological positioning beyond a nod to a […] research label (Dixon & French, 2020, p.4). Dixon was able to align Dewey's theory of inquiry with warranted assertability (Dixon & French, 2020)—the quality of the conclusions became the measure of an inquiry.

What follows in this section is a detailed explanation of Sandoval's conjecture mapping (CM) technique and how it relates to my study. I examine Wu & Chen's (2018) redefinition of CM before addressing the challenges of terminology within DBR.

4.5.2 From Maps to Principles

Conjecture maps are one way to see how a particular theory is being tested through implementation and observation, leading to improvements (see Appendix 4B for an expanded discussion). Some DBR studies use conjecture maps to present the test, evaluate, and improve stages of the research, but my own study favours an adaptation of Test–Learn cards (Osterwalder et al., 2020), which I discuss in more detail in Chapter Five. Test–Learn cards are similar to conjecture maps, as both provide insights into the practices and processes needed to underpin the whole project. Cremers et al., (2017) uses a card format to explain the design principle in two parts: the concept and the description of the principle (Bakker, 2018; Bakker & van Eerde, 2015). Van der Akker describes design principles as 'heuristics' that guide the selection and application of a given design intervention for specific purposes with certain characteristics of a classroom (Van der Akker et al., 1999).

One challenge of DBR is the wide variation in understandings of the terms 'design principles' and 'conjectures' or 'theories' (Bakker, 2018). My understanding of a design principle is that it is a generalised design practice, with norms and documented history in a generalised and argumentative form that can be re-enacted when and where appropriate (Bakker, 2018, p. 5).

The premise behind this statement is clear, but the creation of design principles based entirely on this definition would be challenging.

Bakker examines principles and conjectures in detail, but lacks a deeper understanding of the mechanism and processes involved in the generation of design principles. These principles in any DBR study enable the creation of founding theories that 'guide the creation of other tools and resources' (Hjalmarson & Parson, 2021, p. 144).

4.5.3 Design Principles in DataDrivenDance (DDD)

The design principles of DDD are the fundamental guiding principles that cover all projects relating to DDD, including ballet, workshops, lesson plans, or AR experiences. These principles are designed with ethical considerations in mind, as this is key to the development of any future project. The design considers how much or what type of data needs to be collected to achieve the desired outcome (AR or Ballet), as well as how that data will be generated and within that how it will be sensitively and ethically treated. Any study or data collection process must ensure that its design, development, and deployment is safe, secure, and prevents harm. The iterative development of my chosen approach means that there is flexibility built into the design, and ideas can diverge, pivot, or continue with the current design as appropriate and as directed by these ethical considerations. Table 4.2 outlines the design principles used in this research.

The outcomes of DBR are a set of design principles or guidelines derived empirically from the research which can be implemented by others who are interested in studying similar settings and research questions. While the ultimate objective of DBR is the development of theory, this might only occur after long-term engagement in a certain field and may require multiple investigations.

The literature in this field lacks specific practical advice on how to transform these conjectures into principles. Although Amiel & Reeves (2008) give a clear definition of principles in this context, they omit any discussion of the specific mechanisms used to progress conjecture towards 'empirically, richly described principles' (Christensen & West, 2018). Experienced DBR practitioners or researchers may have a better understanding of this process, but as a new researcher in this field I struggled to comprehend how to make this leap. Consequently, I developed my own blended methodology of Agile and DBR to create a theoretical and practical design approach.

Table 4.2 *Design Principles and Descriptions (Adapted from Cremers et al., 2017)*

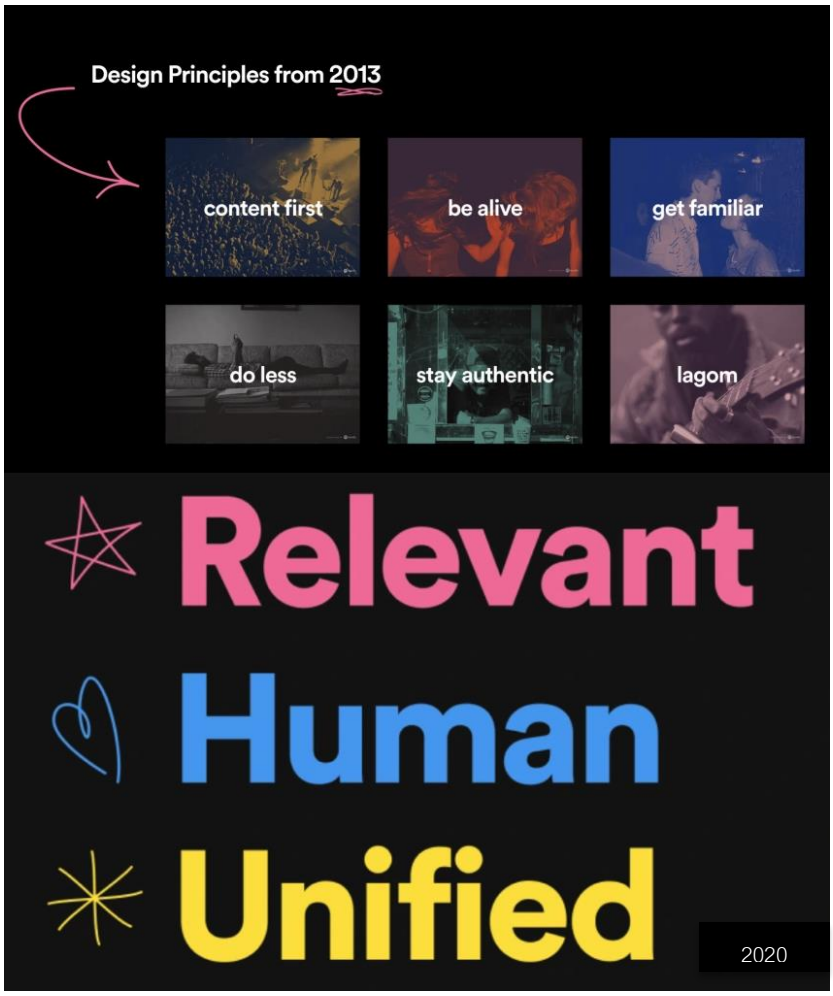
Design Principle	***Details***
Fostering authenticity (Cremers, 2017), fostering risk-taking	This includes using practices, materials, and processes authentic to the participants and their associated environments. I create space and time for participants to explore the materials and approaches without judgement or prejudice.
Bridging (boundaries)	This design brings dance, computing, and education together through performative tasks and activities.
Reflexivity	Participants' cyclic reflections both collectively and individually form part of the research process and design.
Participatory, agency	Participants are equal actors in the research as subjects, creators, and researchers.

4.5.3.1 Spotify's Design Principles

The popular music streaming service Spotify is a good example of an effective use of design principles at an organisational level. In 2012, Spotify's design team was frustrated by the accepted idea that 'design doesn't scale' (Spotify Design Team, 2020; Wood, 2016, p. 16). Spotify originally had six principles outlined in Figure 4.1: content first, be alive, get familiar, do less, stay authentic, and *lagom* (just the right amount). The design team began to experience problems with this framework owing to changes in the company and a significant increase in the number of designers from several in 2013 to roughly 200 in 2020. Three main problems were identified: the focus on consumer music experience, an overlap between concepts, and difficulty remembering the concepts which made them harder to apply.

The response to these issues raised was the implementation of design workshops and working groups that would ensure collaborative contributions towards solutions. The focus question of these groups sought to explore the motivation behind the creation of these principles, their audience, and how they could be used or modified to ensure a collective, collaborative approach to the redesign of the principles and an improved approach to the organisation of the company in future. The use of a matrix board and dot-voting gave a visual representation of redesigned principles and how individuals evaluated potential solutions, which helped to narrow down the selection and drafting of new principles (appendix 4C). The new design principles were reduced from six to three, and are now: relevant, human, and unified.

Figure 4.1 *Spotify's Design Principles 2013 and 2020*



Spotify has also developed specific design principles when designing user experiences powered by ML (2019): (i) identify friction and automate it away, (ii) ask the right questions, (iii) go manual before you go magical. The first principle is self-explanatory. The second was designed in answer to the inability of the initial ML designs to reflect the nuanced nature of the human experience, which meant that they did not generate the desired outcomes. To combat this, the team refocused a human-centre approach and modified the questions posed to the ML algorithms. This led to (iii), as by using a manual approach to assess user feedback and user interactions they were able to identify 'behavioural patterns in the data' (Spotify, 2020). These insights lead to hypotheses that were then applied to ML techniques, creating an iterative, ongoing process. The team concluded that 'if we can't achieve a good quality experience with a manual approach, then applying ML to the problem won't be worth the investment' (Spotify, 2020). Spotify development of a set of heuristics were established with the goal to use these heuristics to prove a hypothesis without applying ML (Spotify, 2020).

4.5.4 Tumultuous Terminology

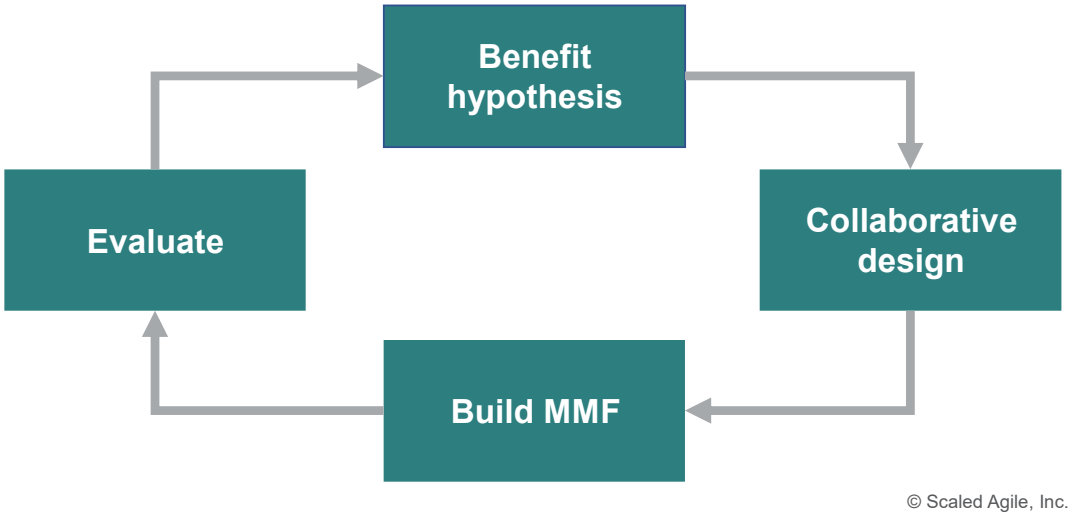
The notion of conjecture development through mapping leading to design principles is challenging. In order to illuminate this area, I turn now to an examination of the terminology used, in the hope that this will elucidate the design/implementation process.

Conjectures can be generalised through multiple interpretations by different readers across many contexts. Bell (2004) explain that design principles are an intermediate step between scientific findings which must be generalised and replicable. I use the word 'scalable' within my own study as it appears in an Agile context, which indicates that a study is both replicable and able to be generalised (Pichler, 2010). The ability to scale a study is complicated by the classroom context, as each classroom is individualised (Pichler, 2016), which makes results difficult to replicate. Principles are inductive from previous examples of success, and are continuously subjected to manipulation and refinement over time. As a result of conjecture mapping, design principles are not initially stated, but instead are formed over time through the whole design process. Every time a new increment of the study is developed, the initial data identifies principles to change, modify, and sometimes remove.

The four Agile methodologies or frameworks that align with research and the notion of knowledge generation are sometimes referred to as the research sprint. Agile is sometimes misrepresented as a way to make a product or service that does not apply to academic research contexts and the generation of academic theories. Research is in fact a key element in Agile, though it may be delivered in a different form from a traditional academic research study. Examples of this include, the Lean UX (user experience) (Gothelf, 2013), the Features And Benefits hypothesis (FAB matrix) (Scaled Agile Framework, *SAFe 5*, 2021.) the EPIC hypothesis statement, (Scaled Agile Framework, 2021), the Value Proposition Design (Osterwalder et al., 2014), and the Google Ventures (GV) research sprint (Margolis, 2019).

Lean UX is a more than just a process, it is a culture and mindset with a focus of implementing functionality in 'minimally viable increments' that measure results against the benefits hypothesis (Gothelf, 2013; Knaster & Leffingwell, 2011, 2020). Lean UX encourages early and continuous user participation with the design and continuous development (Ramos-Vega et al., 2021), not just within the business domain but also in educational settings for improving interventions (Ramos-Vega et al., 2021) or educational authentic design (MacDonald & Rozaklia, 2017).

Figure 4.2 *SAFe lean UX model adapted from Gothelf (2013)*



Features are key within the Lean UX model, but terminology differs slightly. A minimum marketable features category is added alongside the Benefits Hypothesis (BH) and Acceptance Criteria (AC). MMF, within Fig 4.2 above, is the minimal marketable feature (MMF), the smallest amount of functionality that provides value to the client. Features within development are designed for the functionality of multiple users where user stories support the design of the single user role.

The Benefits Hypothesis (BH)—the proposed measurable benefit to the end-user—is framed within a features and benefits matrix (FAB), and each defined feature has an associated benefit hypothesis. This matrix is also used in the Scaled Agile framework (SAFe) and Lean UX. A feature is a service, interaction, or element that serves the needs of a stakeholder. These features have an associated BH and AC, and they may be broken down into smaller elements for delivery within a single Agile release train (*SAFe 5.0 Framework*, 2021.), also referred to as a programme increment. This ability to be broken down into smaller elements enhances the capabilities of the FAB matrix, and each part continues to function in the same way at a higher level of abstraction within the SAFe framework (Gothelf, 2013; Knaster & Leffingwell, 2011, 2020).

Figure 4.3 *FAB Matrix*

Feature	Benefit Hypothesis
In-service software update	Significantly reduced planned downtime
Hardware VPN acceleration	High-performance encryption for secure WAN
Traffic congestion management	Improve overall quality of service across different protocols
Route optimization	Improve quality of service due to faster and more reliable connectivity

© Scaled Agile, Inc.

The Epic Hypothesis Statement in its simplest form asks a series of questions in order to create a hypothesis out of smaller tasks and understandings. These questions link together in the following sequence: For (the intended audience), who (what this audience desire out of this process), the (the platform used), is a (an explanation of the essence of the platform), that (a developed explanation of what this platform may be used for), unlike (sets out previously known competition/existing theories or concepts), our solution (the main aim of the hypothesis or research. Within SAFe analysis of EH reviews whether or not to continue with the epic.

Figure 4.4 *Epics Hypothesis*

Epics	≠	Projects
Implemented by stable, cross-functional Value Streams and ARTs.		Implemented by temporary teams, which disband after work is completed.
No definitive start and end date; scope is variable. Continue until WSJF says otherwise.		Definitive start and end date; scope is fixed. All scope must be implemented.
Progress is measured as outcomes against the benefit hypothesis.		Progress is measured based on task completion.
Lean Business Case, based on benefit hypothesis and definition of an MVP.		Overly detailed business case, based on speculative ROI.
Implementation follows the build – measure – learn SAFe Lean Startup Cycle.		Implementation typically follows phase-gated, sequential (waterfall) process.
After the Lean Business Case is approved, commitment is to the evaluation of the MVP.		After business case is approved, up-front commitment is made to the entire project scope.

© Scaled Agile, Inc.

4.5.5 Limitations of Lexicon

Terminology is essential in understanding knowledge transfer and replicability in all forms of education and research, and in limiting interpretation errors in interpretation. Thouless (1939 [2015]) notes that terms are often used or defined differently in different domains or subjects or according to different authors within these fields. DBR encounters similar challenges as many authors use DBR and other terms interchangeably, which negates the specificity of its

use and generalises the term in a sometimes-reductive way. As DBR is a relatively new methodological approach, we may expect clarity and cohesion within this field to take time, to coalesce into a coherent, widely understood term. Despite their sometimes misleading or confusing elements, 'words are, nevertheless, the tools of all science' (Thousless, 1939 [2015]).

Clarity and the limited duplication of terminology is crucial to teaching, in which a plethora of terms and acronyms are already used. Martens et al., (2019) study employed a student participation approach to disentangling terminology within medical teaching. Each use of a term is laden with value and meaning, which may augment or diminish a learning experience depending on the skill and understanding of the user. The interpretation of these terms is also crucial, and depends on the values, understanding, and interpretive skills of the listener/audience.

4.5.6 Summary

Bakker highlights five main characteristics of DBR, and the literature in this field tends to present these five areas in a specific order or rank. However, Bakker specifically argues that ranking or ordering is not part of the methodological approach (Bakker, 2018). The five main characteristics are as follows: (i) its purpose is to develop theories about learning and its process; (ii) it is interventionist in nature, introducing new or modified materials to the learning setting of the research study; (iii) it is reflexive, incorporating all aspects of the research study implementation; (iv) cyclic timelines act as feedback loops in developing and improving the study; and (v) the theory in practice must do real work towards the benefit of the learners.

Table 4.3 *Methodological Synergies. Table Modified from Bakker (2018. p. 15)*

Commonalities and differences between Design Research, Action Research and my study			
	Design Research	***Action Research***	***My Study***
Commonalities	Open, interventionist, the researcher can be a participant, adopts a reflective, cyclical process.		Many roles within my study align with both DBR and Action Research.
Differences	Design is necessary.	Design is possible.	Design is fundamental.
Focus on instructional theory and improved design	Focuses on action and the improvement of a situation.		Closely aligned to DBR with the focus on theory as well as action.

This notion of real work is a fundamental to Agile through the continuous and incremental delivery of value within any Agile project. Table 4.3, above, outlines the commonalities and differences of DBR and Action Research, along with how these relate to my study.

4.6 What is Agile

Agile refers to a set of frameworks and practices based on the values and principles expressed in the 'Manifesto for Agile Software Development' (The Agile Manifesto, see 4D). The four values and based on the 12 principles of Agile, as defined in Appendix 4D, and although the terminology does not match that of the education domain, it is possible to see the alignments of Agile with DBR. Agile can be used as a practical project management tool to ensure a successful delivery of all smaller projects in a wider whole (Rose, 2015, 2016). This approach was adopted in my study to complement the technical elements of ballet, which require experienced software and hardware developers, and so this use of an approach commonly used in this professional sphere seemed appropriate. Understanding these domain-specific methodologies enables clear communication and effective delivery for the study as a whole. Agile has gone beyond its original field of software development to cover many different domains, from finance (Panetto et al., 2018) to pharmaceuticals Azanha et al., 2017; Shayannia, 2023). The approach was created to address a lack of cohesive methods encompassing the full cycle of software development. Various methodologies addressed certain individual aspects of the development process, such as Scrum teamwork (Lindstrom, 2004), extreme programming, or development and release methodology, which focusing on customer satisfaction, and used iterative release cycles (Lindstrom & Jefferies, 2004). Feature-Driven Development (FDD) is an Agile method of designing, developing, and deploying software by feature (Blokdyk, 2019).

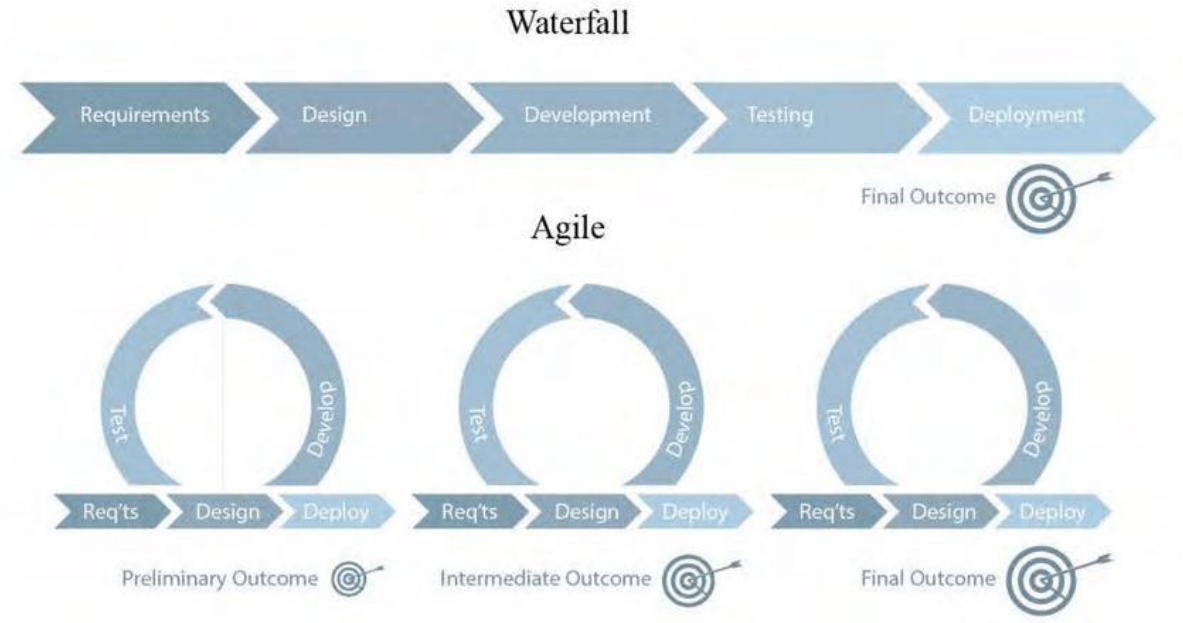
4.6.1 DBR and Agile: Alignment with Industry Practices

DBR and Agile have many similarities, including the use of the iterative development practice and reflective methods. Aligning a study with its reflection in industry is crucial for the validation of research findings in a real-world context, as well as in informing the metrics used to carry out the study (Hoadley, 2004). DBR has a more in-depth and long history of theory generation, whereas Agile is focused on product output (Patton, 2014; Rose, 2015). Product in this study refers both to the educational content and theory generation in equal measure, and so the combination of DBR and Agile works well in my context. The

characteristics of both DBR and Agile make the blend ideally suited to both represent existing Agile practices (Patton, 2014) and relate findings to the broader DBR paradigm.

Figure 4.5 Waterfall versus Agile highlights the process with Agile looping back through its iterative nature in order to successfully complete a given project.

Figure 4.5 *Waterfall versus Agile (Blackwell, 2018, p. 410)*



Many traditional research approaches follow a process akin to a traditional software development process known as Waterfall (Blackwell, 2018). This linear approach to research reflects on the advantages and disadvantages of the methodology only when the study has been completed, and provides no space for altering the direction or line of inquiry as informed by the initial results, findings, or experience. The stages of this Waterfall method follow a distinct pattern of stages: (i) a review of the field, often known as a literature review; (ii) design, in which research aims and questions are drawn up; (iii) development, the main body of the research study and adjacent research activities; (iv) test and deploy, the collection of results through fieldwork; and (v) a writing up period, followed by submission (Newby, 2014; Bell, 2004).

4.6.2 DBR Iterations/Cycles

DBR involves many cyclic stages which move iteratively through the following stages: (i) defining the problem, (ii) defining the features, (iii) an initial sprint, (iv) finding a solution for a feature of the sprint as informed by reflections on previous sprints, (v) test the improved

sprint features, and (vi) repeat the process as necessary. Easterday, Lewis, & Gerber (2014) describe these stages as follows: (i) focus the problem, (ii) understand the problem, (iii) define goals, (iv) conceive the outline of a solution, (v) build the solution, and (vi) test the solution. Each design iteration consists of smaller cycles known as 'sprints' in Agile terminology, which are time-boxed iterations in which specific tasks are completed. Sprints consist of both 'scoping'—new information learned from the previous iteration—and 'plan'—implementing this new information in future iterations.

Each iteration cycle (or sprint) is based on a series of questions that progress and reconfigure the new conjectures or research questions. Flewelling (2018) and Martinelli & Milosevic (2016) explain how sprints work through a series of questions that should be asked during each cycle. These questions address: (i) the 'goal' of the sprint, which helps to determine what tasks, activities, and experiments to include in the sprint; (ii) previous iteration conjectures that inform the current sprint; (iii) the logistics of the plan, including access to participants, materials, and equipment, that may impact the sprint's time frame; (iv) the confidence of the researcher in completing the sprint goals. Confidence is an essential determinant to consider during any research project. The use of Agile tools adds built-in, concrete measures of confidence and reflection so that the researcher may focus on the theoretical development of the study alongside the development and implementation of real-world educational resources and experiences.

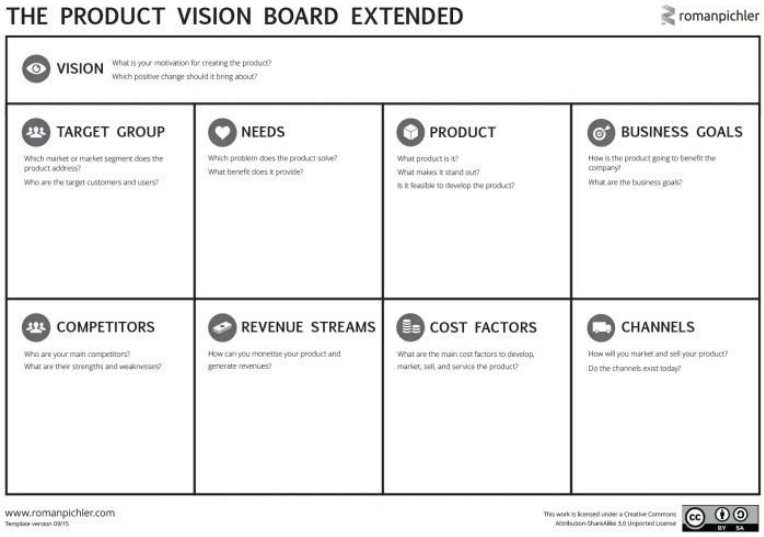
Each sprint ends with a reflection or 'retrospective' in Agile terms, which identifies actions needed for improvement in future sprints (Derby et al., 2006). This iterative reflection differs from the reflection at the end of the study itself, which is a structured, two-hour meeting that systematically reflects on the whole completed project (Derby et al., 2006; Rose, 2015).

Iterations are fixed units of time within the Agile mindset, and velocity is a measure of throughput within that fixed unit. Historical and current velocity can be used as a prediction for the amount of work that can be tackled during a single sprint (Pichler, 2010). Cohn (2005) aptly observes that 'velocity is the measure of a team's rate of progress (p.38) [..] that becomes apparent over iterations' (p. 39). The velocity of a project is adjusted at the end of each iteration through the consideration of activities completed within the most recent sprint. Velocity is not a measure of value or how much an individual can do, but a tool to help predict how much could be done in future iterations.

4.6.3 Agile Tools for DBR

Applied Agile planning techniques, mapped onto a DBR approach, ensure a continuous delivery of all elements of the study, known as a backlog, which includes vision boards and an overall roadmap of critical points for each increment of the study. Each increment or research cycle has one or multiple sprints which progress the process through ideation, design, planning, implementation, and delivery, before moving on to evaluation and feedback which inform conjectures used in the next increment.

Fig 4.6 *Original, top (Pichler, 2010, 2016) and modified Vision Board, bottom*



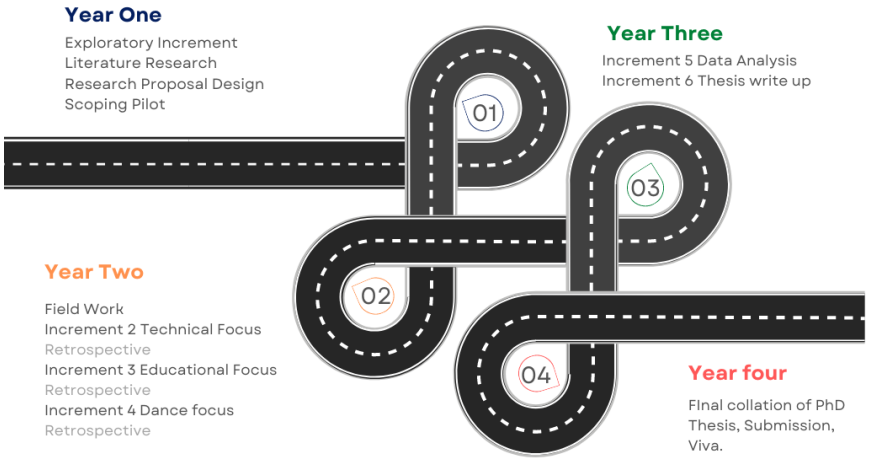
VISION: states your overarching goal, the ultimate reason for creating the product, the positive change you want to bring about.			
Target Group	**ETHICS**	**RESEARCH PROPOSAL**	**RESEARCH GOALS**
Target Group describes the segment you want to address. The participants' collaborators for this study. The number and breakdown illustrate the specific target populations the study addresses.	**Ethics** summarises the research ethics needed for the study to take place. Additionally for this study ethics as subject	**Research Proposal** what makes this study a contribution to the field and the feasibility of the study.	**Research Goals** explain why the study is worthwhile through a series of questions. How is the research going to benefit the participants and the research community/ education field in practice? What problem does the research solve or highlight? and what benefit does it provide?
Literature **Theoretical Framework**	**RESEARCH DESIGN:**How will you design and carry out your research study?	**COST FACTORS**	**DISSEMINATION STREAMS**
Literature / Theoretical Framework the key literatures and theoretical frameworks for this study. Link to Visual Map	**Research Design** the overview of the study design, how you carry out the research from a pragmatic perspective.	**Cost Factors** What are the main cost factors to develop, implement, and service the research study?	**Dissemination Streams** How can you share your research and generate interest? the specific channels that are appropriate for to the study.

Vision boards are high-level documents that capture the scope and requirements of a product to ensure its successful deployment (Pilcher, 2022). Figure 4.6, above, highlights any adaptations of terminology, purpose, and function for use in my research context. This tool helps to focus research objectives, logistics of the study, and theoretical approaches in a

single, clear document. In a research context, a vision board is reconfigured to consider the theoretical aspect of the study in place of the product. Figure 4.6, above, illustrates this reconfigurement of a vision board for my own research process. Several elements of terminology survive from the industry template, but these are adapted to a research context. I have maintained Pilcher's terminology in my consideration of target groups (participants and the education research community), cost factors (relating to the financial and temporal commitments necessary for the completion of the study), and needs (the conjectures or research questions driving the study).

Prior to visualising the road map Fig 4.7, below, a vision board was created 4.6 above, showing component parts of the research study and highlighting each component's purpose and key questions. Figure 4.7, below, presents the roadmap as an overview of this study. This roadmap draws on an Agile roadmap (Pichler, 2010, 2016, 2022), and DBR (Bakker, 2018) focus of my study. The roadmap roughly maps to the following: Year One: chapters 1-4, appendix 6A, Year Two: Chapters 5-7, Year Three: Chapters 8-10, Year Four, chapters 11, 12)

Figure 4.7 *A Visualisation of the Study Simplified Roadmap*



4.7 Data Analysis

Agile analytics focuses on exploring data through finding value in a dataset rather than proving hypotheses, and uses an adaptive approach to data analysis methodology. This approach is iterative and adaptable to change from both internal and external factors, which reflects the cyclical method of data collection and research. Agile analytics prioritises value

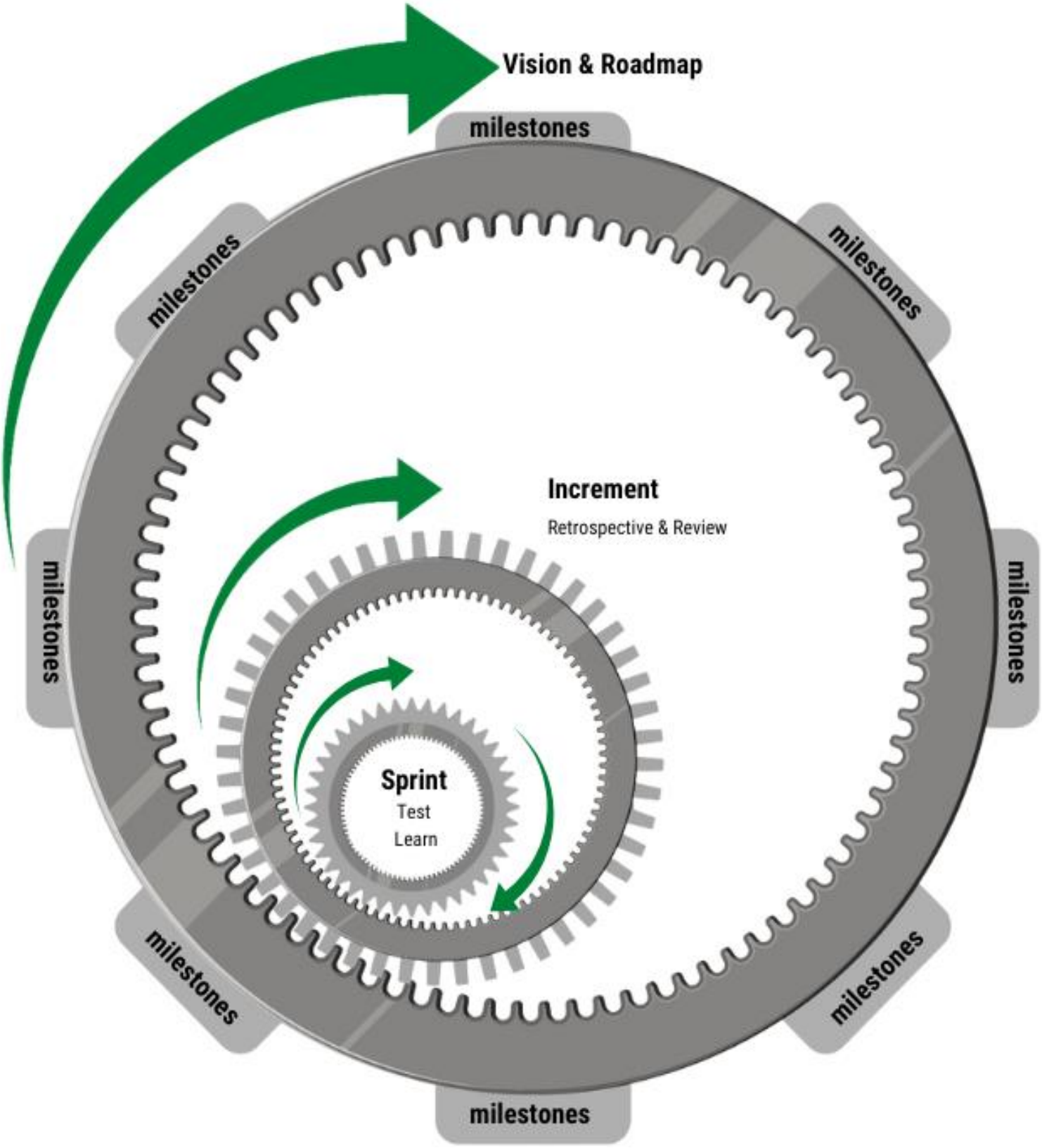
over processes and allows analyses that may not always be fully clean or organised (Collier, 2011). This initial data analysis can then be used to inform future iterations, and becomes more refined as the research continues. McNaughton et al. (2017) use an Agile approach for academic analytics in a case study concerning a HE educational institution in the Caribbean. The final output, a strategic roadmap, highlights the institutions' readiness to invest in high-value resources for use in Agile practices, allowing the institution to rapidly scale their own practices towards enterprise level.

4.8. Summary

Research is fundamental to the Agile process. The continuous learning culture of this approach is a key element, especially on a larger scale (Leffingwell, 2007-11; Knaster & Leffingwell, 2020). Agile and DBR are not dissimilar to academic approaches that seek to benefit stakeholders, and participants/students through establishing practices and principles (theories) for further development cycles or research studies. For these reasons, I adopt a blended approach using both Agile and DBR in my research. AgileDBR scaffolds, processes, structures, outcomes with transparency designed to generate theoretical/practical knowledge within educational settings. This led to the research question (RQ3) Is AgileDBR methodology an effective methodological approach for educational academic research? If so, how would this work?

The goal of this chapter was to outline the research methodological underpinning used in my study, and to highlight how this could be used to effectively answer my research questions. I emphasise the alignment and affordance of Agile with DBR to create new systems that enable the iterative development, design, analysis, and review structure of each. AgileDBR enables deeper understanding of the initial research questions, which both require a flexible, reflective, and Agile approach. The next chapter I will discuss the methods and study design, respectively, used to develop these theories and conjectures generated by this approach.

Figure 5.1 *Research Engine–a visual metaphor illustrating methodological cadence*



5.1 Introduction

This chapter outlines the methods employed in this study, and provides a general overview of all participants, materials, instruments, data management, and analysis approaches used. I then explain the study design itself, an iterative approach with each cohort generating and interacting with the development and design of each increment. The design moves through data collection and generation through to data analysis. I also explore the ethical issues and limitations of the study at the end of this chapter.

It is important to note that this study was conducted throughout the Covid-19 pandemic. The pre-covid design included in-person research in three research sites: Dublin (K7-12 students and their teachers), Antigua & Barbuda (K9-11 students and their teachers), and England (trainee computing teachers). As access to these sites was no longer possible, a pivot in the design was required, leading to design presented in chapter six. The global pandemic played a key role in the tools and mechanisms that I was permitted to use by the ethics board. The fully virtual study limits the methods available, but also provides many opportunities that more traditional, face-to-face methods do not.

5.2 Timeline Grid of PhD

Figure 5.2 *A Timeline Grid (iteration) of the study fieldwork*

Increment 2												
	Jan				**Feb**				**March**			
SPRINT	1	2	3	4	5	6	7	8	9	10	11	12
DANCE												
EDU												
TECH												
Increment 3												
	April				**May**				**June**			
SPRINT	13	14	15	16	17	18	19	20	21	22	23	24
DANCE												
EDU	*											
TECH												
Increment 4												
	July				**August**				**September**			
SPRINT	25	26	27	28	28	30	31	32				
DANCE												
EDU					**							
TECH												

* loss of original PGCE trainee cohort and change to one presented in this thesis,

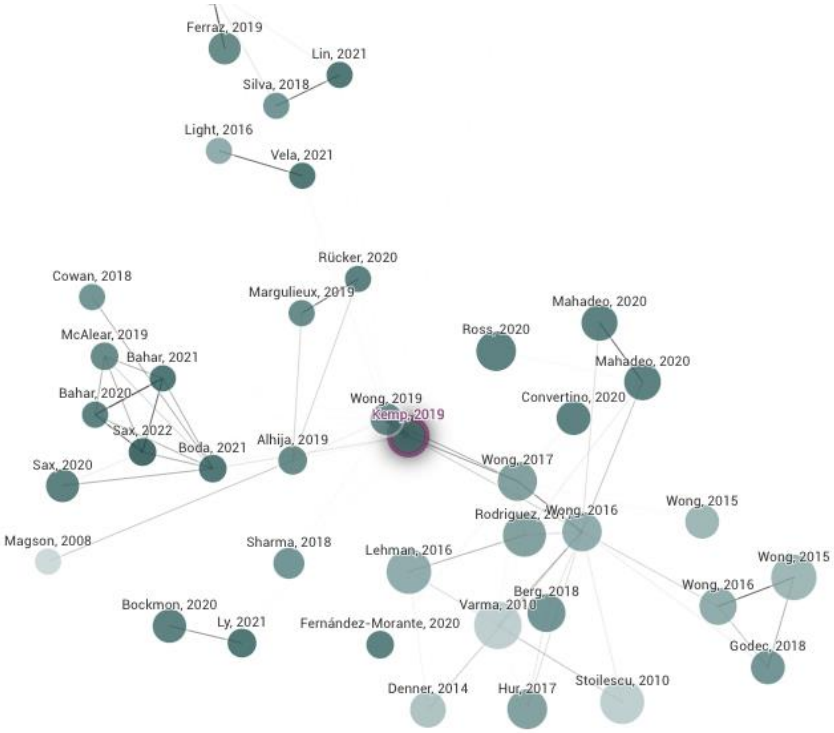
**loss of access to trainee computing teacher participants.

This timeline represents the non-linear and iterative research approach adopted throughout this study, and adapts the project/product roadmap of Agile methods to express the progression of activities towards completion.

As this study follows an AgileDBR methodology that involves cycles of research, it fits well into the traditional PhD research timeline: preliminary research in the field, design and development of methodology, and retrospective/analysis which informs conclusions. The cycles are referred to as programme increments (see Chapter Six) that align with terms used in the Scaled Agile Framework™. This study has the following increments: (i) scoping and literature, (ii) design, (iii) implementation and testing of design one, (iv) implementation and testing of design two, (v) implementation and testing of design three, (vi) 'write-up' and editing. Increments (ii) and (iii) involved all cohorts but focused on the data generation of specifics cohorts.

The use of arts practice and biometric data are interwoven throughout the study to gain insight through data generation. Arts-based practice and dance, specifically classical ballet, allow space for cross-curricular links and non-traditional approaches to computing education. The use of biometric data enables students to connect with the ethical implications of the dataset, which helps to raise awareness of data-ethics.

Figure 5.3 *Literature Mapper Produced via connectedpapers.com*



Visualising literature, Fig 5.3 above, was extremely helpful in the initial stages of research to understanding how key studies in the field fit within the wider matrix of work, and how each academic article had referred to or built upon work that came before. This approach draws on Rose (2001) visual methodologies and Mayer's (Mayer et al., 1999; Mayer 2005, 2020, 2022) multimedia theory of learning Many tools exist for visualising literatures, including connectedpapers.com, litmap.com, and coding using Python. Figure 5.3 is a force graph: the spacing between nodes/papers is based on similarity between them, even if they do not directly cite each other. Similarity is based on the concepts of co-citation and bibliographic coupling (overlapping citation for example). The distance between papers represents the degree of similarity (Tarnavsky et al., 2020). This mapping of literature into a wider matrix was also part of the inspect and adapt process, ensuring understanding of the field was kept up to date but also relevant to the developing study during fieldwork.

Figure 5.3 shows Kemp et al. (2019) as the central node, with the references and interconnection of citations from within their paper spanning out from this point. This technique was used in all increments, and is highlighted appendix 6A, which shows the similarities between a 2020 paper and more recent work.

5.3 All Participants

A distinction must be made here between the participants in my pilot study (discussed further in Appendix 6a) and those in the main study. My discussion in this section focuses on the participants in the main study, who were selected using purposive sampling (Cohen et al., 2018, p. 218) based on their experience and expertise in specific areas: computing education, dance, and technology. The education cohort was made up of 18 PGCE (Post Graduate Certificate in Education) secondary computing candidates (trainee teachers) and two Programme Leads. The dance cohort, responsible for generating data artefacts and sharing their views on the process from a dancer's perspective, included two dancers and one choreographer. The technologist was one developer who developed the data collected into an AR context for use in my study.

As the participants fell into specific cohorts, a purposive sampling technique was employed to ensure that participants had a good knowledge and sufficient experience relevant to the study and could provide insight and relevant personal responses throughout the fieldwork period. This method of participant selection uses specific criteria to select the most relevant participants in order that the subsequent study may fully address the research questions

(Bryman, 2021, p. 378; Gray, 2021, p. 174). Although selection criteria varied between cohorts, the advancement of technology had a significant impact on the interactions between these cohorts, and before the technologists or educators interacted with the dancers and the data produced through their movements, protocols for recording biometric data for motion capture via digital and virtual means were required.

All participants in the educator cohort were secondary PGCE (trainee computing teachers) or PGCE computing programme lead. This ensured that even if an individual's first degree had not been in a computing or related field, they had completed a baseline eight-week Subject Knowledge Enhancement (SKE) course, a prerequisite for the PGCE Computing programme (BCS.org). The education cohort provided opportunities to test, explore, design, and redesign the digital education resources.

The dancers were selected if they had experience of classical ballet to at least Grade Five level, which ensured a good understanding of classical ballet terminology, as well as the proper execution and placement of arms and feet. Pointe work begins at this stage in ballet training, and it is recognised as equivalent to GCSE grade A*–C or NVQ Level Two RAD (Royal Academy of Dance, 2021; AQA, 2021). The ballet dancers were recruited through an open call for participants sent out via the Cambridge ballet society. The number of dancers available was limited by the Covid-19 regulations in place at that time, but the remote technological developments and creation of a fully digital ballet meant that there was no need for a full chorus of dancers, and so this limitation was not a great setback.

The choreographer was selected based on previous experience working with technology and their ability to choreograph data-driven classical ballet pieces. Both the choreographer and dancers were adults. All choreography for this study was developed by the choreographer in collaboration with the dancers.

The technologist was selected based on previous experience working on dance projects and immersive technologies. The combination of the dancers' role and the technologist's development drove my exploration of data-ethics, specifically how awareness may be raised about this pertinent subject, how dancers view their body as a data artefact, and how the use of 3D avatars and/or visualised EEG data influences the participants' views on data-ethics.

It is important to draw on the roles each of these stakeholder groups afford the development of each iteration. In Agile terminology it would be 'cross-functional teams' (Skelton &

Manuel, 2019). In simple terms this is a group formed by individuals from different functional areas or departments working together to accomplish a specific task, goal, or project.

Cross-functional teams (CFT) are an integral element within Agile project management. However, how does that translate to my study? While the terminology ‘cohort’ is consistently employed throughout this thesis aligning with other DBR thesis. It is important to recognise that the participants-collaborators in my study engaged are more akin to a ‘cross-functional team’ rather than being tethered to the historical military connotations of the term ‘cohort’ (Nelson, 2001, p.127). In simple terms a cross-functional teams represent an assemblage of diverse individuals endowed with distinct skill sets and decision-making authority, reflexive–practitioners, as educators, Schön, (2016)–, and aligned towards a singular overarching objective/goal. Alongside being reflexive practitioners

Early studies, such as McDonough (2000), delved into the potential and advantages that cross-functional teams for new product development. McDonough's paper suggest a model encapsulating several facets for successful CFT including stage-setting, enabling, and team behaviours encompassing cooperation, communication, respect, and empowerment (McDonough, 2000, p. 233). Kaysyap on Kanbize.com, exuberantly likens cross-functional teams to superheroes team-ups, they underscores that CFT are not a silver bullet (Kashyap, 2022). Instead, CFT potential lies within a nuanced framework that necessitates communication, collaboration, alignment.

For this study it is the educators, dancers, technologist expertise (functional areas), and me as educator-observer-researcher exploring and collectively/collaboratively developing the research through each iteration. Although my participants were all completely separate or disparate, each one provided insight at each stage, sharing their expertise of each domain, be it computing education, dance, or technical.

5.4 Materials

The materials used in this study depended on the specific increment, research focus, and output requirements at different points during the research. Materials for the development of education resources consisted of instructional videos, pdfs, presentations, sample datasets, and working code examples shared via a minisite, see 5A. All software used was free at the point of use or open source, which facilitated the continued access beyond the workshop experiences for all participants. To replicate the study, however, hardware requirements

would include a device with a built-in camera or external webcam and the Emotiv™ insight device, which recorded the EEG data.

Each increment of the study had a distinct set of requirements, materials, approaches, and a focus on one area of research inquiry that influenced the methods, materials, and data analysis techniques used. The rest of this chapter discusses each instrument individually, and then Chapter Six provides a detailed overview of the study design and entanglement within the different cohorts and the specific materials, techniques, and analyses associated with this integration.

5.4.1 Physical and Virtual Spaces

Due to the online modality and disparate nature of the dancers and technologist many different tools were used in this study. In order to learn and rehearse set choreography, the dancers needed adequate dance space. The choreographer also provided video recordings of sections or motifs of the choreography for dancers to use as an *aid memoir* or to learn the choreography independently before group practices. Live ballet sessions used a video conference platform with full encryption and transparent data tracking policies such as Jitsi™ or Zoom™. This video footage was also used to generate the postpose-estimation data at a future stage of the research (see Section 5.5.3).

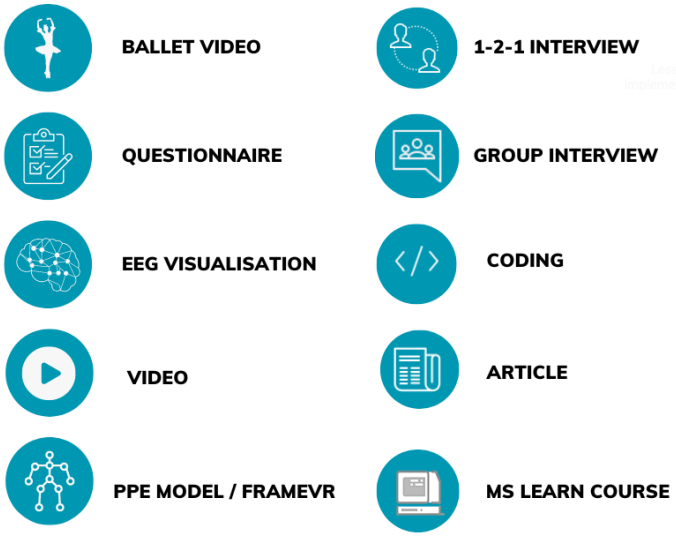
The ever-increasing demand for online and distance learning meant that the interaction design of this study was a big priority. I considered the issues of Zoom fatigue, reduced engagement online, and barriers to engagement through lack of access to technology. The hybrid approach to this study aimed to minimise these risks. The phenomenon of Zoom fatigue has over 12000 published literatures that highlight challenges for educators. Quezada et al., (2020) explore education as it spans from 'bricks and mortar to remote teaching,' and emphasise that continuing with the normal three-hour lecture online results in Zoom fatigue for training teachers. Gulo (2021) discusses the increasing link between stress and excessive use of technology, referred to as tech fatigue, and notes that the exchange of verbal and non-verbal cues are more difficult to process during video meetings.

5.4.2 Iconography

Numerous icons and avatars (such as those depicted in Figures 5.4 and 5.5) were used in this study to reduce complexity and to anonymise participants, an approach which draws on Mayer's (2005, 2020) multimedia learning theory (see Section 2.4.1). Icons used in this way

provide a visual reference to the user/reader that forms part of media and visual literacy. Cooke & Woollard (2006), in their study exploring the effective design of icons for use in ICT and knowledge retention/enabling creativity in early-years classrooms, suggest that children began to understand the new icons in the same way that they would understand symbols and signs used in maths and geography. Figure 5.4 depicts the iconography used in my study.

Figure 5.4 *Iconography of Materials and Instruments*



The icons in Figure 5.4 created using Icons8.com. In addition to icons for data type, participants created avatars for self-representation, which were generated using software, unfortunately named, boringavatars.com (Hayk & Martins, 2020).

Figure 5.5 *Boring Avatars Sample (*see Appendix 5B)

5.4.3 AgileDBR Documentation

AgileDBR utilises the many tools from Agile to support the planning, development, review, reflection, and improvement of the study on both macro and micro levels, including the use of a vision board, roadmap, Planning Increment (PI) Board, sprint board, and Test and Learn cards. These features are discussed in detail below.

5.4.3.1 Vision Board

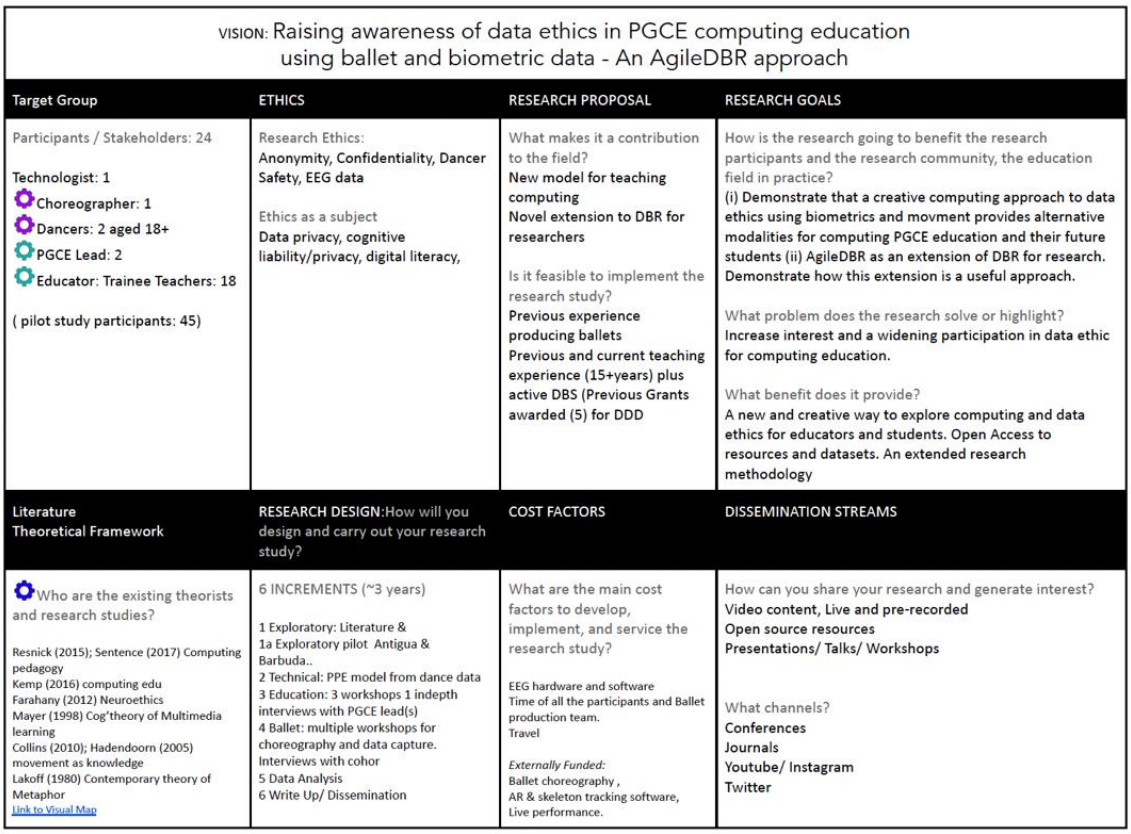
The vision board provides an overall guide and pathways to achieve the research goals, ensuring that the study is not 'pulled in different directions' (Pichler, 2010, May 10, updated 2022, July 8). There are eight sections to the vision board used in this study, adapted from Pichler's (2010) extended vision board, and including areas focusing on: vision, target group, ethics, research proposal, research goals, literature/theoretical framework, research design, cost factors, and dissemination streams. Figures 5.6 and 5.7 below present the planning of the vision board and its completed form.

Figure 5.6 *Vision-board Planning–explainer*

<table>
<tr><td colspan="4">VISION: states your overarching goal, the ultimate reason for creating the product, the positive change you want to bring about.</td></tr>
<tr><td>Target Group</td><td>ETHICS</td><td>RESEARCH PROPOSAL</td><td>RESEARCH GOALS</td></tr>
<tr><td>Target Group describes the segment you want to address. The participants' collaborators for this study. The number and breakdown illustrate the specific target populations the study addresses.</td><td>Ethics summarises the research ethics needed for the study to take place. Additionally for this study ethics as subject</td><td>Research Proposal what makes this study a contribution to the field and the feasibility of the study.</td><td>Research Goals explain why the study is worthwhile through a series of questions. How is the research going to benefit the participants and the research community/ education field in practice? What problem does the research solve or highlight? and what benefit does it provide?</td></tr>
<tr><td>Literature
Theoretical Framework</td><td>RESEARCH DESIGN:How will you design and carry out your research study?</td><td>COST FACTORS</td><td>DISSEMINATION STREAMS</td></tr>
<tr><td>Literature / Theoretical Framework the key literatures and theoretical frameworks for this study.

Link to Visual Map</td><td>Research Design the overview of the study design, how you carry out the research from a pragmatic perspective.</td><td>Cost Factors What are the main cost factors to develop, implement, and service the research study?</td><td>Dissemination Streams How can you share your research and generate interest? the specific channels that are appropriate for to the study.</td></tr>
</table>

Figure 5.7 *Completed Vision Board*



VISION: Raising awareness of data ethics in PGCE computing education using ballet and biometric data - An AgileDBR approach

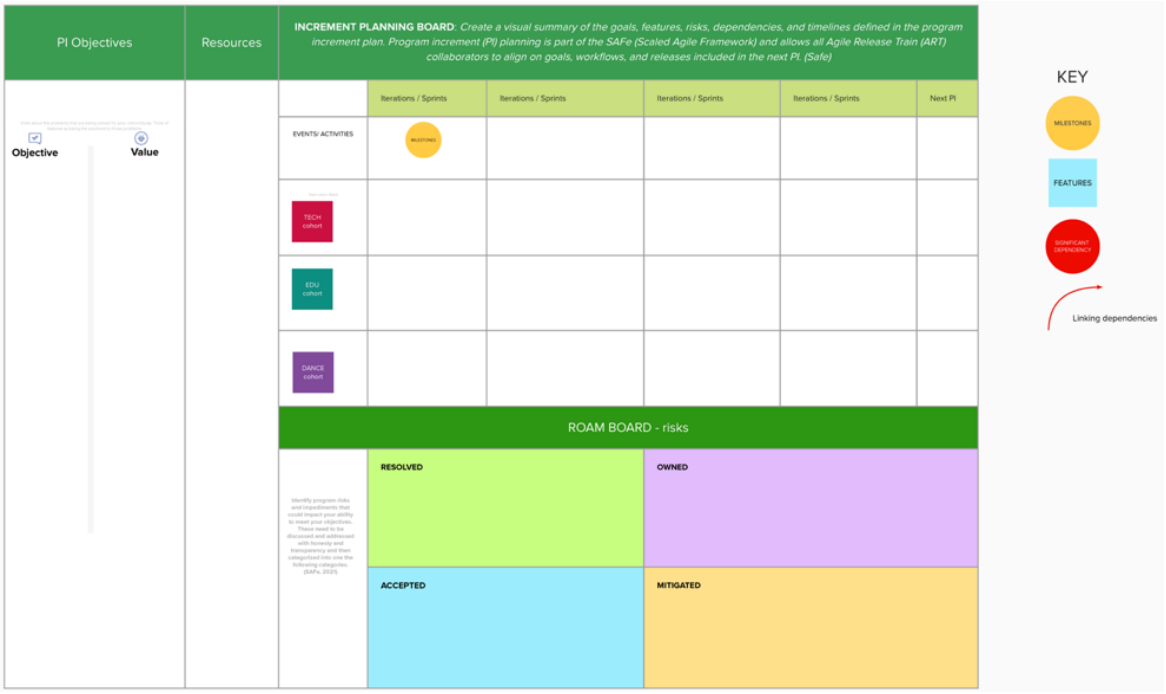
Target Group	ETHICS	RESEARCH PROPOSAL	RESEARCH GOALS
Participants / Stakeholders: 24 Technologist: 1 Choreographer: 1 Dancers: 2 aged 18+ PGCE Lead: 2 Educator: Trainee Teachers: 18 (pilot study participants: 45)	Research Ethics: Anonymity, Confidentiality, Dancer Safety, EEG data Ethics as a subject Data privacy, cognitive liability/privacy, digital literacy,	What makes it a contribution to the field? New model for teaching computing Novel extension to DBR for researchers Is it feasible to implement the research study? Previous experience producing ballets Previous and current teaching experience (15+years) plus active DBS (Previous Grants awarded (5) for DDD	How is the research going to benefit the research participants and the research community, the education field in practice? (i) Demonstrate that a creative computing approach to data ethics using biometrics and movment provides alternative modalities for computing PGCE education and their future students (ii) AgileDBR as an extension of DBR for research. Demonstrate how this extension is a useful approach. What problem does the research solve or highlight? Increase interest and a widening participation in data ethic for computing education. What benefit does it provide? A new and creative way to explore computing and data ethics for educators and students. Open Access to resources and datasets. An extended research methodology
Literature Theoretical Framework	**RESEARCH DESIGN:**How will you design and carry out your research study?	**COST FACTORS**	**DISSEMINATION STREAMS**
Who are the existing theorists and research studies? Resnick (2015); Sentence (2017) Computing pedagogy Kemp (2016) computing edu Farahany (2012) Neuroethics Mayer (1998) Cog'theory of Multimedia learning Collins (2010); Hadendoorn (2005) movement as knowledge Lakoff (1980) Contemporary theory of Metaphor Link to Visual Map	6 INCREMENTS (~3 years) 1 Exploratory: Literature & 1a Exploratory pilot Antigua & Barbuda.. 2 Technical: PPE model from dance data 3 Education: 3 workshops 1 indepth interviews with PGCE lead(s) 4 Ballet: multiple workshops for choreography and data capture. Interviews with cohor 5 Data Analysis 6 Write Up/ Dissemination	What are the main cost factors to develop, implement, and service the research study? EEG hardware and software Time of all the participants and Ballet production team. Travel *Externally Funded:* Ballet choreography , AR & skeleton tracking software, Live performance.	How can you share your research and generate interest? Video content, Live and pre-recorded Open source resources Presentations/ Talks/ Workshops What channels? Conferences Journals Youtube/ Instagram Twitter

5.4.3.2 Project Increment Board (PI)

The Project Increment Board (PI) is the planning document that highlights the new 'feature(s),' including delivery dates and required dependencies. For example, the technical tools needed to be assembled and tested prior to their use in data collection with the dancers. Figure 5.8 breaks up the study into roughly 12-week intervals according to significant events that occur throughout the study (Knaster & Leffingwell, 2020; SAFe 5.0 Framework, 2021). It covers the current state of the study, and demonstrates the output in terms of software, learning materials, activities, and choreography. This planning board is a problem-solving tool which identifies opportunities for improvement during the process (Derby et al., 2006; Leffingwell, 2011). The PI then measures performance through both qualitative and

quantitative data collection and develops a set of actionable items that improve the design, outcome, and processes of this and future studies.

Figure 5.8 *Increment Planning Board (Blank)*



The increment milestones depicted above support the researcher's ability to objectively evaluate progress towards the technical, practical, and theoretical conjectures of the study. Fixed-date milestones refer to external constraints which are often controlled by others and not the researcher, such as the dates and times of the educational sessions, which were dictated by the PGCE candidates' availability. Learning milestones help to validate business opportunities and hypotheses (*SAFe 5.0 Framework*, 2021.), which can be reflected in an academic context through highlighting theory generation or hypothesis validation as learning. Though the industry practices in this area are somewhat modified for use in academia, the principles of theory generation as part of research align with Agile and are incorporated into AgileDBR through modified materials, tools, and instruments.

5.4.3.3 Sprint Planning and Review

Figure 5.9 outlines my incorporation of two Agile boards (planning and retrospective/review) into one document, which allowed me to track the processes used in the study and evaluate them alongside the outcomes. The sprint board provides an overview of each sprint, which is then used to improve the next sprint. The retrospective/review element is conducted

separately but documented on the same board. As numerous sprints are included in the study, only one example is listed below to illustrate the point.

Figure 5.9 *Pilot Sprint Board*

INCREMENT: Exploratory Phase	**SPRINT**: Exploratory scoping pilot - Education workshops with K9-12 students and their class teachers Antigua & Barbuda & UNOPS initiative
SPRINT GOAL: Test data collection instruments. Ensure Students have a positive experience of creative physical computing	
Conjecture being tested: Using physical computing will engage novice learners **Description:** A series of creative computing 1 day workshops with max 15 students and 3-4 class teachers. Additional adults in the room included 1 UNOPS officer and 1 Education Ministry staff member. **Goal:** See if physical computing has a positive impact on students understanding and confidence levels of Computing as a subject	
METHOD: Which artefact/materials, validation techniques, and test group are used?	
Artefacts/Materials: Paper backup of instructions, educational resources (online), kitronik's robots, microbits, batteries, pencil, paper, stickers. **Delivery**: Introduction to the day, health & safety announcement, introduction to Computational thinking and key computing terms. This to ensure that we collectively understand the terminology as Antigua & Barbuda curriculum is not the same as in England. This co-created activity was modified for each delivery to suit the participants needs and ways of understanding. Two robotics workshops, one with a Moving floor rover (MiniMove) and a second robotic Arm kit.	
DATA / REVIEW: How do you determine if or how the sprint goal (conjecture) has been met or not?	
Baseline metrics: of students' understanding of computing and their self perceived confidence and ability in the subject via Keller's ARCS survey method. All participants requested to completed survey **Observations**: researcher notes of observing participants using problem solving strategies or techniques students use when completing the task **Interviews:** Semi-structured focus group (conducted by UNOPS - no access to data)	**Retrospective and Review:** 45 participants. Initial low confidence in Q1 self-perceived computing and Q2 robotics level both with 64.6% in none- poor confidence and only 6.5% in the very confident category. Post workshop all responses in confident 33.6% to very confident 66.4%. Interest rate increased post work from 25% not being interest to all responses being in the interested to very interested categories. *"I enjoyed the actual coding aspect of this course because we were free to add our own creativity into it and there were many new and interesting things that I learned about computing."*
ETHICS	
Consent to participate in the research did not have any bearing on participation in the workshop Data collected by the researcher was anonymous and confidential Risk assessment on the workshop that highlights and mitigates any harm that might come to the participants	

The review elements incorporated in this board address the content, while the retrospective elements addresses the processes used in the study. The primary goal of a sprint review is to show current outcomes, evaluate the backlog, and conduct a fast analysis using Agile analytics (see Section 6.4 for further details). Due to time constraints or other external factors, it was not always possible to include all participants in all meetings. The technologist and dancers did, however, attend the majority of retrospectives and were able to inspect and adapt processes, drawing on their own expertise and experiences.

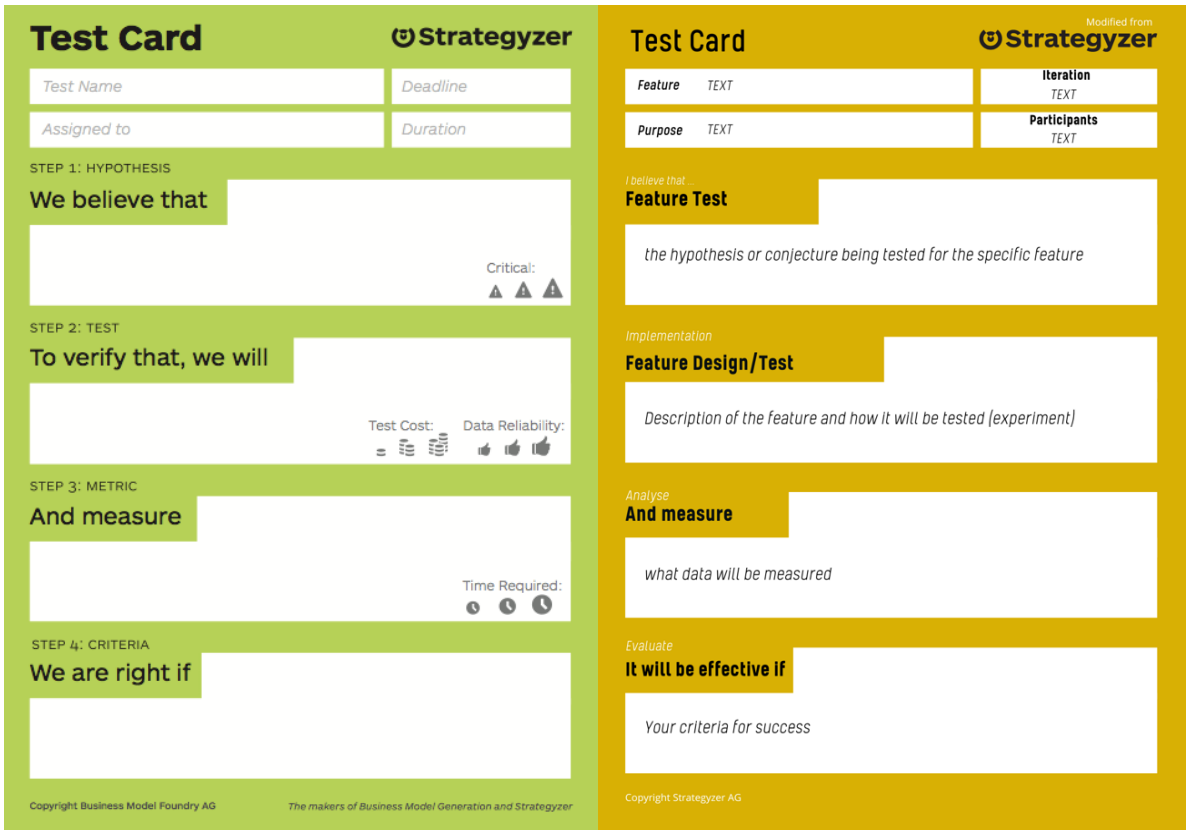
5.4.3.4 Test and Learn Cards

Test and Learning card serve to understand the effectiveness of a particular feature, **a conjecture tested at artefact level**, see Figures 5.9, 5.10. These cards are part of testing '*procedures to reduce risk and uncertainty of a business idea'* (Bland & Osterwalder, 2020. p. 44). Test cards encapsulate who, where, what is being tested through four areas: feature/conjecture test as an *I believe that* statement – conjecture. A description of the

experiment. What data will be used to measure the text and lastly the success criteria through an *I am right* if statement.

The original Test and Learn cards were modified to represent the theoretical and practical tasks of educational research. These cards are designed by Bland and Osterwalder (2020, p204) for industry rather than academia, so I modified, in line with Mayer (2005) the following items as appropriate: deadline, cost, business importance, and time required.

Figure 5.10 *Test Card Original (Green) and AgileDBR Adapted (Orange)*

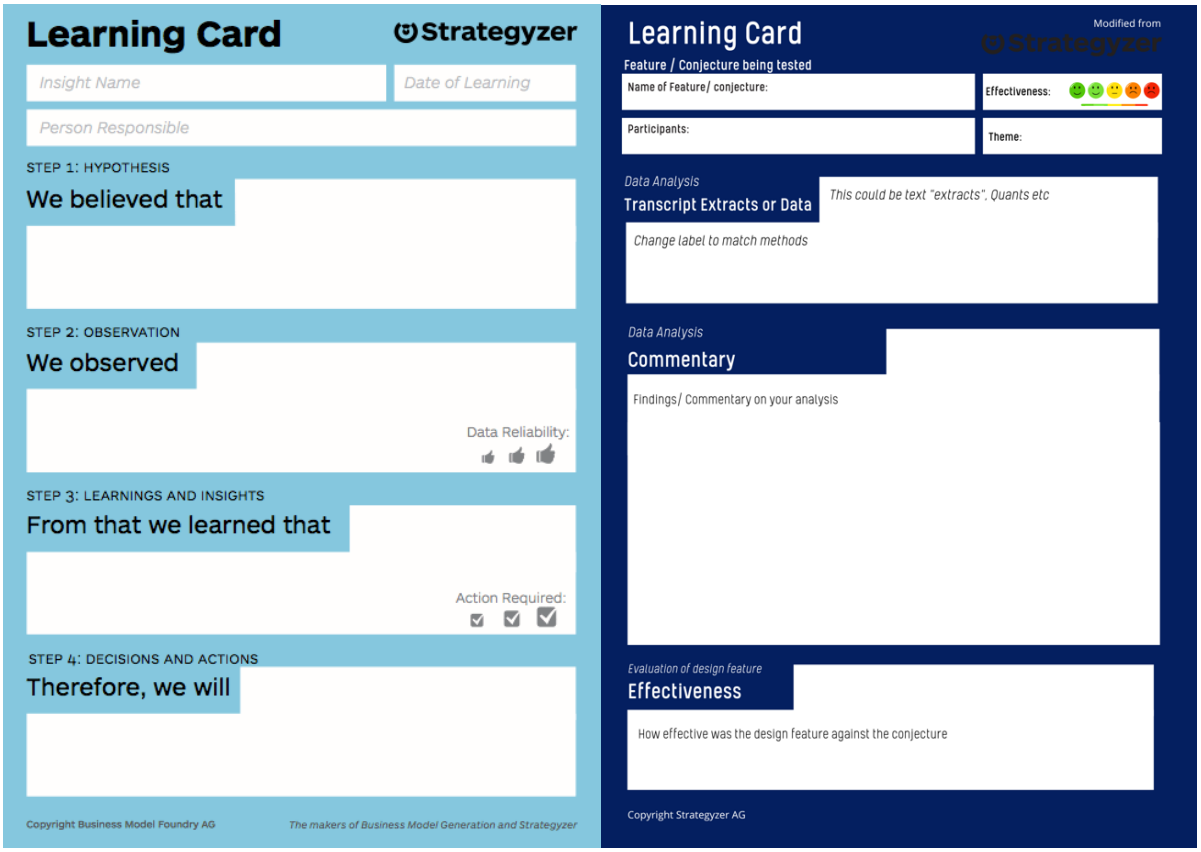


The adapted Learn card, Figure 5.11 below, was used during the data analysis finding phase of the study to capture the learning and evaluation of a given feature/conjecture, including participants' extracts, their comments on the effectiveness of the feature against the success criteria, and a scale rating.

The adaption of these Test and Learn cards meant that I could inspect and critique past development and processes without changing the entire study. DBR offers slightly different terminology—'conjecture, evaluate, and reflect'—and does not include a specific stage/artefact designed for responding and generating new adaptions before creating the

new/modified design. Adaptation is central to both Agile and DBR's iterative-continuous improvements. Additional space for extracts/data, commentary/analysis combines observation and IPA analysis. Within each learn card data type will be labelled if text or chat, otherwise the extract is voice data. Effectiveness combines what was learned and actions. This is further illustrated through emoji rating scale, top right corner 5.11. Also, in Feature-conjecture effectives diagrams at the end of each iteration, Figures 8.16, 9.13 and 10.16.

Figure 5.11 *AgileDBR Learn Card Original (*Bland and Osterwalder (2020, p206) *pale blue, left)) and Adapted (dark blue, right*)



5.5 Instruments

The instruments used in this study include questionnaires, interviews, biometric data capture, data governance, and data types, all of which will now be discussed in detail.

5.5.1 Questionnaires

The study uses a prior knowledge and competency questionnaire (see Appendix 5E) to test the trainee computing teachers' computing, data-ethics, and creative pedagogy competencies. This questionnaire was designed using Keller's (1987) ARCS model of motivation, which tests Attention, Relevance, Confidence, and Satisfaction, coupled with Loorbach et al's

(2015) RIMMS (Reduced Instructional Motivational Materials Survey) methods, which capture and measure changes in understanding following a learning experience. RIMMS reduces the number of items on a questionnaire from Keller's original ARCS model, which uses 60–70 items (1987), to 12, as Loorbach favours 'self-directed instruction' and motivation. When designing the questionnaire, I considered the use of colour theory (Weller & Livingston, 1988; Buttle & Thomas, 1997) and engagement with emojis (Alismail & Zhang, 2019) in order to improve engagement, completion rates and, if possible, to diminish any adverse effects previously experienced.

5.5.2 Interviews

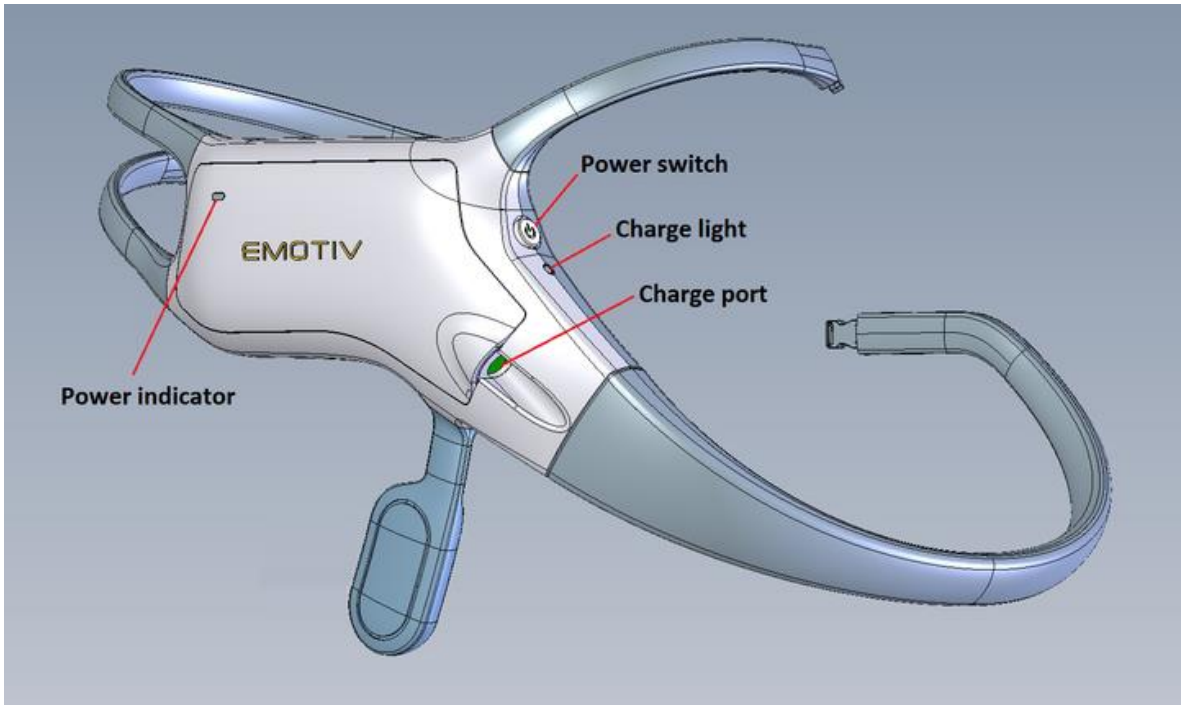
Interviews (both 1-2-1 and group) were used as a way of collecting data (for RQ1, RQ2) as a suitable way of interacting with the target audience, and to reflect on and develop each participant's role within the research. The reasons for selecting this approach align with Watts & Ebbutt's reasons (1987, cited in Cohen et al., 2018, p. 527): time, cost, and the broader participant response are advantageous and outweigh the disadvantages of conducting a group interview. Prompts through data, imagery, and video were employed to explore participant meaning (Clark-Ibáñez, 2004; Kwasnicka et al., 2015). The group interview method differs from focus group interview technique. Focus group interview techniques include documenting 'interaction' within the group as part of the methodological process (Kitzinger, 1995, p. 299). This study employed group interviews as collecting data simultaneously from a group of people are data-rich, inexpensive, and adaptive was appropriate for this online study (Punch & Oancea, 2014). See Appendix 5F for the interview schedule used in this study. All interviews were voluntary participation.

Semi-structured group interviews with the dancers during the online dance rehearsal session(s) ensured that they had adequate experience using the technology (such as the EEG headset and 'dancing for motion capture'). Audio recordings were made using the otter.ai platform via smartphone or laptop, which generated an editable transcript. Otter.ai uses AI to improve the process of live transcribing via automatic speech recognition, and can distinguish between voices, performing much better in quiet environments, although there are often errors in the text. The generated text can be shared, and a voice recording is also provided. One consideration and potential hazard when using tools such as this is the privacy and security of the data. According to Otter's website, 'all the data is stored and moved around securely, with no one except the owner having access to it' (Liang & Fu, 2018).

5.5.3 Biometric Data Motion Capture

To generate the biometric data from skeletal data required to develop the 3D digital avatars (RQ1)and the EEG data utilised in data-ethics discussion (RQ1) and coding activities (RQ2), several tools and methods were used or built. The first step in this process is to acquire video footage of the dancers from the rehearsal session. Zoom and smartphone recordings in 2D video capture format were planned and accomplished with data-ethics as the first principle RQ1 (see Figure 5.13). Participants were told to keep their entire body, including their feet, in the frame during the video, which meant using a smaller space than a stage for live ballet performance. However, as the study was conducted virtually, this posed minimal problems. Following the recording, the video footage was fed through MocapNet2 (Qammaz & Argyros, 2019), a machine learning algorithm that uses post-pose estimation to extrapolate the position of an individual's joint data in 3D space from the 2D video. The data output from this process is a JavaScript Object Notation (JSON) file. JSON files, a test-based data structure, are a standard for lightweight data-interchange (Charollais, 2017). Additional custom software (Shaw, 2022) was required to remap the joint data to the correct positions.

Figure 5.12 *Emotiv™ Insight Headset*



Brainwave (EEG) data were recorded via the Emotiv ™ headset, Fig 5.12, and these data were then stored securely on encrypted hard drives and cloud servers. Each recording was converted into an aggregated dataset to be used in the workshops. Each dancer generated an

individual dataset, which was recorded and stored without identifiable information attached to it to protect their privacy. The position of dancer's joints over a series of keyframes within several minutes of footage was a vital dataset which would inform the creation of a virtual ballet performance. The EEG data are used to create data visualisations, musical scores, and data for wearable electronics on the dancer costumes.

5.5.3.1 Episodic Ballet

The decision to develop an episode ballet was partial born out of the Covid impacts and the biometric data capture and recording process. Linked to changes in society's data-media consumption (Livingstone, 2018) delivering DDD as an episodic AR ballet would bring new interactions to different audiences. The development will occur outside this study, as is beyond the scope of this study. The AR ballet Choreography was developed by Choreographer (collaborator/participant) in this study with input from the dancers.

5.5.4 Data Capture, Generation, Management, and Storage

This section concerns the creation, processing, storage, and analysis of data produced in this study, and is a vital consideration in research which involves biometric data. The use of various tools aided in the effective management and storage of the data and code. All the computer code was stored in GitHub to allow for versioning and eventual sharing using the following open-source licenses: (i) Apache 2.0 software, which states that the 'software distributed under the License is distributed on an as is basis, without warranties or conditions of any kind, either expressed or implied' (The Apache Software Foundation, 2004); (ii) GNU General Public License 3, which states that 'everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed. GPL requires that modified versions be marked as changed' (Free Software Foundation, 2007). Additionally, the 3D avatars and all non-software digital artefacts are shared under the Creative Commons Attribution Share 'cc-by-sa-4.0' license, which requires that derivatives be distributed under the same or a similar, compatible license. This license is often used for media assets and educational materials.

As all the research was conducted during the global pandemic, different modes of data generation had to be implemented, which impacted the volume of data generated versus the data analysed. This study took the 'privacy by design/default' approach to data protection, whereby data protection requirements are embedded into systems and processes from the

beginning. Privacy by design falls under Article 25 of GDPR (General Data Protection Regulation, 2016). Data protection and privacy expands across the whole GDPR bill, as Section Two covers security of personal data and Section Three discusses data protection. Additionally, the IEEE 2089–2021 Standard for an Age-Appropriate Digital Services Framework, based on the '5Rights Principles for Children' (*5Rights*, n.d.), plays a role in initial teacher education and the use of personal (including biometric) data in the classroom.

Research data refers to any information in a digital, computer-readable, or paper-based format, including notes, facts, figures, tables, images (still and moving), audio or visual recordings, and programming code. Research data are collected, generated, or obtained during, or because of undertaking research (which includes but is not limited to conducting field or laboratory experiments, conducting trials, surveys, interviews both 1-2-1 and group, or the analysis of data), and is securely held in a repository, usually owned by the university or made available to the researcher. The researcher uses these data as a basis for making calculations or drawing conclusions to develop, support or revise theories, practices, and findings (Research Data Team, University of Cambridge, 2021).

The embedding of research data management practices in researchers' practices and processes is critical in establishing future effective data management skills and approaches. Good research practice requires planning the collection, storage, security, processing, and use of research data in accordance with university rules and compliance regulations. Certain questions may be considered at each stage of the research to ensure that correct data management protocols are followed.

Figure 5.13 *Research Data Questions*

Figure 5.13 illustrates the questions to ask when dealing with data. These questions ensure that any research study is planned, secured, stored, and accessed correctly from the beginning. It is important to distinguish the difference between data collected and research data in this, or any study, with a virtual modality.

5.5.5 Data Types

This section highlights the different forms of data generated during the study and their purposes in the research, alongside how these datasets were subsequently used and/or analysed. Table 5.1 demonstrates the difference between collected and research data, and illustrates the quantity and types of data collected during the fieldwork period, as well as how much of the data were used in the study as research data.

Table 5.1 *Data Types–Fieldwork*

Data Type	Collected	Research	RQ
Voice	11 hours	4.5 hours	1,2
Chat	3 files	3 files	1,2
Questionnaire	1 file	1 files	1,2
EEG recording	11 sessions	11 csv files	1,2
Video	43 hours	25 including hours to generate motion capture	1,2
Motion Capture	25 hours generated data	40+ JSON files	1,2

5.6 Data Analysis

This section examines the various methods designed to generate outcomes and useable value from the various forms of data collected throughout the study. My aim was to explore new ways of raising awareness of data-ethics within the computing classroom through arts practice and biometric datasets, drawing on computing concepts of data transmission and signal processing reimagined through ballet in digital forms using biometric personal data. These EEG and motion-capture datasets provide the potential to develop programming and ethical awareness for educators and learners.

The integrated data approach to data generation (Hesse-Biber et al., 2015; Hesse-Biber, 2015b) is used when both qualitative and quantitative data are combined to address a given research question/conjecture/hypothesis. Agile analytics used unprocessed, uncleaned data to understand the value of the current sprint or increment during the data generation period. This analysis varied depending on the sprint's contact and interaction with the different cohorts. Understanding how outcomes are not achieved through data generation and processing in different activities across the research study is just as vital as achieving positive outcomes.

I employed an integrated data approach, complemented by interpretative phenomenological analysis (IPA) of interview/workshop data using qualitative techniques to analyse the research

findings. The selection of IPA developed from initial investigation into Thematic Analysis, specifically the works of Braun & Clarke (2006) Clarke & Braun, (2013) and their updated 2022 book 'Thematic Analysis: A practical guide'. Braun & Clarke are very specific about the development of the themes and content that the term 'emerge – emergent' inaccurate to the process within thematic analysis as 'emerge-ent can be misinterpreted to mean that themes 'reside' in the data' (Braun & Clarke, 2006, p. 80). Their 2006 paper and 2022 book highlight the adaptability of the TA approach and offer a set of terms and guidelines for individuals to engage in thematic analysis in a manner that is both theoretically robust and methodologically rigorous. This was to address some critiques TA, in a similar way to DBR, for its lack of clarity or rigour. This then led to the specific selection of IPA due to: (i) the voice of the participant is paramount, (ii) acknowledgement of the non-neutral researcher within the research process, and (iii) the iterative nature that aligns with AgileDBR, see 5.6.2 below for expand details on IPA.

The integrated data approach also included Natural Language Processing (NLP) through the stemming and lemmatisation techniques (Carvalho et al., 2007) used for triangulation. The in-depth analysis was conducted using an Interpretative Phenomenological Analysis IPA of all data. The combination of these techniques aids analysis and reduces researcher subjectivity through triangulation where possible. As part of the study, the educative components and development of teaching resources were evaluated for subject suitability and impacts on participants' computing knowledge. The biometric data collected through the initial stages of the research were not analysed as part of the key findings of the study, but was instead used as an anonymised dataset for educational XR creation and for data-ethics discussions.

A variety of methods for analysis were used to understand data from each iteration, including analysis of surveys, interviews, and retrospectives. All data were collected through digital channels, including video, audio, spreadsheets, collaborative planning boards, images, and text. Data generation tools included: video conferencing platforms (Zoom, Teams); video recordings (via smartphone); audio transcripts (via Otter.ai); EEG data (via Emotiv pro software and exported to a CSV spreadsheet; text interactions (Email, Trello, and chat applications such as WhatsApp/SMS/Teams); multimedia (shared via email or Trello); and motion capture BVH (which generated shareable, anonymised datasets as a resource).

Figure 5.14 illustrates the data analysis approaches and reasons for selecting each technique. The data collection period occurred between January and August 2021, and so the context of national lockdowns as a result of Covid-19 should be kept in mind.

Figure 5.14 *Data Analysis matrix for raising awareness of data-ethics*

Evaluation Question:

RQ1 How to raise awareness of Data Ethics?

Indicator Sub Question	Data Source & Methods	Increment Cohort	Timing	Analysis	Interpretation	KEY
In what ways is data ethics important for the computing classrooms? How participants define data ethics?	questionnaire Semi structure group interview		increment 1 sprint 1 increment 1 sprint 1, 2	An integrated data analysis approach that used both qualitative & quantitative statements together generated from participants via anonymous questionnaire. Quantitative analysis of survey data to determine difference (if there is any), correlation between participants and at each sprint stage. Looking at the data in multiple ways, or perspectives.	Identify which, if any, factors have been influenced by the intervention. Note down changes in definitions over time.	1-2-1 INTERVIEW GROUP INTERVIEW CODING ARTICLE MS LEARN COURSE BALLET VIDEO QUESTIONNAIRE EEG VISUALISATION VIDEO PPE MODEL / FRAMEVR
In what ways does the intervention demonstrate raised awareness of data through DDD with this cohort?	Semi structure group interview Observation via video		Education: increment 2 & 3 Dancer Increment 1, 3	Group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference Videos used for recall and input for generating 3d models (at this stage of the design)	Interpretative Phenomenological analysis (Smith, et al., 2022) to explore subjective viewpoints (Flick, 2009) examining the ways that people make meaning out of their experiences.	
How the participants engaged with the EEG data to explore ethics	Data interaction	Discussion of EEG data using visualisation and EEG articles	Education: increment 3 Dancer Increment 3	Participant response (chat, voice) using the biometric dataset from the dancers coupled with dancer stories	Identify common factors, if any, influenced by the intervention.	Dance Technologist Education
How to dancers view their body as a data artefact?	biometric skeleton tracking data – creating the 3d avatars		Post with visual prompt of the EEG data and 3d models	Dancers responses to data capture during and after sessions. Transcripts from rehearsals and Retrospectives	How has the dancer's understanding of data ethics changed over time? Including the use of their own body as data artefacts?	
How do the avatars (3d models) influence your view of: 1.Computing? 2.data ethics?	Semi structure group interview Artefacts/Video		Increment 3	*Edu* VR voice a variant of photo voice as part of the group interview 1-2-1 IPA interview additionally addressing the intervention & materials *Dancers* VR voice a variant of photo voice as part of the group interview	Area for development: HCI avatar analysis (most studies are quants based)	

The evaluation data matrix, fig.5.14, template (Wingate, 2017) was developed as part of an NSF grant to aid in evaluation of project data, as it is a critical part of ensuring project success. The matrix includes a clear description of the data collected, the source and method of collection, the researcher responsible for data collection, the date on which it was collected, and the proposed analysis of that data. Above is a slightly modified version that aligns with this study and includes the iconography used.

Figure 5.15, below, illustrates the entanglement 3.3.1 and diffraction 3.3.3 occurring in this study. For methodology matrix see appendix 5G.

Figure 5.15 *Data Analysis Plan Including Sub Questions for RQ2*

Evaluation Question:

RQ2 What new insights and unexplored approaches are there in combining classical ballet and biometrics data to broaden participation in computing education?

Indicator Sub Question	Data Source & Methods	Increment Cohort	Timing	Analysis	Interpretation	KEY
What did watching the ballet performance adds to your (teachers) understanding of teaching computing?			Edu session 1	An integrated data analysis approach that used both qualitative & quantitative statements together generated from student participants via anonymous questionnaire. Voice (transcript) and text data analysed using NPL during fieldwork. Post fieldwork phase reanalysed using IPA for in-depth analysis. Test Learn Cards	Crafting Mixed-Option Evaluation Designs by Caracelli & Green (1997) Interpretative Phenomenological analysis (Smith, et al., 2009, 2022; Smith & Nizza, 2022) designing mixed methods research by Creswell, Fetters, Ivankova (2004).	1-2-1 INTERVIEW GROUP INTERVIEW CODING ARTICLE MS LEARN COURSE
How can ballet be used in the computing classroom as a pedagogical tool			Increment 1, 3	Group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference FrameVR, Spatial.io, and Videos used for recall and input for generating 3d models (at this stage of the design) Test Learn Cards	How the participants used this is their own teaching practice. What	BALLET VIDEO QUESTIONNAIRE EEG VISUALISATION VIDEO PPE MODEL / FRAMEVR
How does this approach to ballet, choreography, and technology compare with the dancers/ choreographer's previous experience?			Each sprint: Observation after re-watching the recording	Observation via video (researcher) Test Learn Cards	Semi- structure interviews – IPA what they are saying. How this changes over time	
In what ways has DDD had on the participants experience and confidence levels when working with technology for dance.			Increment 1,2, & 3	Group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference. IPA interview analysis: 1-2-1: How do the choreographer and Program lead view the intervention in relation to the role as "educator" Test Learn Cards	Comparison of confidence levels over each iteration. Dancer participants potential independent use of the technology in the future.	Dance Technologist Education

5.6.1 Questionnaire Analysis

Survey data were analysed using the Likert scale for competency questions (Carlson & Dormody, 1994; Bryman, 2021). Videos, matrix questions, and free form response boxes that draw on video elicitation (Bryman, 2021) were also used, alongside an IPA analysis of the text data corpus. All questions included in the surveys/questionnaires were optional. As the research was conducted fully online, a substantial amount of data were collected, which then had to be safely managed, stored, and secured, see appendix 5G.

5.6.2 Interpretative Phenomenological Analysis (IPA)

All text generated from questionnaires, workshop recordings, and chats, were analysed using an updated version of IPA (Smith et al., 2009, 2021–2022). Using IPA, the researcher can acknowledge their position as an insider and use this to enhance the interpretation of data, rather than attempting to manufacture neutrality. IPA requires the separate examination and interpretation of each participant's contribution prior to seeking common patterns and group experiential themes in the data as a whole, which sets it apart from other methods of data analysis. IPA was selected as the study aimed to take participant's contributions into account as much as possible in order to design education resources that addressed the needs of

computing education, as seen by the educators themselves (Smith et al., 2021, 2009; Smith & Nizza, 2022). Appendix 11A illustrates this rigorous method in detail, highlighting the transparency and complexity of the IPA analytic process (Smith et al., 2022, pp. 151-152).

Secondary/support computation analysis using NLP with Python was employed to generate semantic meaning and analyse the frequency of word use (see Appendix 5I). This secondary analysis was conducted during the fieldwork and then compared to the researcher-generated IPA, qualitative approach. Analysing data through NLP involves sorting entire transcripts into word types and reducing words to their root form in order to recognise the frequency of different words throughout an interview, survey response, or other body of text. Python achieves the same function as R (a statistical programming language), but Python enables code sharing with the trainee teachers as additional educational resource. Python is also one of the most common languages used in GCSE Computing GCSE (AQA, 2022; OCR, 2022) and so this approach aided the development of educational resources alongside the analysis of research data.

5.6.3 Agile Analytics

Agile analytics is iterative and focuses on 'finding value in each dataset as opposed to proving a hypothesis' (Collier, 2011), making it a valuable approach to data analysis in this study. This approach prioritises value over process and allows the analysis of data as the study develops, but does not necessitate the cleaning or organisation of that data at each state. This analysis of data in an iterative fashion allows the final dataset to be refined, organised, and cleaned in an efficient, in-depth way, using formalised, theorised data analysis methods such as IPA (Smith et al., 2021, 2009).

Owing to the relatively small sample size of my study, the findings are not generalisable in the traditional sense, but they are scalable through use of Agile methods. Agile analytics is the quantitative and qualitative examination of sprint data presented in the form of a retrospective—a scheduled meeting or series of workshops designed to provide space to reflect on an entire project. This approach encourages researchers and participants to learn from both the successes and failures of a project in order to improve future endeavours. There is no set format for this type of retrospective, but it should include significant study participants (Rose, 2015; Leffingwell et al., 2018). The collaborative process of reflection and discussion occurs inside a 'safe space,' in which participants may offer constructive criticism

as well as praise. Prior to the conference, a high-level summary of the study's successes, obstacles, and inadequacies is compiled (Leffingwell et al., 2018).

In summary, the materials used in the study include documents, datasets, working code, and presentations. Each increment of the research required a distinct set of materials and approaches, and focused on addressing different areas of the research, which informed the use of different methods, materials, and data analysis techniques used.

5.6.4 AI-imagery

AI-imagery is a hybrid of AI, computational social science, educational research, and art which was employed as a secondary data analysis technique during my research. AI-imagery as analysis enabled the creation of new forms of expression and experimentation, as well as the creative analysis and interpretation of vast amounts of data. This expands the scope of data visualisation (Anantrasirichai & Bull, 2022, p. 611) pattern recognition, and even re-analysis. Findings were developed through IPA as text-to-image prompts to generate an image ML model via Dalle-2, craiyon.com, and others. Some post-photo manipulation was required to achieve the desired interpretive outcome that is representative of the findings. This promising area of research is still in its early stages (Smith-Nunes, 2023), and the images at the beginning of each subsequent chapter of this thesis were created using this technique, see appendix 11B for expand discussion.

5.7 Ethics

Data protection is critical to research in this ever-broadening field, especially after the introduction of the 'General Data Protection Regulation' act (GDPR) in May 2018, (updated in the BERA (2018) guidance in Statement 48). Advice from these guidelines and stipulations was applied to the design of consent forms and the questionnaires used in the study (see Appendix 5A and 5C). The UK Government's guidance for ethical research document entitled 'Ethical Assurance Guidance for Social Research in Government' provided a comprehensive guide alongside the BERA documentation. This government document includes a list of ethical responsibilities, referred to as principles:

1. Sound application and conduct of social research methods and appropriate interpretation and utilisation of the findings.

2. Participation based on valid informed consent.

3. Enabling participation.

4. Avoidance of personal and social harm.

5. Non-disclosure of identity and personal information. (Gov.UK, 2020).

A recent example of the utilisation of this guidance in a research field is Cambridge Analytica's use of data collected from Facebook (Cadwalladr & Graham-Harrison, 2018).

5.7.1 Confidentiality and Anonymity

Each participant created a 'boring avatar', see appendix 5B, to enable privacy and protections for the participants through labelling all data from the study, including brainwave EEG files, and finally any paper records. If any personal information must be preserved (e.g., contact information in case participants are re-tested), the key linking codes to personal details will be kept in a secure, encrypted, password protected spreadsheet. The importance of data compliance when working with personal identifiable information (PII) is at the core of research (see 5.5.4 and 2.2.2.1), it is covered by GDPR (2016, 2021) and ISO 2700 standard (ISO/IEC 27001:2022) in addition to ethics governance and data compliance of the university.

5.7.2 Ballet and Injury

As a very technical, precise, and structured form of dance, ballet is accompanied by unique hazards that do not impede other forms to the same extent, and there is a significant body of research on technological applications which may be utilised to reduce dancer injury in ballet (Clay et al., 2014, AR system; Trajkova & Cafaro, 2018, Visual & audio feedback; Vastola et al., 2016, gait analysis; Wang & Wang, 2017, home interactive learning system). This consideration increased the overall risk of this study, which was compounded by the use of the EEG headset (see Appendix 5C). However, this risk was minimised as the headset is lightweight and wireless, and so dancers could wear it without significant disruption or discomfort.

5.8 Summary

This chapter explored the methods, materials, and instruments used in this study, alongside the origins and modifications of the above where necessary or appropriate. The next chapter discusses the study design, beginning with an in-depth exploration of the first increment of research, which constituted the pilot study of this project. As no single research methodology provided adequate scaffolding to sustain the study, I developed AgileDBR as a

blended/extended methodology which permitted the crucial iterative development, design, analysis, and review aspects of the study, and the academic framework was developed only after demonstrating the congruences and affordances of Agile with DBR. The following chapters then present the analysis and findings of subsequent design iterations, building on the work and findings from this initial increment.

Chapter Six: Dancing With Data – Study Design

Figure 6.1 *AI generated art using Midjourney AI with text prompt 'dancing with data, futurism' (Midjourney Lab, 2022)*

6 Introduction

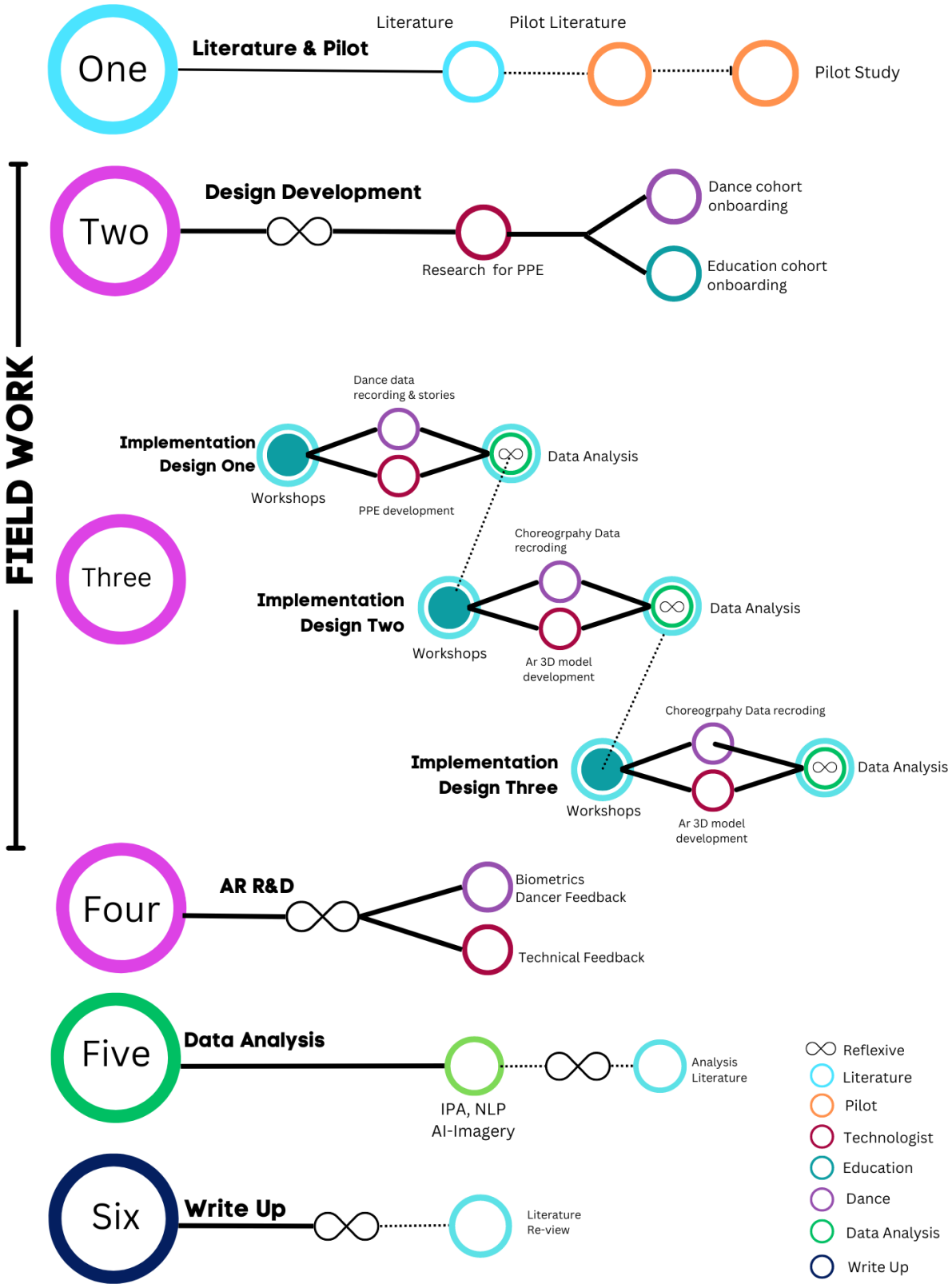
This chapter provides an overview of the specific materials, techniques, and analysis methods used in each increment and how it interacts and enmeshes the different cohorts with one another. Figure 6.2, below, depicts the overall study design, outlining the six increments as follows: (i) literature review, scoping pilot, see appendix 6A, (ii) initial design , (iii) testing design one, (iv) testing design two, (v) data analysis and findings (including a metadata analysis of all increments—a study retrospective), and lastly (vi) write up. The cyclic nature of increments and sprints leads to the iterative development of the next increment as the study develops.

The Covid-19 pandemic necessitated the shift of the study from in-person to totally online/virtual, which influenced the development and interactivity of the AR ballet. Throughout the data collection period, the technological features of the initial design were developed and interacted with the development of educational and dance materials. Working with the technologist from the beginning enabled the continual development of technological, instructional, and ethical elements of the research.

The images at the beginning of this and subsequent chapters were created using AI-imagery, and were generated from findings and observations following retrospectives and/or cohort interactions, see 11B. Images were AI-generated using Dalle-2, a web-based subscription text to image generation AI service. This is a 'Generative Pre-trained Transformer 3 (GPT-3)' model that translates natural language as written text into code, before generating and editing original images (Nakano et al., 2022). Alternative platforms were shared with participants, such as craiyon.ai (Dayma et al., 2021)

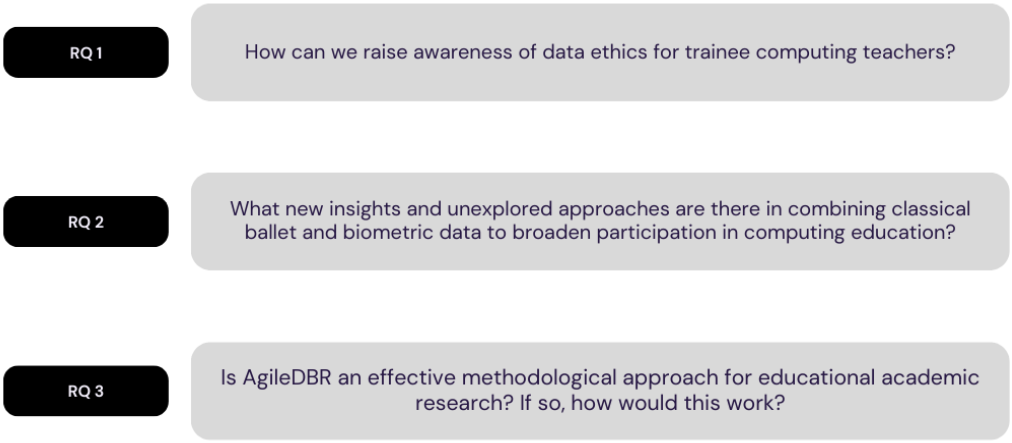
The rest of this chapter covers the literature review and the pilot study, also see appendix 6A, both of which took place before the arrival of the pandemic, and the pilot was conducted in Antigua and Barbuda. This site was part of the original study design before covid restrictions limited the study to a full online modality. Unfortunately, due to data instability this site was removed from the design. The literature is discussed across three lenses: components, context, and theory and research Ethics, (see Chapter Two). Each lens illuminated the research questions posed throughout the study, which were: (i) how to raise awareness of data-ethics, including biodigital ethics, focusing on PGCE Computing, trainee computing teachers; and (ii) What new insights and unexplored approaches are there in combining classical ballet and biometric data to broaden participation in computing education?

Figure 6.2 *Study Design – a visual representation*



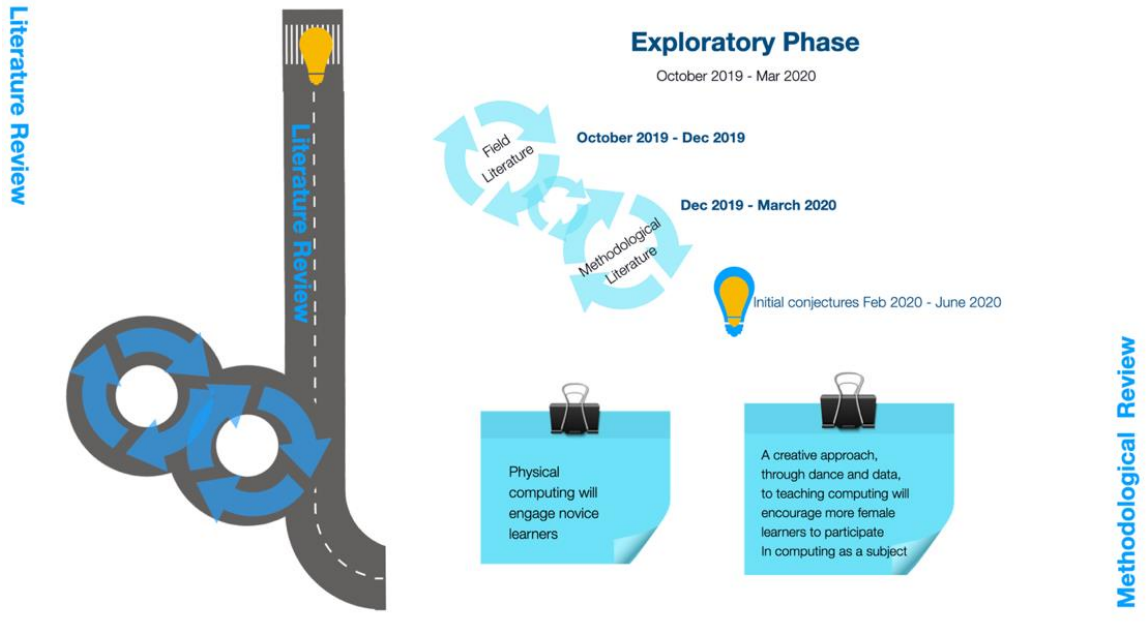
6.1 Increment One: Literature and Scoping Pilot

Figure 6.3 *Research Questions*



This pilot phase, see appendix 6A, was designed to develop and evaluate the initial conjectures drawn up in answer to the research questions, fig 6.3. This stage involved drafting and developing educational resources for use teaching novice pre-university learners in a computing classroom. Figure 6.4 illustrates the literature and background research needed when developing this pilot stage.

Figure 6.4 *Increment One: Research and Exploratory Phase*



The pilot study was conducted in person, before any Covid restrictions were in place, which differed from the main study of this thesis. Although, Antigua and Barbuda have connectivity issues and relatively high data costs, this pilot study was vital in providing insight into some of the challenges faced in the later study. The pilot offered a practical exploration of proposed materials and instruments in a low data-access environment, using participants who were novices in the specific computing activities involved. The findings highlighted a need to reduce the number of questions included in the questionnaire, but showed positive feedback on the use of emojis to depict scaled choices.

6.2 Fieldwork

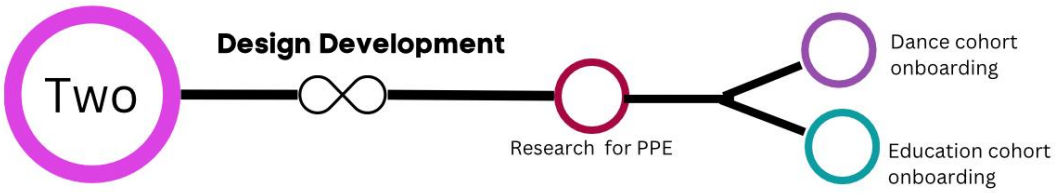
Table 6.1 outlines the timeline of contact with the three cohorts over the fieldwork period of the study, covering the period of design and testing of the educational experiences and resources across three increments. The main implementation occurred during increment three. Each educational session followed a similar three-part pattern, covering (i) ballet and computing, (ii) data and neuro ethics, and (iii) a practical element, usually a coding exercise. The efficiency and value of various features, such as videos, articles, prompts, and coding activities, were tested through this iterative method.

Table 6.1 *Fieldwork Timeline in Weeks*

Increment 2												
	Jan				Feb				March			
Weeks	1	2	3	4	5	6	7	8	9	10	11	12
DANCE												
EDU												
TECH												
Increment 3												
	April				May				June			
Weeks	13	14	15	16	17	18	19	20	21	22	23	24
DANCE												
EDU	*											
TECH												
Increment 4												
	July				August				September			
Weeks	25	26	27	28	28	30	31	32				
DANCE												
EDU					**							
TECH												

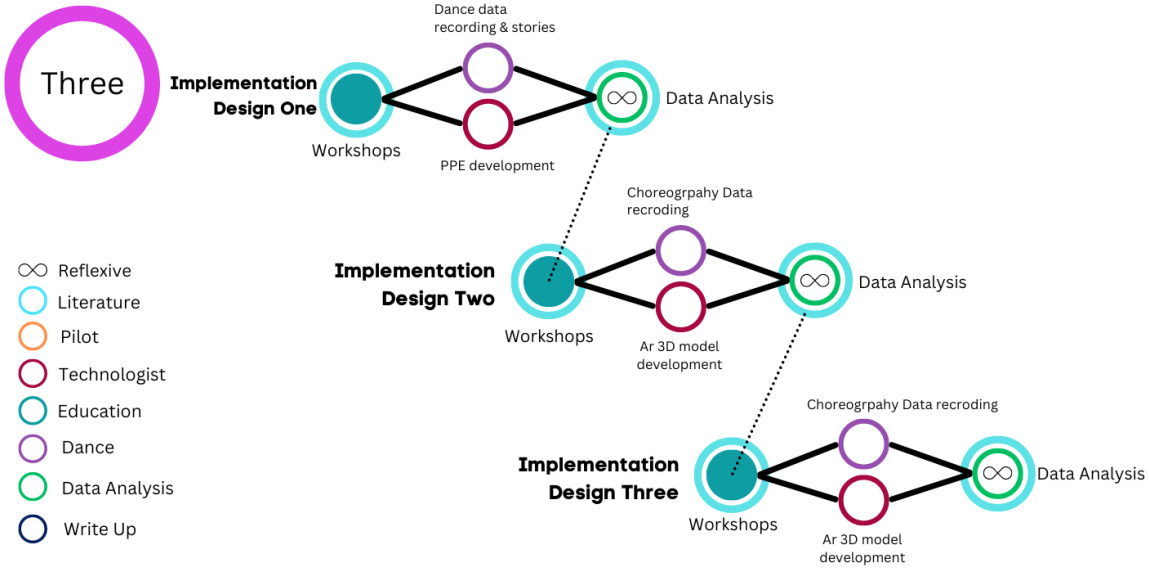
Key (owing to Covid impacts): * = loss of initial education cohort. ** = session cancelled

Figure 6.5 *Increment Two—Design Phase*



As discussed, the development of the pilot increment focused on the technical instruments to ensure that remote data capture was (i) possible, (ii) accurate enough to be used for 3D animation, and (iii) could be introduced effectively across all cohorts. Sprints 1-4 of the second increment involved working solely with the technologist to developing the procedures and software needed to be able to record and generate biometric data from the dancers, using findings and results from the pilot study to inform these subsequent iterations. Figure 6.6 explains the implementation and testing of Design One through this framework.

Figure 6.6 *Increment Three—Implementation and Testing*



Design One improves on the prior design's implementation and testing. A questionnaire was distributed to participants, week 15, to assess their knowledge of ballet and data-ethics in computing. Initial feature testing and dance data collection for 3D model creation was then carried out, weeks 13-17. Following the review of Design One, aspects of the study design, and material see 5A, were changed and improved, see humanising data 7.5.2 , such as the neuroethics element—EEG films—which was integrated into the next design iteration, week

18 (Design Two). Design Three, week 21, expanded on the coding element, with each activity explicitly related to data-ethics and/or widening participation through ballet, as informed by results from Design Two.

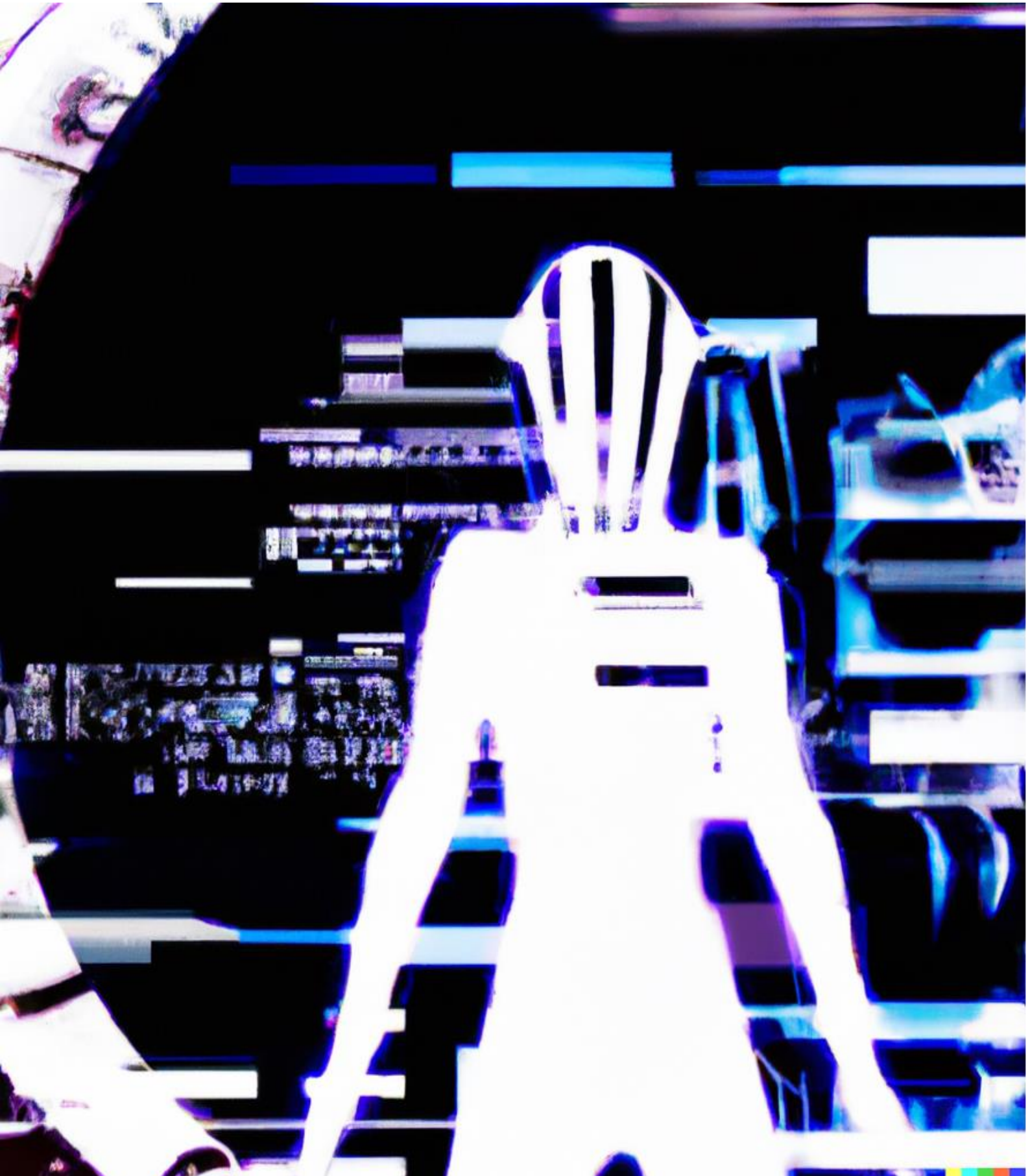
6.3 Summary

In summary the fieldwork component of this study consists of four increments: development of Design One, followed by the implementation, testing, and modification of the design over three further increments. The pilot study offered a vital experiment which tested the efficiency and effectiveness of the tools, methods, and materials proposed for use in the study, and the findings from this study were used to illuminate the initial design stages of the main study. As the research was forced to move online as a result of the pandemic, this initial test became even more vital to the success of the research, and allowed me to develop an understanding of digital methods of research and data collection prior to their use.

The next chapter includes the evolution of the initial design into Design Two, including the technical hurdles faced and how these were resolved. The design phases involved translating the highly technical concepts, code, documentation, and tools into usable classroom tools with open source or free-to-use software. I present the analysis and findings of the initial design, along with the refinement and development of these aspects over subsequent iterations.

Chapter Seven: Exploration and development of initial design

Figure 7.1 *Open.AI via Dall.E2 Generated Image with Findings Text Prompt 'immersive, technology, dancing with data, see 7.4.1*



7 Introduction

This chapter focuses on the design and development of the initial educational intervention design, see 7.4.2. That incorporated a large amount of technical and ballet knowledge and understanding required prior to the development of Design One. This chapter covers the specific tools and artefacts created to raise awareness of data-ethics for computing PGCEs using biometrics and ballet.

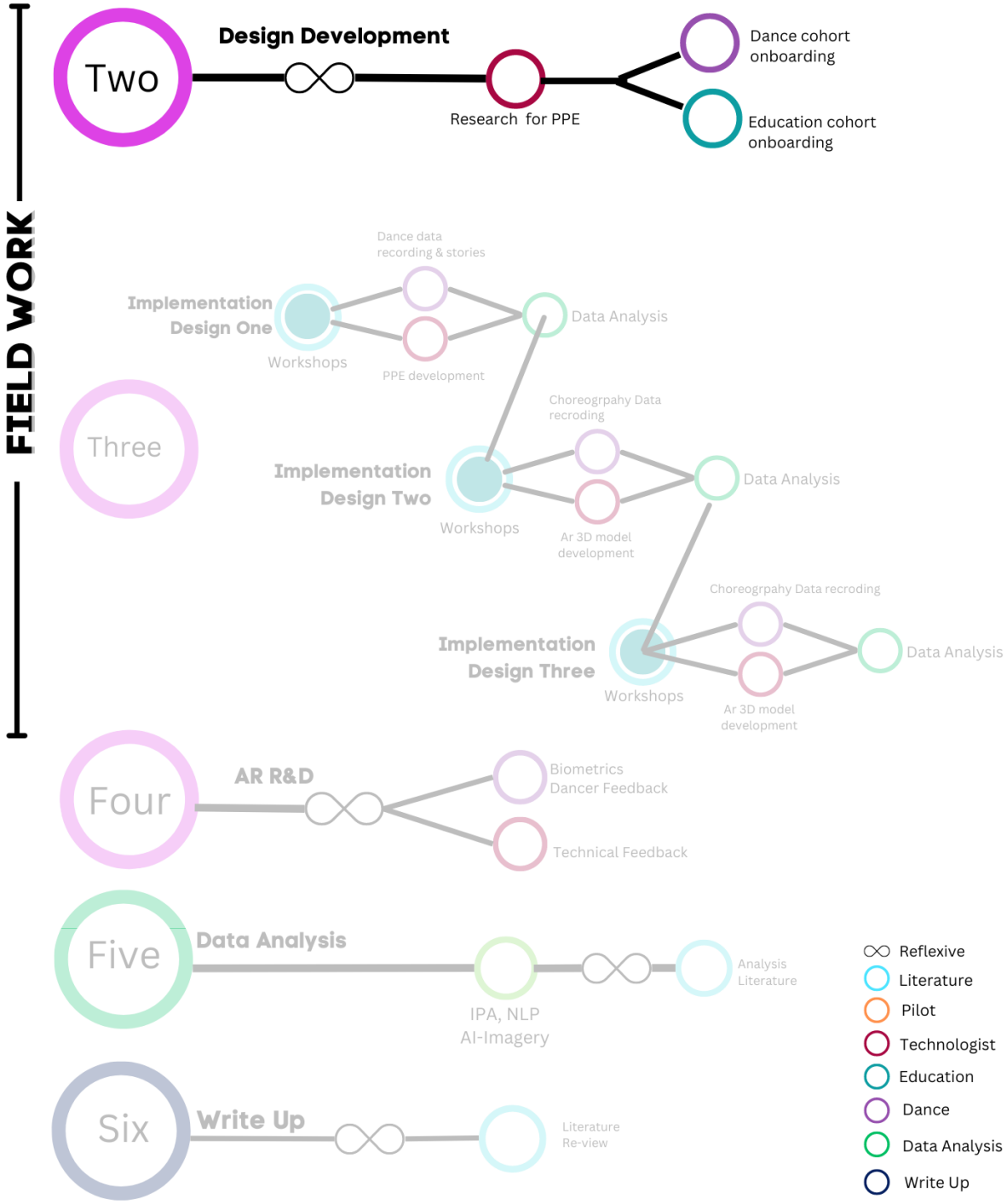
7.1 Technological development

Increment two (Figure 7.2) consisted of the following participants: the technologist, the dancers, the choreographer, and the PGCE programme lead, who collectively contributed to the initial design for the first twelve weeks of the data collection period. Data for analysis were gathered through interviews (RQs1-2), retrospectives (RQs1-3), and text interactions (RQs1-2), which are discussed in detail in the following sections.

This chapter explains technical terminology and jargon relating to the capture of human body data, generally known as biometrics (RQ1). As the study aimed to be as transdisciplinary and accessible as possible, I employed relatively non-technical vocabulary and language whenever possible, as this enabled the participants to effectively use and explain these terms in their feedback and data generation.

Transitioning from in-person to virtual modality required extensive research, as it represented a significant departure from the existing and planned tools used in the study. The first four weeks focused on finding the best tools for performing post-pose estimation in virtual settings.

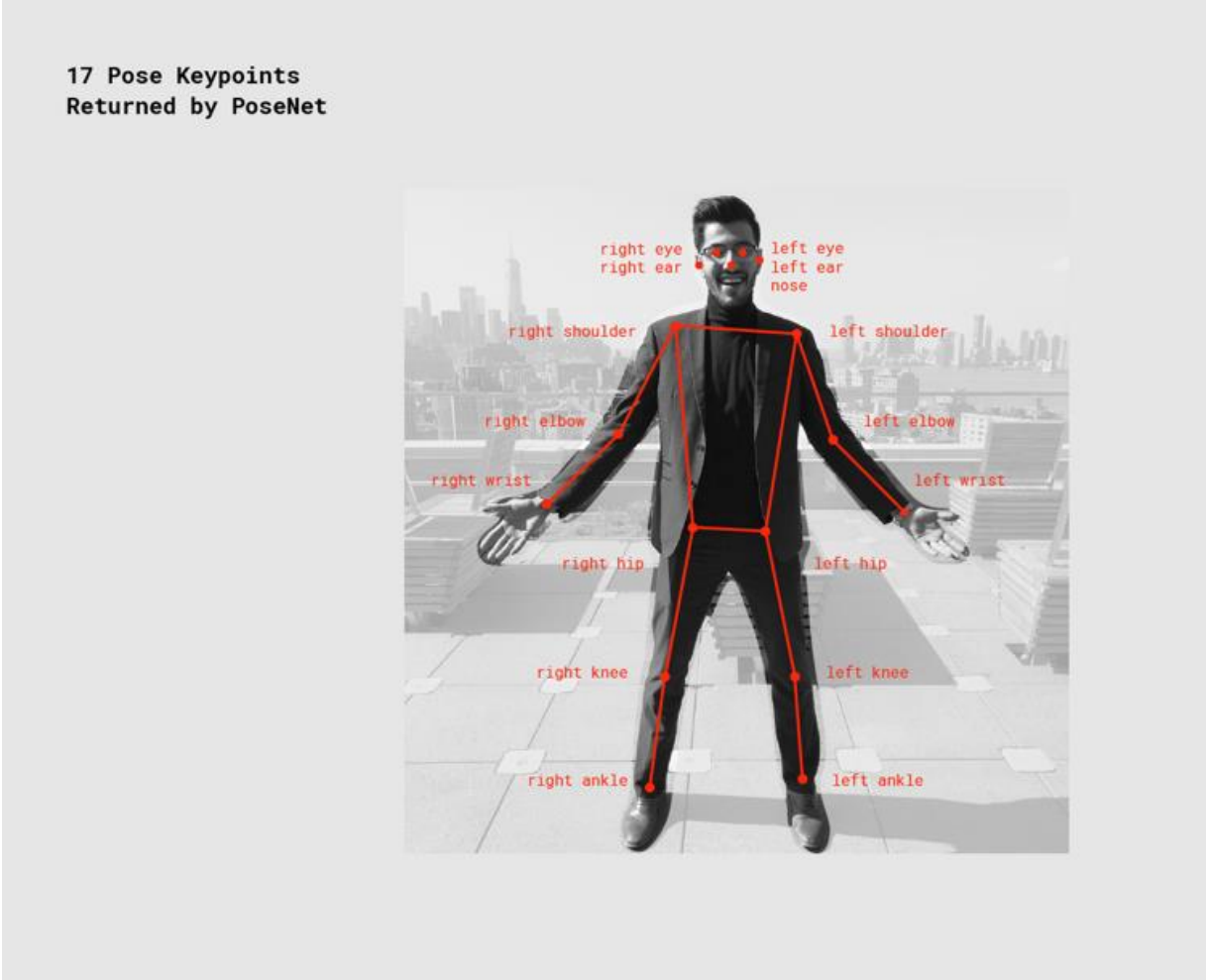
Figure 7.2 *Increment Two–Study Design*



One technical challenge posed by the PPE model was the need to capture the full foot, not just the ankle, in data, as is acceptable in other models such as OpenPose, MoveNet, PoseNet, DCPose, DensePose, HigherHRNet, OpenPose Lite, AlphaPose, and TransPose. As none of these alternative models included foot and ankle articulation at the time in which my study was developed (early 2021), PPE was found to be the most appropriate model for use in

classical ballet XR, which relies on the full movement of the body and all joints, especially when using pointe work. Figure 7.3 provides an example of PoseNet skeleton tracking, which crucially does not capture the foot or hands in detail.

Figure 7.3 *Posenet Keypoints. Note–No Foot or Hand Tracking* (*Oved, 2018*)



Ballet posed additional challenges, including the speed of rotation and leg position. The speed of the rotating human body when performing pirouettes requires more data, meaning that video must be recorded at a high frame rate—how many individual frames (single images) can be recorded per second, more frames mean more detail. Many ballet steps position the leg in line with the head or at an upward angle behind the dancer.

Figure 7.4 *Dancer in Arabesque Position on Demi-pointe (Image from [data]storm, 2015)*

Figure 7.5 *Dancers Performing a Penché* (*Image from [pain]byte, 2017*)

Figures 7.4 and 7.5 illustrate the challenges posed by these complicated leg and/or foot positions during an arabesque on demi-pointe (Figure 7.4), or performing a *penché* (Figure 7.5). These images are taken from [data]storm, (Figure 7.4) and [pain]byte (Figure 7.5) (Smith-Nunes et al., 2015, 2018)

Owing to the way many PPE models are trained, their training datasets do not include classical ballet data (Zhang et al., 2017). This means that the PPE model does not recognise the limb and joint positions presented in ballet data (at the time of initial research), as they do

not match expected outcomes. As of the end of 2022, many PPE models can now capture rotational movement data with full foot and hand articulation.

7.1.1 Technical Development Over Time using AgileDBR Documentation.

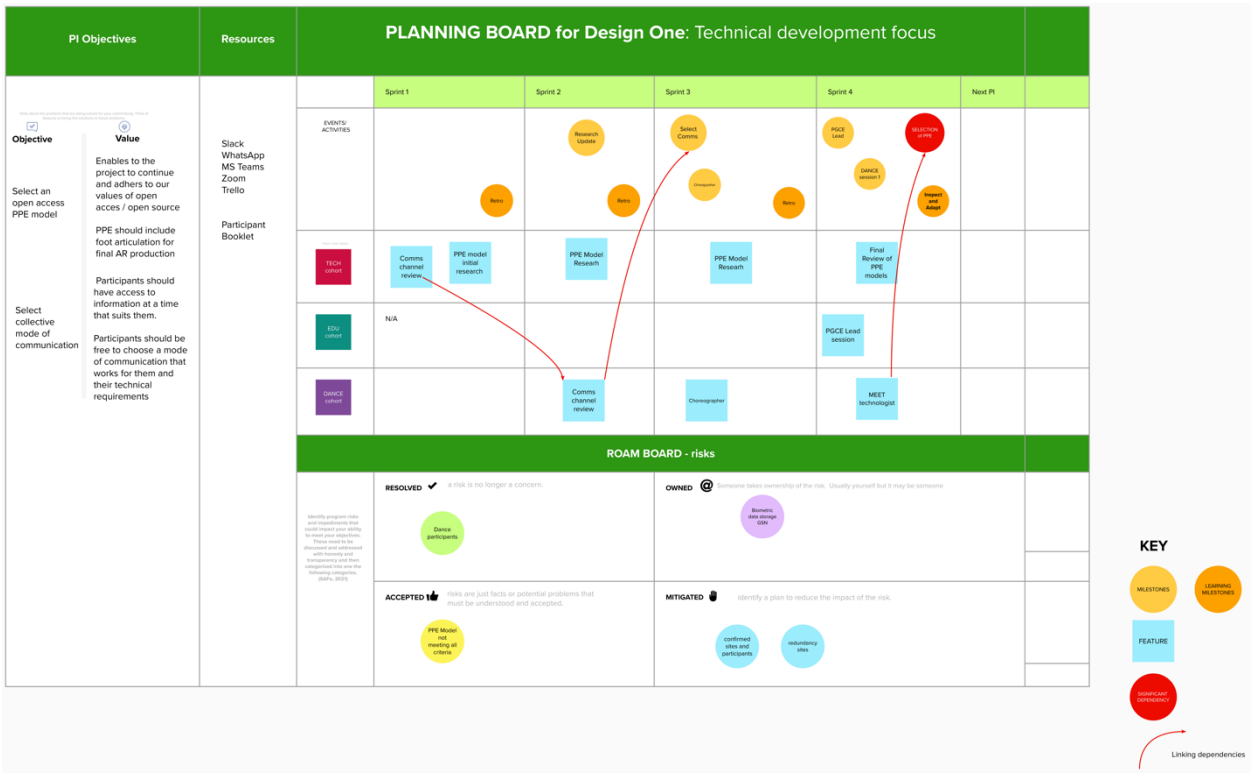
Many DBR studies discuss analysis and findings as milestones of design changes, whereas my AgileDBR approach uses milestones over time at both a micro (individual sprint) level and a macro (increment) level.

As this increment focused on the research and selection of an appropriate PPE model, there were only two objectives for the Planning Increment (PI): (i) the selection of a PPE Model, and (ii) the selection and implementation of the most appropriate communications channel as decided by the participants. The only viable, accessible model at the time for completing the first objective was MocapNet (Qammaz & Argyros, 2019). Multiple platforms were selected to address the second objective: the technologist used Signal and Slack; the dance cohort used WhatsApp and email; and the education cohort used Microsoft Teams and email. It was important to be as flexible as possible with participant channels of communication to reduce any barriers to access or participation.

The Planning Increment (PI) board set out in Figure 7.6 covers a 12-week period incorporating all the elements needed to achieve the technical, research, and theoretical requirements of the study. The increment principles/objectives used are similar to conjectures in DBR. The board includes the expected materials, the timeline of development, and the planned period of reflection, and offers a snapshot of planning expectations for the increment. This allows future work to track the actual progression of the study against its design, explaining any modifications made to the process.

The selection of the PPE model prior to the first session with the dance cohort was a major positive influence of the progress of the increment, highlighted below by the thin red connecting arrows.

Figure 7.6 *The Planning Board for Technology Focused Increment*



7.1.1.2 weeks One-Four

The selection of MocapNET (Qammaz & Argyros, 2019) and subsequently MocapNET2 was due to the inclusion of the specific positioning of feet and hands that occurred in Week Four. Weeks One–Four focused on testing and discussing each model in turn against set criteria to find the most appropriate and useable model for the bulk of the research.

The discovery of this suitable PPE model enabled full foot and hand articulation data capture which was vital for the progression of the study. Videos for MocapNET, created by the developer (Qammaz & Argyros, 2019), provided supplementary materials for both the education and dance cohorts, which explained how the model captured skeleton data in non-technical language. Additional videos from TensorFlow and PoseNet models were also shared. Data-ethics concerns were discussed in most, if not all, retro/review sessions.

The sprint planning and review board (Figure 7.7) gives an overview of the planning and the retrospective/review which took place in Week Four (see in particular the bottom right section.

Figure 7.7 *Sprint Planning and Review Board*

INCREMENT: Technical Build	SPRINT: Find a PPE ML model that works with feet
SPRINT GOAL: Select a suitable PPE ML that includes feet	
Conjecture being tested: PPE model with hand and foot capabilities will lead to improved 3D development and connection to the biometric data **Description:** (1) Find a useable PPE ML model that works with feet. (2) Free or opensource if possible **Goal:** ***Selected a specific model that meets the requirements of the AR ballet***	
METHOD: Which artefact, validation techniques, and test group are used?	
Artefacts/Materials: Internet and computer processor(s) needs to be fast enough run the ML models. **Delivery**: Researching github and other repositories alongside academic publications to locate any PPE models that had work with some form of dance or had an articulated foot.	
DATA / REVIEW: how do you determine if or how the sprint goal (conjecture) has been met or not?	
Baseline metrics: The location, review, and selection of a PPE model **Observations**: N/A **Interviews:** N/A **Video**: weekly meeting	**Review:** MocapNet was found to be the most suitable with foot articulation and free access to the ML. Add test MocapNET to backlog for next sprint **Retrospective:** The process was effective but communicating with the ML experts at this stage would have speeded up the selection process.
ETHICS	
Ensure that the recording of the data from the PPE Model is only accessible by the research study team. Ensure MocapNET model data is only accessible by authorised individuals	

The next four-week block covered testing of the MocapNET model, which was an important element not only for development, but also to explain the technical challenges when computing educators work with ML models.

7.1.1.3 Weeks Five-Eight

The purpose of Weeks Five–Eight was to put the chosen PPE model (MocapNET) to the test by figuring out exactly how and what dance data needed to be recorded to produce useable results. I constructed a set of rules for the dancers that could easily be transferred to any school or dance studio, which ensured that data were collected in an efficient, useful manner. I investigated specific technical issues that computing educators might confront in their own classrooms that arose from this process of recording data. These issues included: (i) the full body of the dancer needed to be kept in the camera frame, including extremities, to ensure clear data capture for the PPE to extrapolate joint data; and (ii) the elevated frame rate, which needed to be 60 FPS (frames per second) to ensure that MocapNET could generate accurate skeleton data. More frames per second improved the data error rate. When on Zoom with the dancers, I was able to ensure that their whole bodies were included in the recorded frame, but when the dancers recorded themselves, it resulted in several instances of movements rotating out of camera range or not accurately facing the camera.

Following this data collection, the translational code was developed, which took the information from MocapNET—mapping correct joint connections and rotational planes—and aligned it with anatomical placements in the digital avatar versions of the dancers. This phase also included the establishment of procedures and further training sessions with the dancers to improve full-body recording, in order to create a functional prototype for use in educational contexts.

7.1.1.4 Weeks Nine–Twelve

Weeks Nine to Twelve covered the creation and testing of the 3D model from 2D video dance recordings. Technical challenges relating to ballet movements caused errors in matching joints to limbs in the PPE model. These errors highlighted the need for an addition to the development pipeline: new script (code) to translate output from MocapNET to an expected/industry standard 'rigged character' format was added to combat this issue. The errors, although frustrating, gave real-world stories that became part of the educational instructional material. Table 7.5 shows the main goals of this stage, which were to create an MVP of a 3D dancer model for use with educators and to test the software development pipeline. These are very technical issues relevant to the computing classroom, as programming is challenging both to teach and to learn (Guzdial, 2019).

By week twelve, there was a near-working 3D prototype model (see Appendix 7a), but errors still persisted when certain ballet movements were performed. The complexity of the PPE pipeline prompted the decision to use a different tool set with the education cohort in order to retain the simplicity and useability of the framework in educational contexts. The selection of P5.js was made based on its ability to perform PPE and render it to the screen, while not recording detected data, which meant that teachers could use the tool without recording biometric data. This was made clear in the ethical code of practice, terms and conditions, and learning materials of both P5.js and ML5.js—the ML model for human post-pose estimation (Dacanay et al., 2021). Table 7.1 highlights the features and conjectures tested during this iteration.

Table 7.1 *Features—Conjectures for Design Phase*

Feature(s) being tested		Conjecture/Purpose	RQ
	1-2-1 Interview(s)	Interviews with participants will explore data-ethics within various contexts. The interviews will provide insight into data-ethics awareness from different vantage points: Technology, Computing education, and dancers' perceptions and awareness.	2
	Group Interviews	These formed the baseline knowledge for developing the questionnaire and initial intervention design. Collaboration with the Technologist, dance cohort, and one PGCE lead will lead to the effective initial design of the questionnaire for trainee computing teachers along with materials for Design One.	1,2

The following sections discuss the analysis of interviews undertaken during the design and development of educational data-ethics resources. A series of interviews led to the following principal themes: (i) movement as knowledge; (ii) humanising data; (iii) meaning through data; (iv) the PGCE curriculum landscape; and (v) barriers.

7.2 Overview by Cohort

This section discusses the interviews conducted with each cohort that fed into the development of the initial research design. Below is the technologist's self-selected icon/avatar. The cross-functional nature of this increment offered specialised guidance in technical development and training to fellow collaborators from the technologist. The PGCE lead excelled in sharing their curricula understanding and highlighting the challenges for both the secondary classroom and for the trainee teachers. The Dancers contributed their ballet expertise, delving into its synergy with computing and subsequently sharing their insights gained from the experience.

Technologist

The data gathered from the technologist were collected over the course of the increment from recordings of retrospectives and an in-depth interview which occurred in Week Twelve. From the technologist's data corpus, the main Personal Experiential Themes (PET) which arose

were (i) divergence–convergence, (ii) meaning through data, (iii) understanding the ML model, and (iv) non-inclusivity (of the tech scene) drawn from many PESs.

When collecting data from the dance cohort, it was critical to record not just their biometric data but also their reflections on and reactions to the data capture method and subsequent sharing of their personal biometric data. The topics of the group interviews were analysed using IPA, with data from video session transcripts, text data, and Trello updates, where they affected the design of the instructional intervention.

The choreographer and dance participants' self-selected icons are included below:

Choreographer

Dancers

The group interview with the dance cohort was conducted in order to gain an insight into their human reactions to the sharing of identifiable personal data. Three main questions were given as prompts during the interview: (i) Is there a difference in sense of self (identity) between the human and the virtual? (ii) How does sharing your personal biometric data make you feel? (iii) How do biometric data and immersive tools aid in raising awareness of data-ethics?

PGCE programme lead self-selected avatar:

Interview areas with the programme lead were: (i) What is currently happening in the interviewee's own PGCE Computing secondary programmes in relation to data-ethics? (ii) What is the value of data-ethics and its place within computing education? (iii) How could dance, specifically ballet, be used within the PGCE programme for teaching coding and raising awareness of data-ethics? Although each institution may provide varying answers to these questions (as each university provider creates their own unique PGCE curriculum based on the teaching standards and the core subject structure), it was interesting to include this perspective to inform the general principles of future studies alongside my own.

Another significant aspect discussed during the interviews was the biometric data requirement of this study, covering two technical areas: (i) the selection of the MocapNet (PPE) model, and (ii) the process and data capture requirements for the EEG brainwave data. This period of collaboration provided clear guidelines on what and how to explain the technology to a non-expert audience. The ethical implications of recording and storing biometric data acted as a constant throughout the study, and ongoing discussions centred on these themes during data collection in relation to both the technologist's and the dancers' data. I ensured that data were secure at all times and that all participants were happy to share each dataset before proceeding with each iteration.

7.3 Understanding Ballet in Relation to Post-Pose Estimation

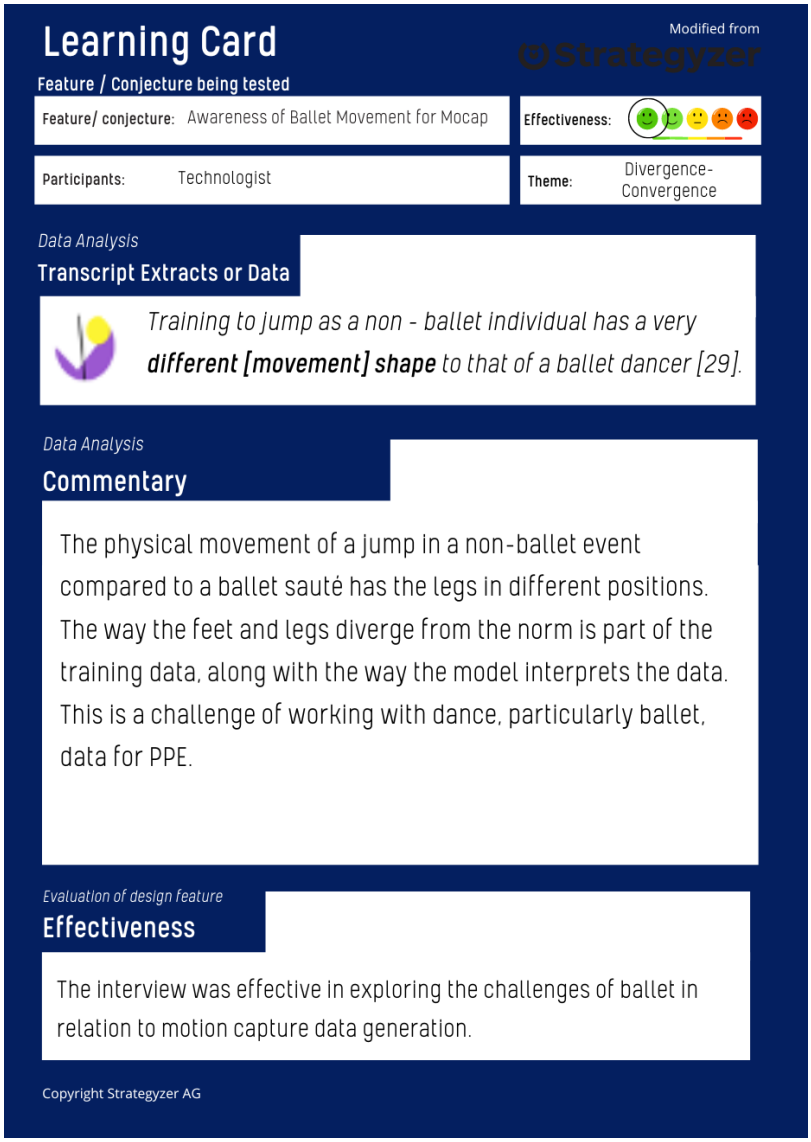
Figure 7.8 *Test Card—Awareness of Ballet Movements from Motion Capture*

Figure 7.8 presents an understanding of how ballet movements impact PPE development, which may lead to future awareness in (i) dancer body positioning with the recording frame, and (ii) mitigating development pinch points such as occlusion (Cheng et al., 2019) and frame rates .

The interview with the technologist illustrated the understanding needed for the technical and pragmatic challenges for ballet dancers when generating motion-capture through PPE. Ballet movements diverge from what could be considered as normal, everyday human movement, as movement in ballet is about making a specific, clear expression through the body, similar to functions in coding.

7.3.1 Divergence-Convergence

Figure 7.9 *Learn Card—Understanding Ballet Movements for Motion Capture* [*voice data*]



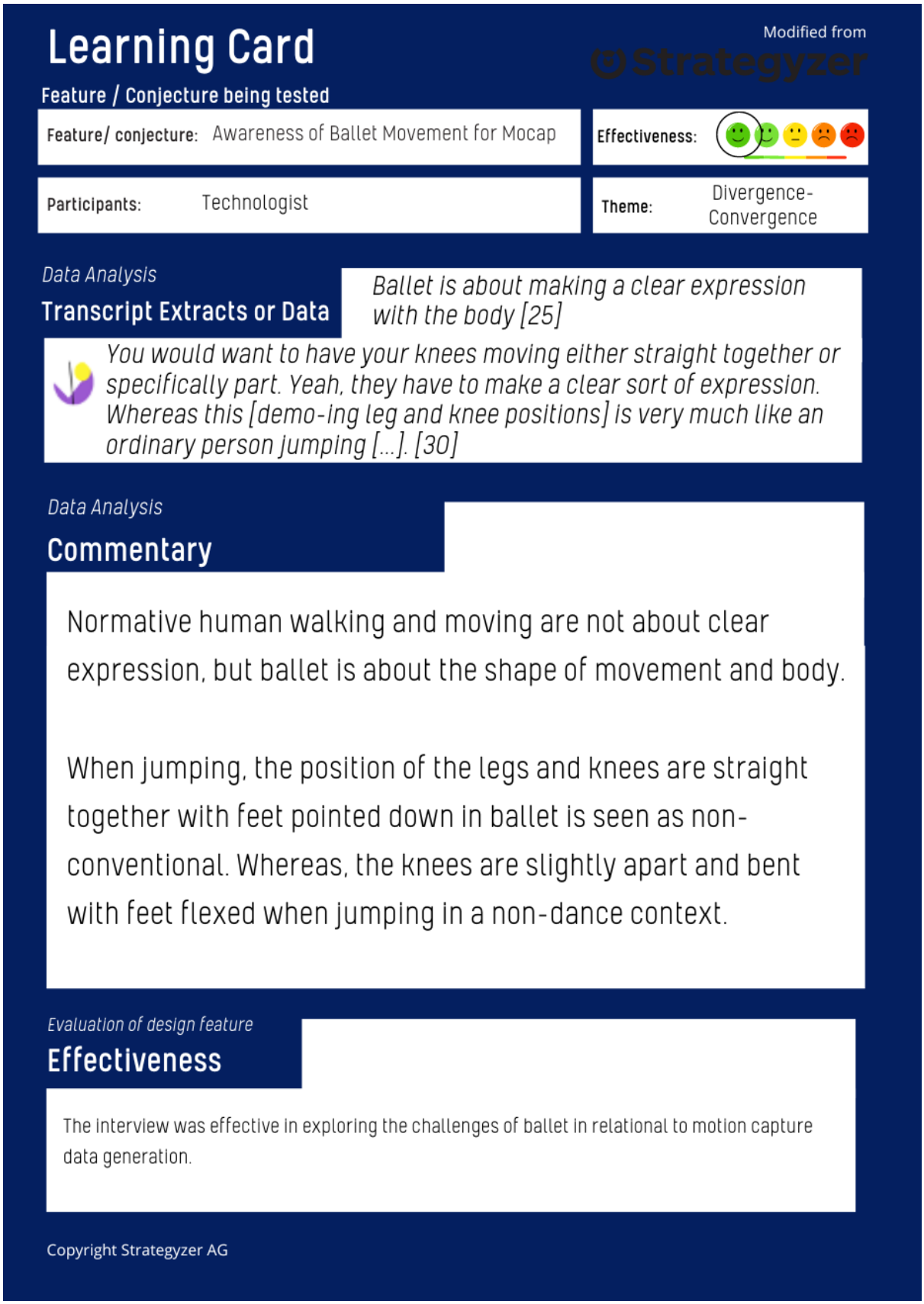
There are both conscious and subconscious elements to this movement. Movements in ballet are deliberate, different, and specific, and are constantly learned, trained, and retrained to achieve the maximum skill level. To achieve this level, however, ballet dancers' movements must become automatic, and therefore subconscious, once choreography is learned and internalised. There are two sub-themes to this issue raised: (i) conventional and non-conventional movements, and (ii) the convergence of computing with classical ballet.

7.3.2 Conventional and Non-Conventional Movements

Ballet consciously diverges from conventional movements, and as such, ballet dancers do not move in ways that aligns with ML PPE models' training, see Figs 7.4-5, p.170. For example, a kick upwards into the air (a grand battement) is a common movement in ballet which places the foot above the head, but the PPE model then realigns the hip joint to either the shoulder or the head, not accustomed to witnessing this movement in normal human motions. This posed several developmental challenges for the study design, but also sparked interesting questions and discussion points in the sessions with the technologist.

Figure 7.10, below, highlights the notion of non-conventional movements in ballet and their impact on data recording. It also illustrates the challenge of this activity from both a programming and learning (teaching) perspective. The repeated use of the phrase 'clear expression' emphasises how ballet movements were seen as shape and statement making. Non-conventional movements are, however, not the problem; these ML models merely lack the ballet/dance training data needed to teach them how to correctly map joints to limbs in this context.

Figure 7.10 *Learn Card—Divergence: Non-conventional Movements and Expression [voice data]*



7.3.3 Machine Learning Model

Because the MocapNET model did not employ ballet dancers as training data, the technologist had a strong urge to 'retrain the model' during this investigation, and noted that the model did not recognise the movements 'because it's never seen a human do this before,' which solidifies the limitations of using this model. These errors highlight the challenges of using ML in computing education, but these challenges can be overcome. Many XR performances are not using PPE, but instead use multiple-camera motion capture with depth sensors. This differs from using 2D video, as depth sensors improve the accuracy of limb-to-joint data. The voice extract explains how motion capture, which includes the PPE process, sees the human body as a structural object, a technical or data body:

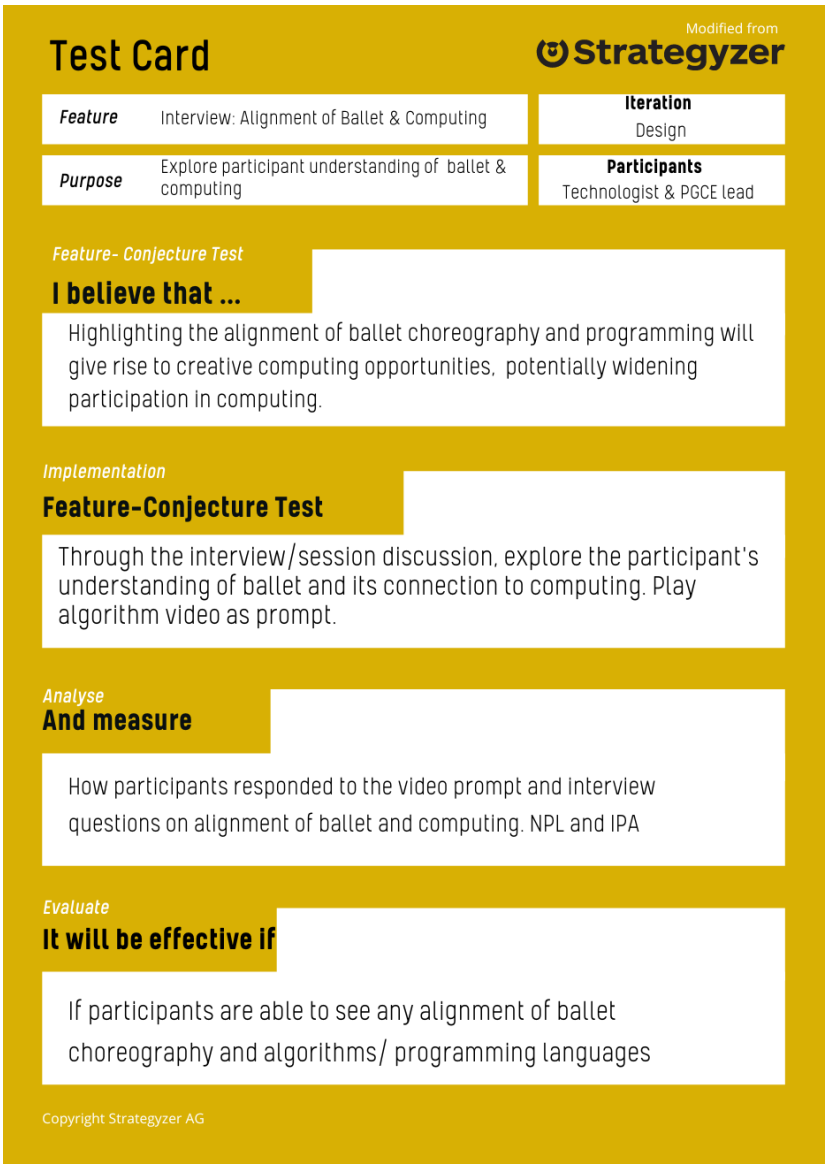
> *So, it's kind of like the technical side of sort of what's* ***a normal body****? And so obviously, because it's been* ***trained on people*** *who have four limbs that* ***move in the normal way, plus a head that moves in a force of norms*** *along with it.* [37]

The technology states that to limit these inaccuracies, the training data that affect the post-pose estimate model must be retrained on ballet data. 'Occlusion' was the primary error—this occurs when one object in a 3D environment blocks another object from view, thus making it difficult for the computer to distinguish between them or recognise that two objects are sharing a 3D space.

7.4 Ballet and Computing

A key requirement of this research was to investigate the alignment between computing and classical ballet (alongside awareness of this alignment), and its potential for widening participation through the use of DataDrivenDance. To this end, a series of interviews were conducted with participants, using video prompts to elicit their understanding of this alignment. These video prompts engaged participants in a thoughtful and reflective dialogue, and enabled me to gain a deeper understanding of the potential of using DDD in the computing classroom. Learning and themes which developed from these interviews are presented below through (i) convergence–divergence, and (ii) movement as knowledge-somatic.

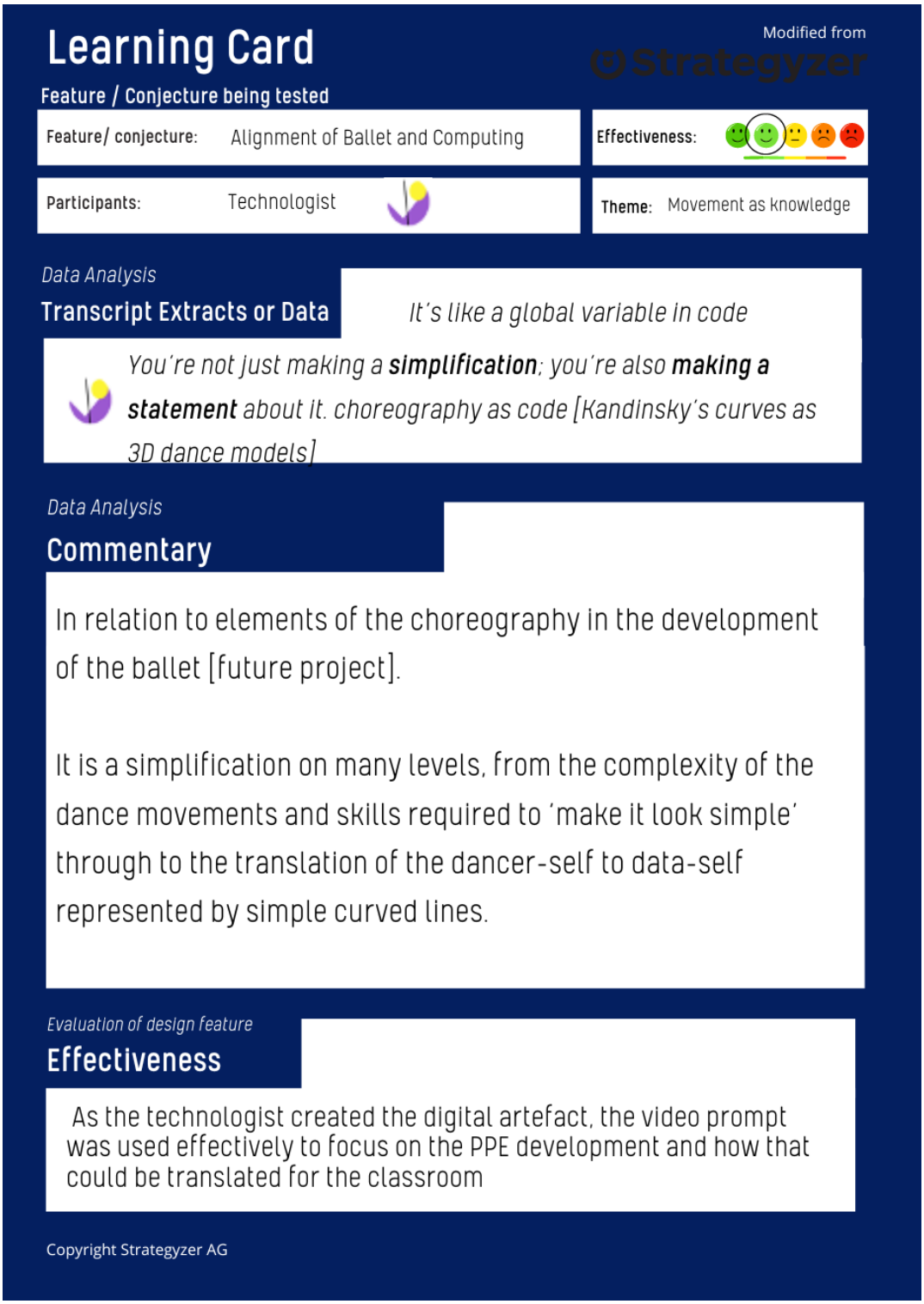
Figure 7.11 *Test Card—Alignment of Ballet and Computing*



7.4.1 Convergence: Computing with Classical Ballet

Discussions regarding choreography with the technologist (who had previously taken ballet classes) drew on computing to describe their thoughts about ballet shapes and movements. This sparked the idea of employing Kandinsky's curves to describe dancer data transmission '*dancing with data'* over intergalactic distances for AR output, see figure 7.1. They discussed how ballet provided a 'clear type of expression.'

Figure 7.12 *Learn Card—Convergence: Computing with Classical Ballet [voice data]*

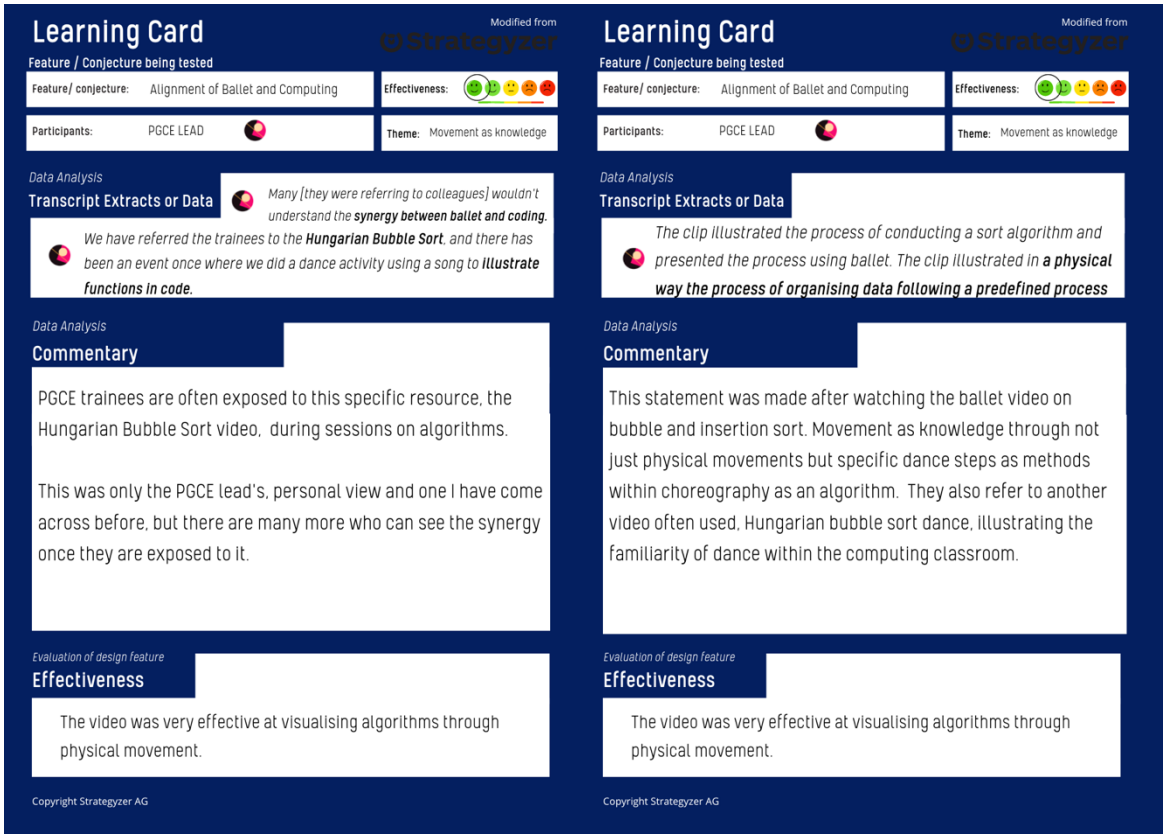


The divergence and convergence displayed in Figure 7.12 illustrates how the technologist viewed the technical parallels of ballet and computing, which converged through expressions such as 'choreography as code.'

7.4.2 Movement as Knowledge – Somatic

This theme specifically relates to dance and movement as a form of knowledge transfer, and explores how the PGCE programme lead understood and interpreted the role of ballet within and for the computing classroom. Dance is part of the PE curriculum, and the idea of movement as knowledge, under **cross curricular opportunities** was discussed during the interview. The convergence and divergence of computing and classical ballet is important in looking at the potential of using ballet in computing education, as well as in raising awareness of data-ethics through videos, biometrics, and the alignment of these two distinct fields, figure 7.13. The somatic knowledge transfer occurs through ballet movement and the alignment of choreography and code.

Figure 7.13 *Learn Card—Alignment of Ballet and Computing* [*voice data*]



7.5 Meaning through Data

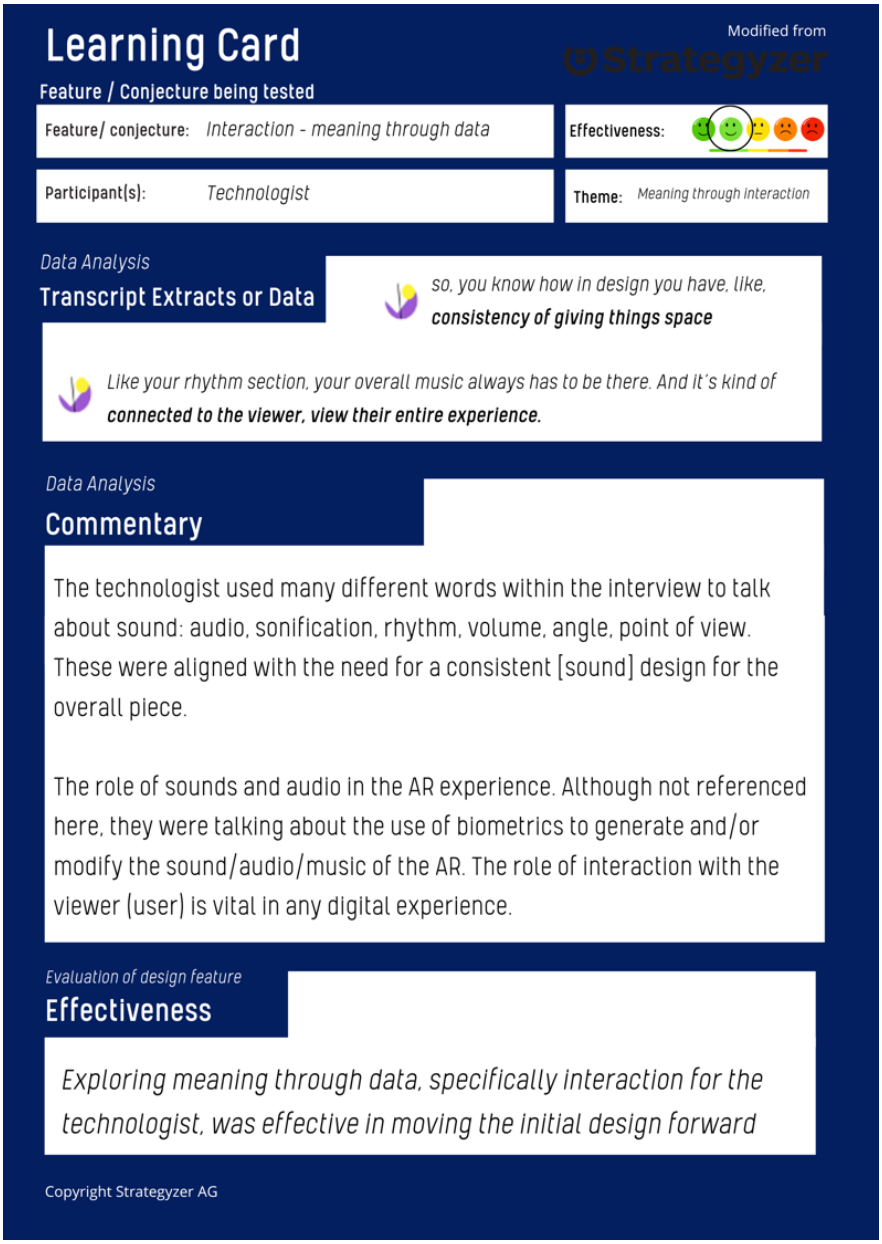
Data can be used in a variety of ways to produce or develop meaning within a digital artefact, such as an interactive web app or an AR experience. Several distinct ways of understanding 'meaning through data' developed during the interview with the technologist, including interactive, visual, and auditory means. These differed from those found in the group

interview with the dance cohort, which focused on the sense of identity in the data and dancer self as affected by this data collection.

7.5.1 Meaning Through Interaction

The technologist presented various ideas through which one may make meaning out of data, including the use of sound interaction between experience and viewer and creating rules of interaction to govern these experiences. Figure 7.14 illustrates the technologist's, spoken, views on meaning through interaction across the whole process, from design to data collection.

Figure 7.14 *Learn Card—Meaning Through Data* [*voice data*]



Interaction with and through data-generated sound/visuals was critical for the technologist to make sense of the data. The voice extract in Figure 7.14 exemplify how the technologist's learning, comprehension, and research of computer complexity was brought to life through participation in the production and output processes.

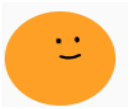
The viewer's interactions (either passive or active) with an experience inevitably influence the meaning they gain from that experience. This creation of meaning is a purposeful act by the developer to allow the spectator to explore and, to some extent, have agency within the confines of the constructed experience. The technologist phrased this phenomenon as follows.

because there's ***interaction*** *which is predicated on* ***the rules of the universe****. […] And then the* ***stuff which is outside of the rules of the universe*** *like, you know, like touching a snowflake or something, and* ***causing an effect*** *to happen deliberately. This will be good for showing the dancers and teachers. [voice]*

7.5.2 Humanising Data

The purpose of the group interviews with the dancers and choreographer was to explore their human stories of what it means to share one's identifiable biometric personal data. Two main questions were given as prompts during the interview, which are outlined below, along with the [voice] responses from the participants.

Q1: Is there a difference in sense of self (identity) between the human and the virtual?



'*There is a difference–- human self is authentic, but virtual self is part of your identity'*

Through ML and AR tools that manifest and visualise the virtual self, the abstract concept of the biometric (as hidden data) lived experience was rendered concrete and tangible. This gave participants the ability to make the invisible visible, which also provided learning opportunities for data-ethics awareness. As a result, the data and human selves were equally authentic for the participants.

Q2: How does sharing your personal biometric data make you feel?

I think I should be concerned about it but I don't know enough about it to understand why'.

A recurring topic throughout these conversations was 'concern,' which was often accompanied by inadequate understanding of the risks or how to navigate them, as shown here. This gap in the general public's education is attributable to a lack of exposure or

attention given to data-ethics in classrooms or dance studios, which has not accompanied the rise of or rapid advancements in technology. The participants were unable to clearly articulate their understanding of data-ethics, of their EEG or skeleton data, or how best to protect themselves in the digital world, which emphasises the need for an increased awareness and focus on these vital skills within education.

7.6 Data-ethics for PGCE Computing

PGCE programme lead's interview excerpts revealed their perspectives on data-ethics for PGCE Computing and the curriculum at the time of the research. Figure 7.15 is an extract from one of these interviews, which focuses on ethical standards involved in training computing teachers. The extract also suggest how trainee teachers may be confronted with data-ethics during their placements. The numerous areas mentioned demonstrated the topic's complexity.

Figure 7.15 *Exploratory Notes, see appendix 7B for accessible text* [*voice data*]

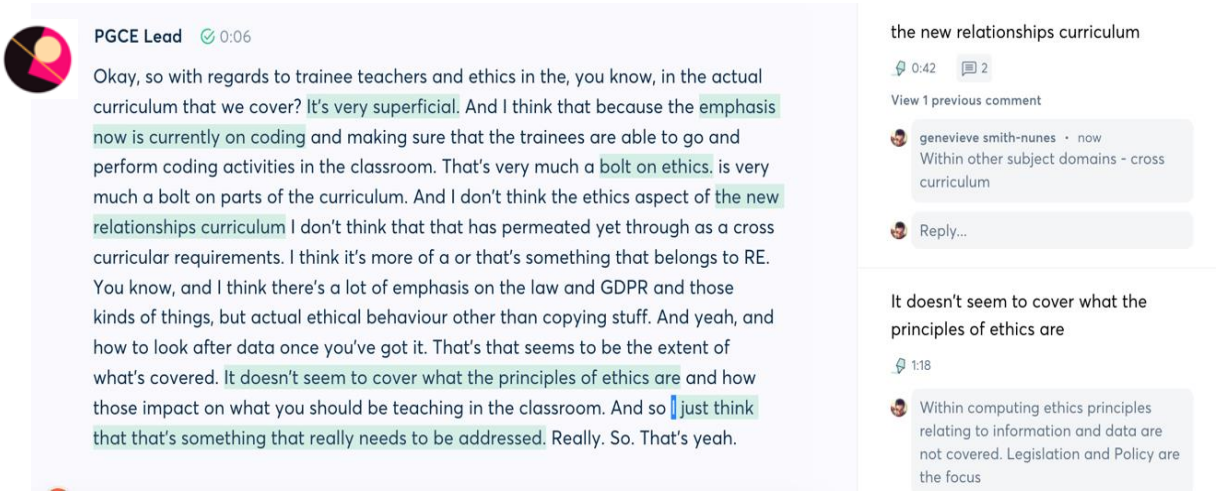


Figure 7.15 illustrates the initial exploratory note and sense making in the IPA process. The participant explained their personal lived experience of the role of ethics and data-ethics in the PGCE programme. This interview served as the foundation for the original design of the instructional materials, which include personal experiential statements as a way to humanise and contextualise the data in real-world scenarios. Prior to the workshops, the programme lead reviewed workshop materials to ensure that they met their institution's delivery standards and would have a positive impact on the workshop participants and wider educational field.

7.6.1 Bolt-on-ethics

Figure 7.16, below, highlights the problems experienced by the PGCE Computing programme lead in relation to data-ethics in the PGCE Computing curriculum. Terms such as 'ancillary,' 'superficial,' and 'bolt-on' note the low priority given to ethics in these programmes. The programme lead noted how a lack of data-ethics in the PGCE curriculum would have a knock-on impact, as teachers who were not taught about data-ethics during their foundational training phase were unlikely to teach it in their classrooms.

Figure 7.*16* *Learn Card—Bolt-on Data-ethics* [*voice data*]

The PGCE programme lead stated that computing educators should understand and know the fundamentals of data-ethics which are currently '***omitted by examining bodies***.' Though there are some aspects of data-ethics covered as part of the GDPR training, '***largely as a topic area it is not addressed***.' Clearly, then, there is a pertinent need to expand the general understanding of data-ethics for computing that goes beyond the legal aspects to include philosophical and ethical discussions.

7.6.2 Data Ethic as a Core

As a reflection of the rapid growth and development of technology generally, computing as a discipline is always changing. The PGCE Computing programme lead suggested that data-ethics should be made a crucial, core area of study for both PGCE Computing teachers and by extension the GCSE and A-Level students they then go on to teach. Making data-ethics a fundamental, core part of these modules and subjects would ensure its continued development and attention alongside technological developments, and would ensure that future generations remain aware of the risks of digital learning/existence.

Figure 7.17 *Test Card—Data-ethics and PGCE Curriculum*

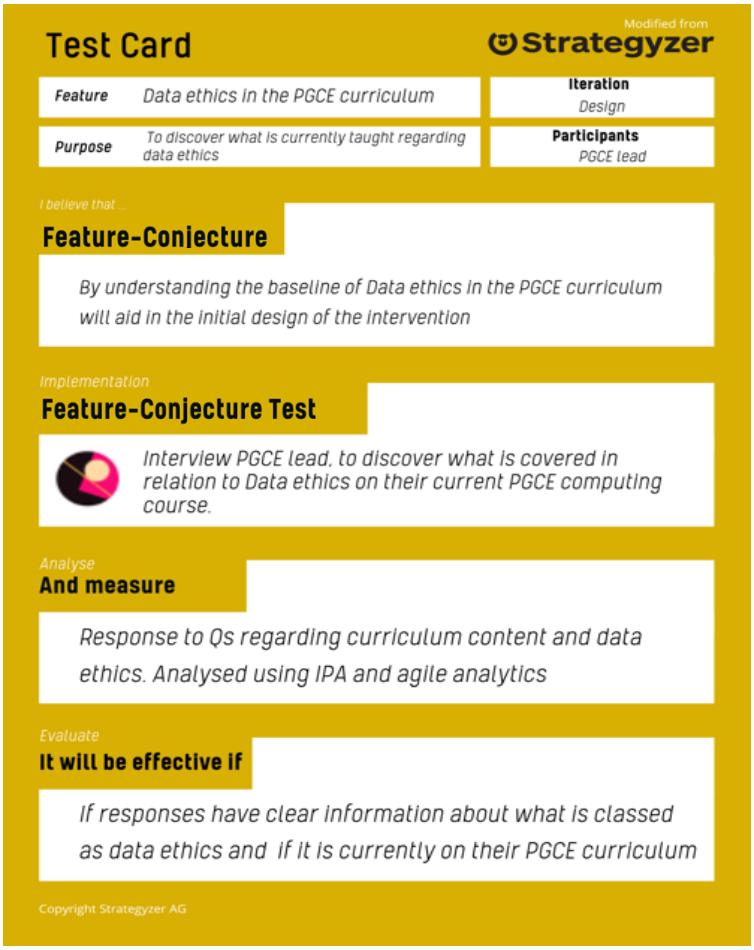
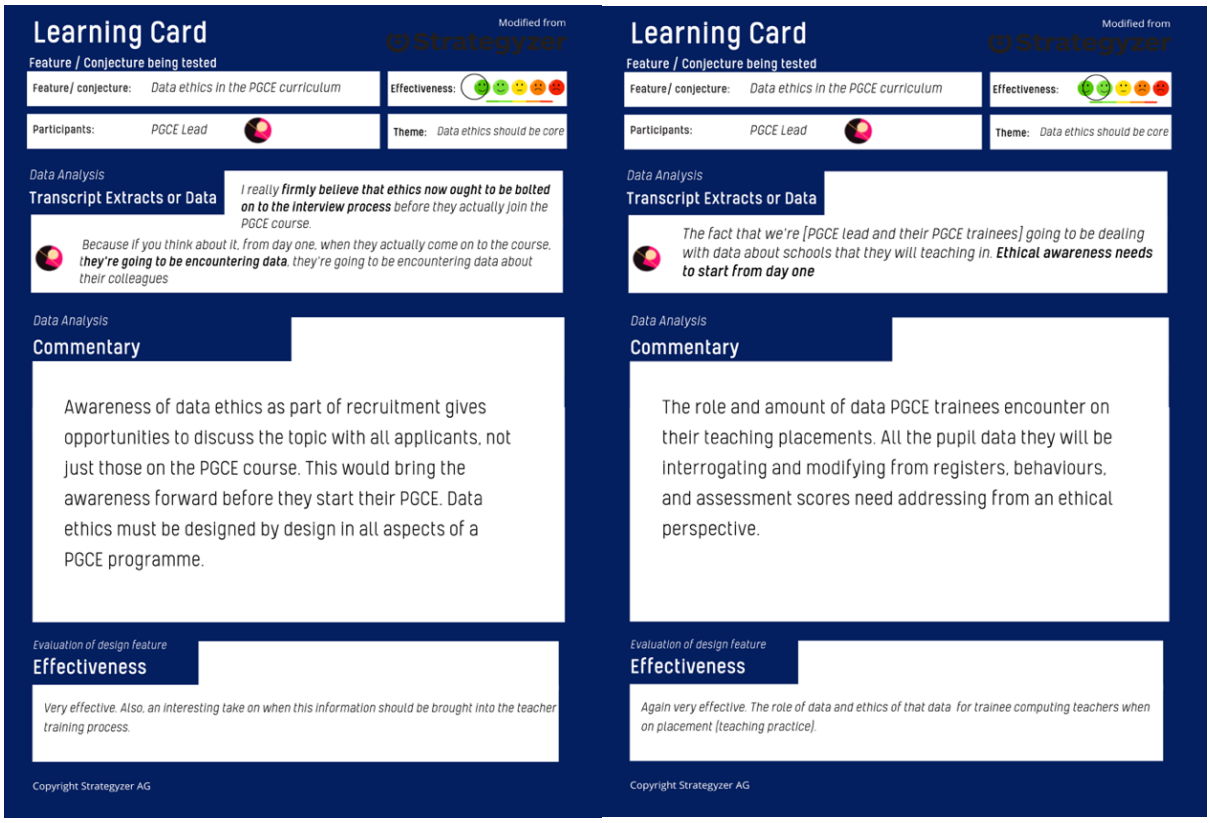


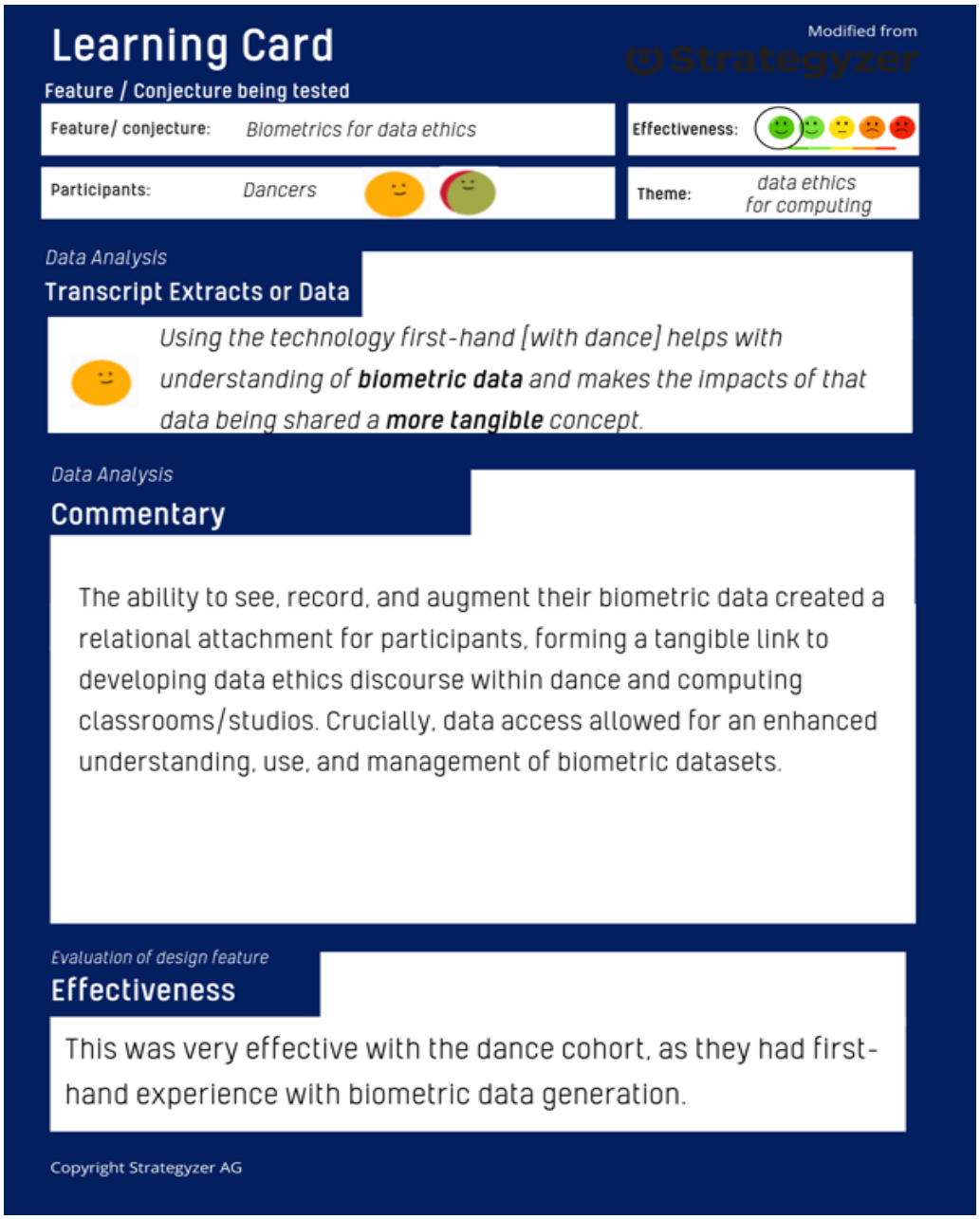
Figure 7.18 *Learn Cards—Data-ethics [voice data]*



The Learn Cards, Fig 7.18 illustrate PGCE lead's awareness of the current **lack of data-ethics content within their current PGCE** course (RQ1).

The dance participants experienced data in tangible ways by engaging in and utilising biometric data through embodied practises. Fig 7.19 below, achieved through the use of kinetic sensors or webcams to generate skeleton tracking, such as P5.JS with ML5. Additionally, the Emotiv™ EEG headset for brainwave data capture**.**

Figure 7.19 *Learn Card—Biometrics for Data-Ethics* [*voice data*]



As discussed above (Figure 7.19), it was evident from interviews with the PGCE Computing programme lead that there was some awareness of the need for data-ethics among their trainee teachers, but that this was limited. The dancers' tangible experience of recording and using biometric data raised their awareness of data-ethics, as through reflection and feedback I was able to explain this topic and their thoughts and opinions on their own data security clarified as a result. I now turn to a discussion of the barriers and constraints faced during the research.

7.7 Barriers

The main barriers in my research fell into three distinct categories: (i) licensing and access to software; (ii) content and design, including government guidelines and frameworks to which my study must adhere; (iii) limited time for all participants, but particularly for the PGCE Computing teachers. I discuss these three areas in detail below.

7.7.1 Licensing and Software usage

MoCapNET's software licencing states that 'no alterations are allowed,' which meant that I had limited access to the MoCapNET model code for use in this study. This posed a challenge as I could not correct specific defects that occurred owing to the nature of ballet movements as different from normal human movement. It was critical to get access to training data, since this significantly influences algorithm performance, and would have allowed me to train a model on ballet rather than normal movement and reduce errors. While many models are open access and therefore free to use, they cannot be freely adjusted. This limitation meant that developing my own neural network was outside the scope of this study, and, due to MoCapNET's technical complexity and licencing concerns, I chose a different ML model for teaching with the education cohort.

7.7.2 Tech – Not inclusive, Not new

Feedback from the weekly retrospectives, particularly in joint sessions with the dance cohort, revealed that participants perceived tech as 'not inclusive.' This was somewhat expected, as my research aim to explore the possibilities through DDD as potential pathways to **widen/broaden involvement and participation** in computing was developed in light of this commonly held perception. It was crucial not to edit or modify the study to be more inclusive, as this would give false results and would not work towards changing the wider problem.

Although the lack of inclusivity in tech was predictably not a recurring subject in feedback from the discussions with the technologist, it was still an important idea that needed consideration across all areas of the study, and they provided evidence of seeing this exclusivity within their field. In one interview, the technologist recalled an event involving an online community in which some individuals were unaware that their online behaviour was not inclusive to all members.

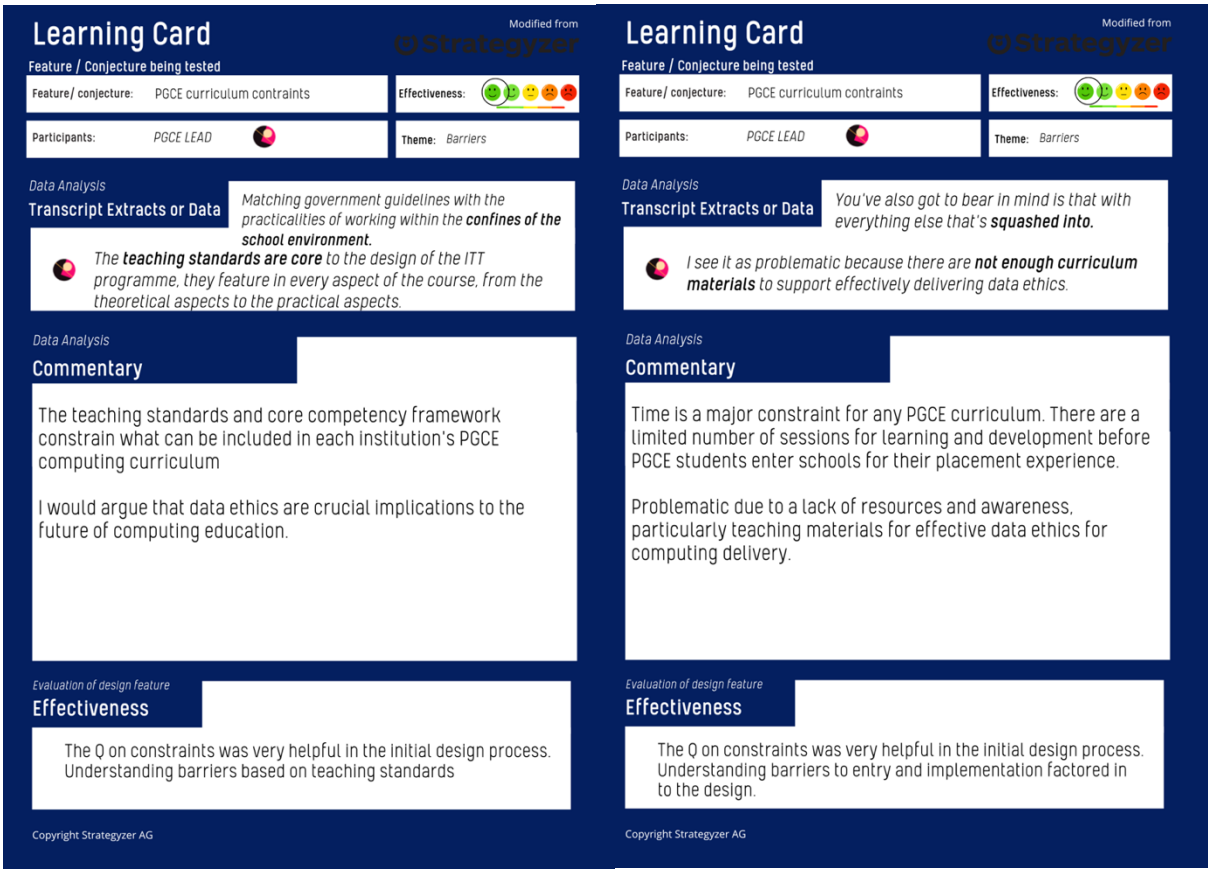
‘[…], you know, some great people are coming in [to the community]. [but] There’s also like some **really terrible sort of racist, misogynist**, [pause]. Yeah, that was somebody is not getting when they, when actually[they] are the problem in this case, the problem was, somebody who’s just like, why can’t we include people with all different opinions, and it was like, we tried doing that **all the women and LGBT people left**. And it’s like’ [they] I’m being inclusive.’ It’s like no, no you’re not.’ [some content deleted for community privacy concerns] [voice]

This extract exemplifies some of the challenges of inclusivity in tech environments for online/digital communities, particularly when the anonymity of the screen may be used as a shield for defence as well as attack. The above example occurred over Discord, a messaging app commonly used for gaming, but this is a widespread issue, and Gillespie (2018) discusses content moderation in Facebook groups that are ‘interwoven algorithmically, individuals hiding behind their profiles or avatars’ (Gillespie, 2018, p. 127). Some social media apps such as these include moderation during live, online events, and this language, through both voice and text, can be **non-inclusive for certain groups in society**, leading to a narrowing of participation.

7.7.3 PGCE Constraints

Figures 7.20 and 7.21 outline the main constraints for the PGCE Computing cohort, which mainly consisted of time, awareness, and instructional materials used to develop their teaching around this subject. To mitigate these constraints, where possible, PGCE trainees **need to be given opportunities to explore and raise their awareness of data-ethics**. Teachers would then have a good comprehension of the subject matter if this issue was covered during the initial training period, including guidance on how to best develop teaching materials and resources. With the caveat that each PGCE course design must ensure that it meets government guidelines before larger themes or content are added

Figures 7.20 and 7.21 *Learn Cards—Constraint [voice data]*



Additionally, the PGCE lead also spoke of the Agile methodology, iterative learning, and the constraints trainee teacher had, especially with regards to access to explore current research

> … if you think about Agile as well. In terms of initial teacher training, there needs to be a space where you can respond to most recent developments and at the moment, they don't have that space until February. And that's because the I've already failed their first placement by then. [voice]

The PGCE lead's focus revolved around the spiral curriculum in relation to constraints on components included in the PGCE curriculum due to time constraints of the program. Consequently, this prompted connecting Agile methodology and iterative approach towards capitalising on learning opportunities.

7.8 Summary: Inspect and Adapt

The expertise provided by the technologist (who also had vital experience of working with non-experts) enabled clear instructions and explanations to be developed for all participants in this study. The prior experience of teaching novice programmers that the technologist had informed the development of educational resources as part of the study, and was a crucial element in teaching PGCE teachers how to present complex or novel ideas/technologies to new audiences in an inclusive, understandable way.

The collaboration of the technologist, the education cohort, the dance cohort, and myself resulted in Design One. Together we also developed materials, explanations, code, and data stories specifically designed for use in computing classrooms, and this multi-disciplinary approach sought to ensure that these resources were fit for purpose and covered a wide range of perspectives and considerations across the disciplines.

The PPE pipeline toolset implemented enhanced the skeleton tracking software capabilities to create a rigged 3D digital avatar. A simple spreadsheet of EEG data was produced alongside for visualisation/sonification purposes. Note that the neutral nets, ML, and PPE models used in this study have not been analysed in accordance with traditional data science methods. Nonetheless, it is important to acknowledge the work on PPE models and associated impediments to this study.

Inspect and adapt is a key phase in the design-development cycle, undertaken after every iteration of the study, in which the researcher reflects on the process in light of the aims and objectives, and develops areas for improvement. I used this approach in this study when considering which model to use in my specific ballet context. The main objectives were to select an appropriate PPE ML model with foot and hand articulation, and to select appropriate communication channels for use with the different cohorts. Both objectives were met, but the process presented issues for the next increment of technical development. The initial PPE model functioned as designed, but was challenging when producing an AR ballet experience. However, the development of a working basic model, an MVP, was sufficient for the purposes of this study. Drawing on the interview analysis, divergence and convergence fed into the educational increment, offering a human perspective on the technical development of these types of products alongside the use of a different toolset for the education cohort. Through selecting appropriate communication channels, I was able to share video and EEG

data effectively and securely online to widen participation and inclusion in the study and raise awareness of data-ethics simultaneously.

7.8.1 Update Conjectures

The two conjectures that informed the first design were that computing teachers would enhance their knowledge of data-ethics by engaging in DDD modalities, and that DDD would creatively enhance trainee computing teachers' knowledge and modalities for widening participation in computing education. The next Increment focused the following areas: (i) trainee computing teachers need specific (data-ethics and PPE) knowledge and terminology to raise awareness of data-ethics (ii) explored and discovered of alternative less technical tools for teaching students about PPE, which could be implemented into teaching or the curriculum more broadly; (iii) the technologist's perspective on the alignment of the fields of ballet and computing; and (iv) the insight and refinement of dance data capture led to the development of specific protocols for recording the dancers' data, which should be studied and implemented in the development of any resources or materials for teaching.

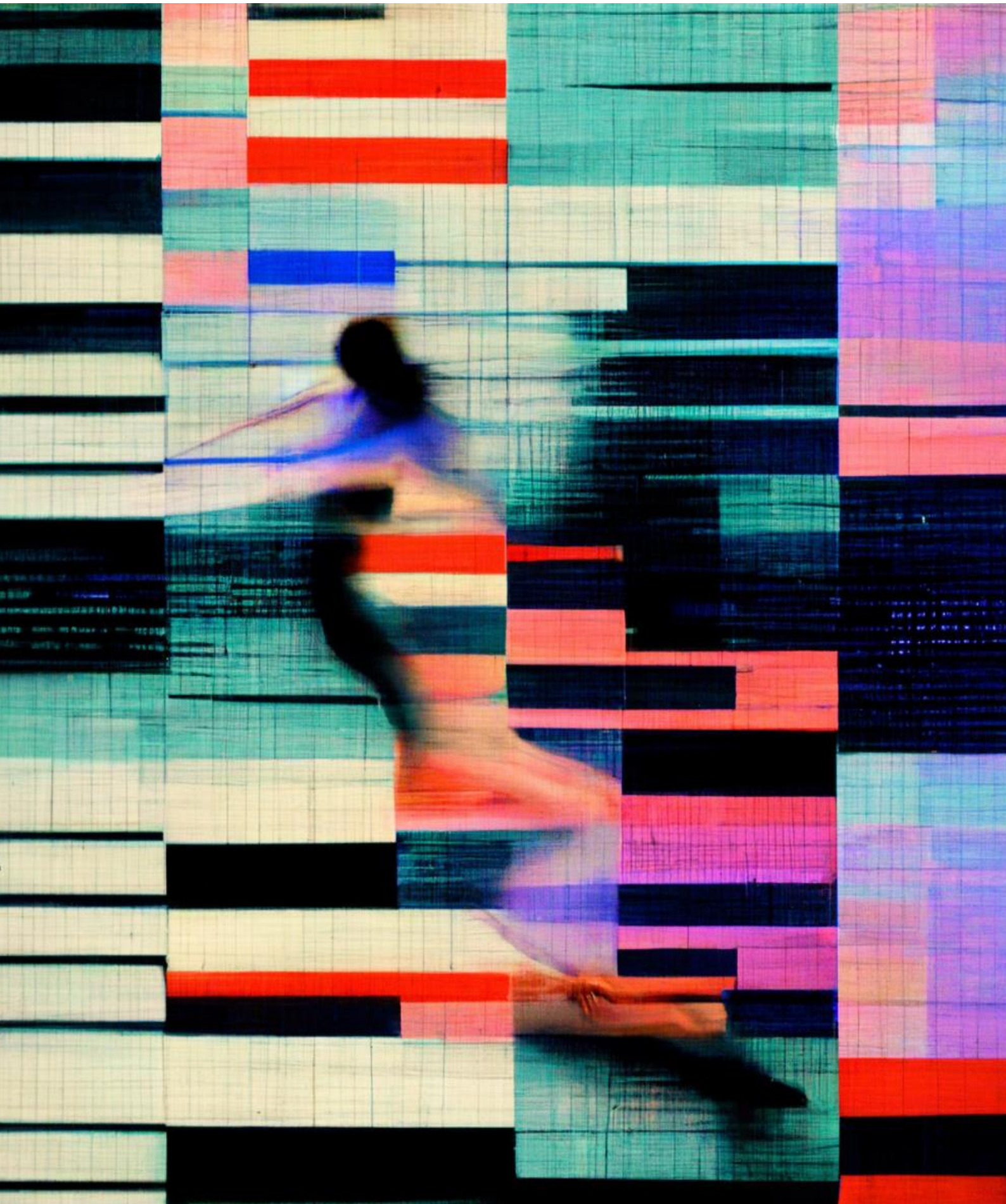
The divergence and convergence of ballet and computing provided the potential additional modality for teaching and learning within the computing curriculum. Making meaning with data allows computing educators to investigate data-ethics using programming and huge dataset activities such as sonification, visualisations, and text analysis.

7.8.2 Initial Design One

This first increment focused on the technical needs and requirements of exploring the use of biometrics in computing education. Mechanisms were developed to humanise the datasets in order to facilitate discussions regarding awareness of data-ethics. The kaleidoscope of perspectives provided by participants facilitated the initial design of the data-ethics education intervention. Key takeaways: (i) That training/education and awareness of data-ethics are crucial in the digital world. The participants saw virtual and human selves as equally real, highlighting the need for better instruction in this area. (ii) The importance of teaching trainee teachers about data-ethics, which is a complex topic. Unfortunately, there is currently not enough emphasis on data-ethics in the PGCE curriculum, as examining bodies do not include it. While the use of biometric data in physical practices helped participants understand data-ethics, there are still (iii) barriers and limitations explored in the implementation of Design One, next chapter.

Chapter Eight: Testing and Implementing of Design One

Figure 8.1 *Chapter Image Dalle2: findings prompt 'Collaboration, Dance, and Data'*



8 Introduction

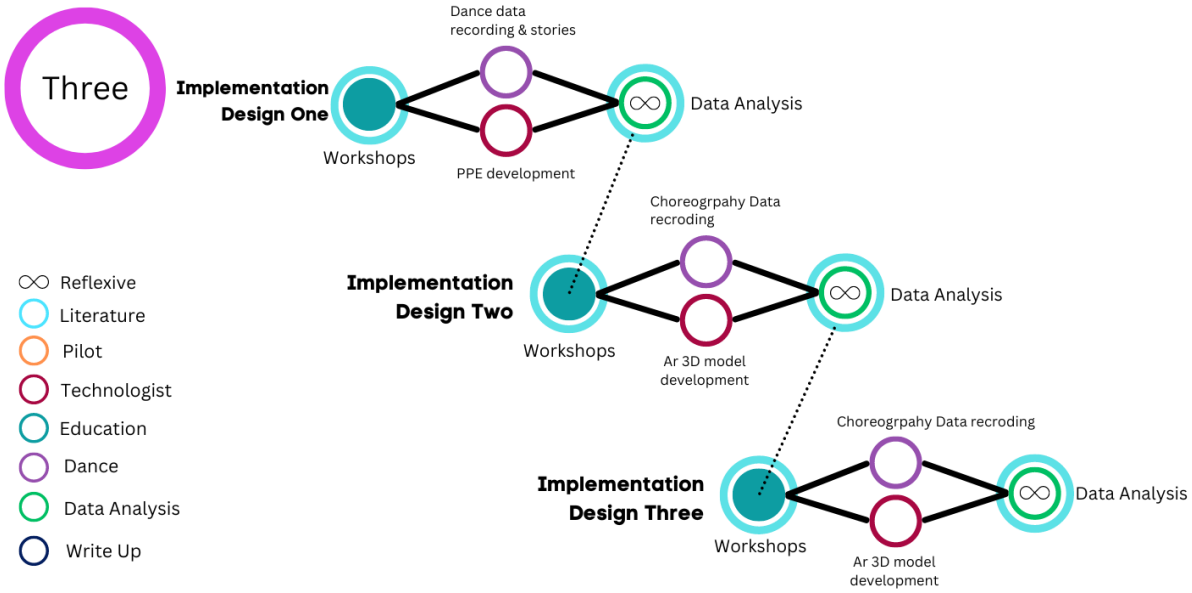
This chapter is split into three main sections covering the implementation of Design Iteration One, the analysis (consisting of the survey and IPA analysis), and the evaluation and summary of findings for this iteration. Figure 8.1 was generated via Dalle-2 from my own observations following the workshop activities, which explored skeleton biometric data with P5.js. As Dalle-2 is a subscription-based service, a free open access alternative, craiyon.ai, was shared with participants (Dayma et al., 2021).

Design Iteration One was delivered online via Microsoft Teams, as requested by the participants and necessitated by the pandemic context of this study. Video recording of the sessions and the production of an audio transcript ensured that all voices were captured and could then be analysed at a later stage. The dance and technology cohorts recorded and processed data for the development of the 3D model prototype throughout this iteration, while the education cohort were involved in creating the initial baselines of awareness of data-ethics and exploring ideas about how ballet could be used in computing education to widen participation, both of which directly addressed my main research questions.

The purpose of Design One was to understand what the participants already knew about data-ethics within a computing classroom context. The uniqueness of PGCE Computing courses was evident through conducting this research, as different teachers had different levels of understanding and awareness according to their different institutions of learning. The preliminary session in this initial iteration introduced the study and provided an information booklet (see Appendix 5D) to each participant. I was informed through these initial discussions that the current PGCE Computing curriculum includes one lecture on the philosophy of computing, but the specific detail of that lecture was not explained.

The cross-functional nature within this increment was to certain extent unbalanced is this was the first round of implementation and testing mainly focusing on the trainee teachers. Following the insights gained from increment one the Educators provided a baseline as their understanding of data-ethics within their PGCE curriculum. Their knowledge and expertise as trainee teachers as to what, if any, elements would work for them, and inhibitors.

Figure 8.2 *Increment Three, Covering Design Iterations One–Three*



The planning increment objectives and values (design principles) for this iteration were:

(i) Data-ethics for PGCE computing, including approaches to raising awareness.

- Participants should recognise what they currently know and understand about data-ethics.
- They should be aware that data-ethics covers more than just legislation and legal aspects.
- Participants should be able to expand data-ethics in the curriculum beyond sections on legislation and/or online safety.
- Students/participants should be able to explore cross-curricular opportunities.

(ii) How can ballet be used in the computing classroom as a pedagogical tool?

- Need to establish clear links between classical ballet choreography and computer programming.
- It should be possible to form the connection between ballet choreography and programming a language/algorithm design.

Overall, these main principles highlighted the need to establish the link between the modalities of ballet, biometric data, and computing curriculum content, with potential cross-curricular opportunities. This included the expansion of data-ethics as a subject beyond just legislation considerations. Table 8.1 provides an overview of the features tested during this iteration, their purpose, and the link to my research questions.

Table 8.1 *Conjecture/Features Tested—Design One*

Feature(s) being tested	Conjecture/Purpose	RQ
Ballet video clip 'Algorithms'	Participants will demonstrate alignment between computing and classical ballet.	2
Questionnaire	Capture baseline data of trainee teacher awareness of data ethics, ballet for computing, and competencies. Data will highlight level of awareness of data ethics.	1,2
EEG BrainViz recording Video	Video will demonstrate the hidden nature of EEG biometrics, leading to raised awareness of data-ethics.	1
Neuroethics Video Prof Farahany	Prof. Farahany's keynote on cognitive liability will lead to discussion and awareness of data-ethics for computing classrooms	1
PPE Model work in progress (WiP)	Prototype 3D model, hosted inside FrameVR, will raise awareness between human-data– 3D model–body-as-data-artefact & creative-computing	1,2

8.1 Implementing Design One

All sessions started with a reminder of the research ethics, aims, purpose of the session, and participants' choice of consent. The ability to follow ethical and consent guidelines when sharing personal information was important in this study, as the study needed to embody data-ethics principles and lead by example.

8.1.1 Session Design and Delivery.

The implementation and testing stages focused on awareness and the current curriculum design in relation to data-ethics for PGCE Computing. This enabled the development and revision of materials for the education cohort, including consideration of any challenges and impediments to coding and data-ethics they might face. Materials and dancer stories provided the practical application and limitations of the technical materials, along with the initial humanising of the biometric data.

The online session started with an introduction to the study and tools used within it, such as questionnaires used in online environments. The participant booklet was also redistributed so that all participants had functioning access to the tools needed and were aware of how to use them.

The first part of the session focused on the alignment of ballet and computing, using biometric body tracking data. The participants watched short video clips of ballet dancers performing algorithmic chorography, which showed human ballet dancers as well as virtual ballet dancers generated from skeleton tracking data. The participants then responded to two prompts: (i) Have you seen these videos before and what do you think of them? (ii) How do you think this ballet video relates to the computing curriculum? This led to a short explanation of how the virtual dancers were generated, and the code was shared as an initial exposure to biometrics for data-ethics.

As **data-ethics** is not yet a discrete part of the computing curriculum, the second part of the session introduced the main concepts of data-ethics, using Floridi (2013, 2016) , Floridi & Taddoe (2016b) 'What is data ethics?' and Farahany et al.'s (2012, 2015, 2018) approach to/framework for neuroethics (see Chapters Two and Three for more detail). These theories and frameworks were then linked to the current computing GCSE specification in order to contextualise this knowledge, and a close look at the relevant legislation illuminated the extent of this lack of awareness surrounding data-ethics. Following the introduction, another prompt was given: 'What do data-ethics have to do with the computing classroom?' This prompted an open and free discussion which gave the participants an opportunity to make connections and interconnections beyond legislation and computing. Responses to this prompt were particularly valuable for gaining additional insight into all potential opportunities, not just ballet, for **broadening participation** within computing education.

The third part of the session focused on how to pragmatically discuss data-ethics through programming and web activities in a classroom. A brief explanation was given of how the motion capture technology works from video onto post-pose estimation, followed by sharing the 3D model. I then demonstrated and explained the P5.js and ML5 PPE code (see Appendix 8A). The session ended with an exploration of FrameVR (a free web XR tool involving no code) and the prototype model both as teaching and learning tools, exposing participants to an accessible XR platform, along with a working output of the motion capture pipeline of this study.

Programming activities introduced biometrics and the **concept of personal data**, using P5.js code for the creation of a full-body skeleton and filters. I explained how to code simple lines, circles, colours, and how to use filters, illustrating simple approaches that produced complex or diverse results. Although some participants were unfamiliar with the programming language JavaScript, they were nevertheless able to read and understand the code by introducing simple lines and circles (ellipses).

A live display of the EEG tools and output (visualisation, raw graph, and spreadsheet data) **sparked important discussions about data-ethics**. Participants were unable to wear and test the device and outputs owing to the online nature of the programme, but they did have access to videos and raw spreadsheet(s) containing the EEG data collected.

In summary, the Design One implementation and testing involved the alignment of ballet and computing via the use of biometric body tracking data, with participants responding to prompts regarding their perceptions of the videos/activities used. Data-ethics and neuroethics were also introduced and connected to the new GCSE Computing specification. Data-ethics was discussed through the use of programming and online activities, including demonstrations and walkthroughs of P5.js and ML5 PPE code. Finally, questions of the **ethical implications of biometrics and personal data in relation to the computing curriculum were addressed through programming**, including conversation prompts and coding tasks to aid understanding of these issues.

8.2 Analysis and Findings

This section presents the analysis and findings through the following data types: questionnaire data (small sample size); voice and chat transcripts from workshop(s); and interview transcripts. The first analysis section focuses on the questionnaire data, and I then discuss the IPA analysis of the PGCE trainee teacher cohort.

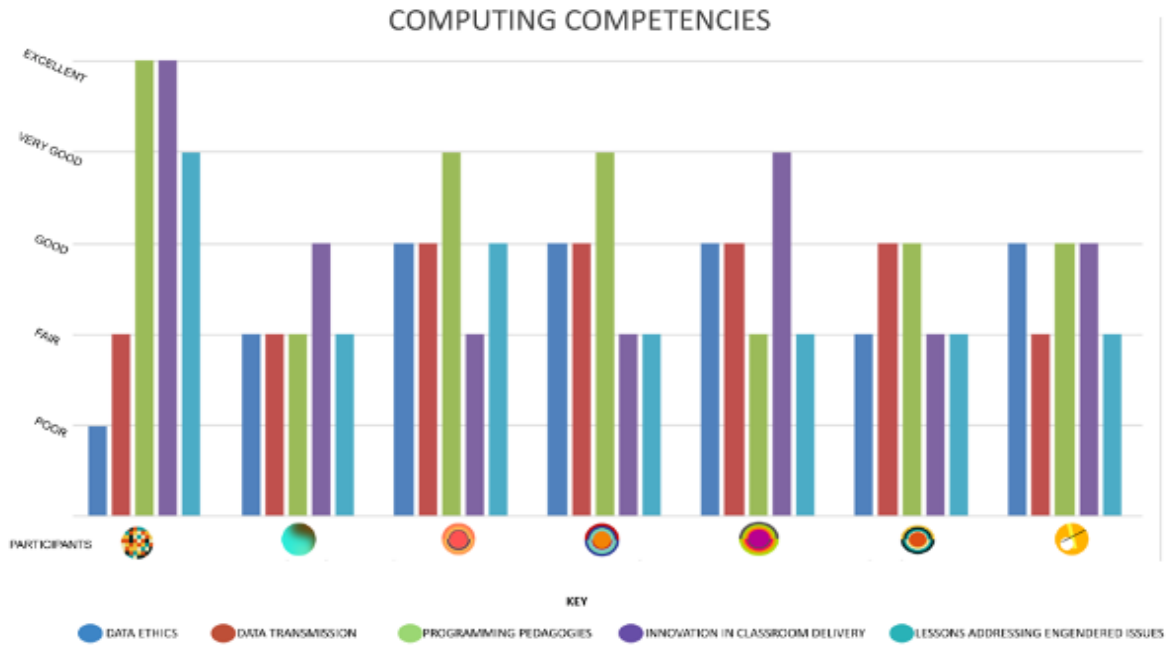
8.2.1 Questionnaire Data

The questionnaire used in this study (see Appendix 5E) may have a small sample size, but the participatory principle that all participants are equal actors means their voices, as data, all have equal and significant value. The sample size for the questionnaire was *n=18* trainee computing teachers, and had a completion rate of 7/18 (*n=6* male teachers and *n=1* female teacher). Reasons for this low questionnaire completion rate could be attributable to time constraints for the participants, the fact that some participants were absent when the

questionnaire was shared, or a lack of initial engagement with the study. Figure 8.3 highlights the low(er) levels of self-perceived competency in the field of data-ethics and gendered issues compared with programming pedagogies within these responses.

Figure 8.3

Chart of Responses by Participants on self-perceptions of Computing Competencies



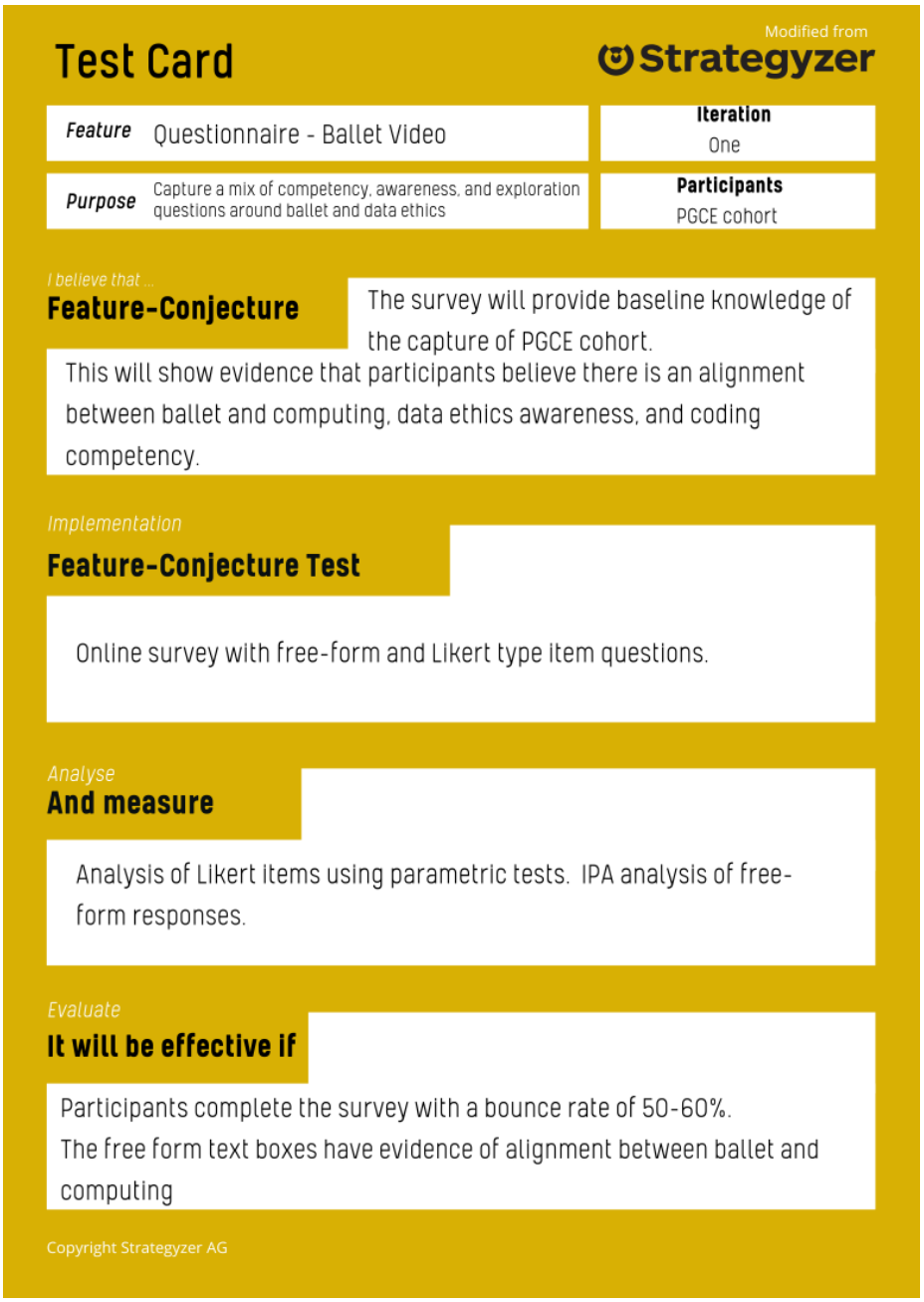
Significantly, the data-ethics bar in figure 8.3 (the left first bar, dark blue bar for each participant) did not rise above the 'good' level, and this lack of competency in data-ethics was also evident in the transcript data. The data were collected towards the end of the PGCE course, suggesting that data-ethics awareness is not currently a key area of study on this course. Although this cohort had two dedicated lectures on the philosophy of computing and diversity, equality, and inclusion within computing, which were briefly revisited in other lectures, data-ethics was not covered, and so competencies in this area remained low.

8.2.2 Ballet and Computing Alignment

The experiential themes derived from Iteration One findings include: (i) cross-curricular opportunities with and for the computing curriculum; (ii) ballet and its alignment with programming as a pedagogical tool rather than just a fun modality of teaching; (iii) time constraints, including classroom time, planning, and educators' learning time; and (iv) the

challenge of high coding competency required for DDD. The subsections that follow provide a more detailed explanation of each theme.

Figure 8.4 *Test Card—Ballet Video*



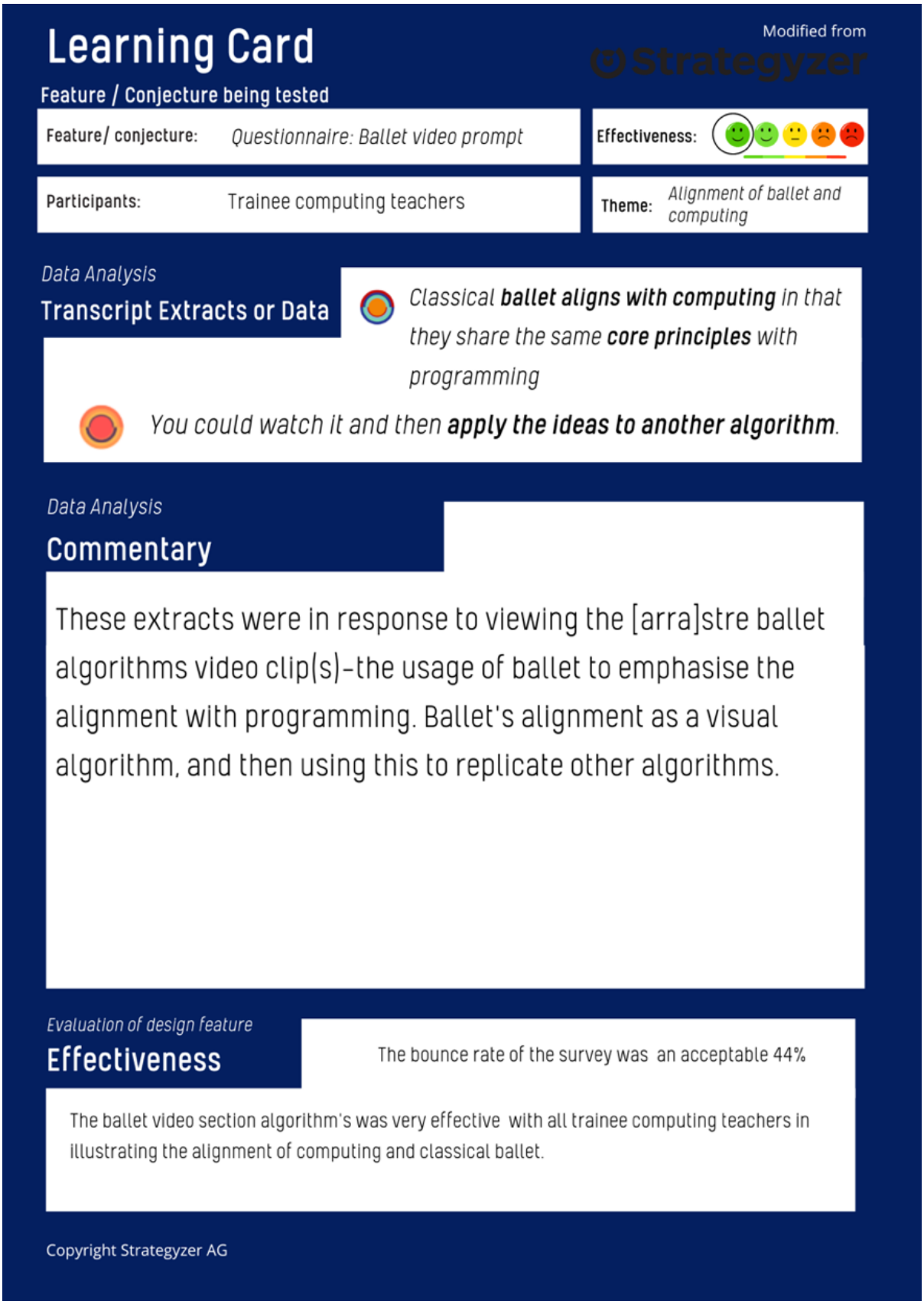
The questionnaire responses focused on how **ballet (video clip,** see 5E**) could serve as a framework for creative computer expression**, and also posed a practical obstacle for implementation of ballet practices within a classroom context. Figure 8.4 highlights the purpose of the video prompt that led to a richer, more comprehensive understanding of ballet and its alignment with programming.

The text extracts from feedback outlined in Figures 8.5, 8.6, and 8.7 indicate how the participants connected ballet choreography with computer algorithms. Algorithms, according to this feedback, involve progressively performing steps to obtain the desired outcome. There was a somewhat surprising awareness of the correlation between ballet and programming exemplified in this feedback after participants had watched the ballet videos. The extracts and observations both demonstrate this awareness of the relationship between creativity and structure. Following these videos, participants were able to communicate that the structure of ballet and computer algorithms are at least partially aligned, and that this alignment holds the potential to develop creative alternatives to computing education. This indicated that the participants had a nuanced understanding of the interplay between structure and creativity in both dance and programming, as well as the ability to make links between these disciplines**.** This was not the case for all participants, and additional reinforcement via dancer narratives would be required for future iterations.

Furthermore, the extracts reflect the similarities between ballet and programming, such as a reliance on exact and precise execution, attention to detail, and a focus on achieving a desired outcome using structured procedures. As the clips show, the creative aspect of ballet, which allowed for individual expression and interpretation within the constraints of a structured framework, can be compared to the creative problem-solving and creation that is usually required in programming.

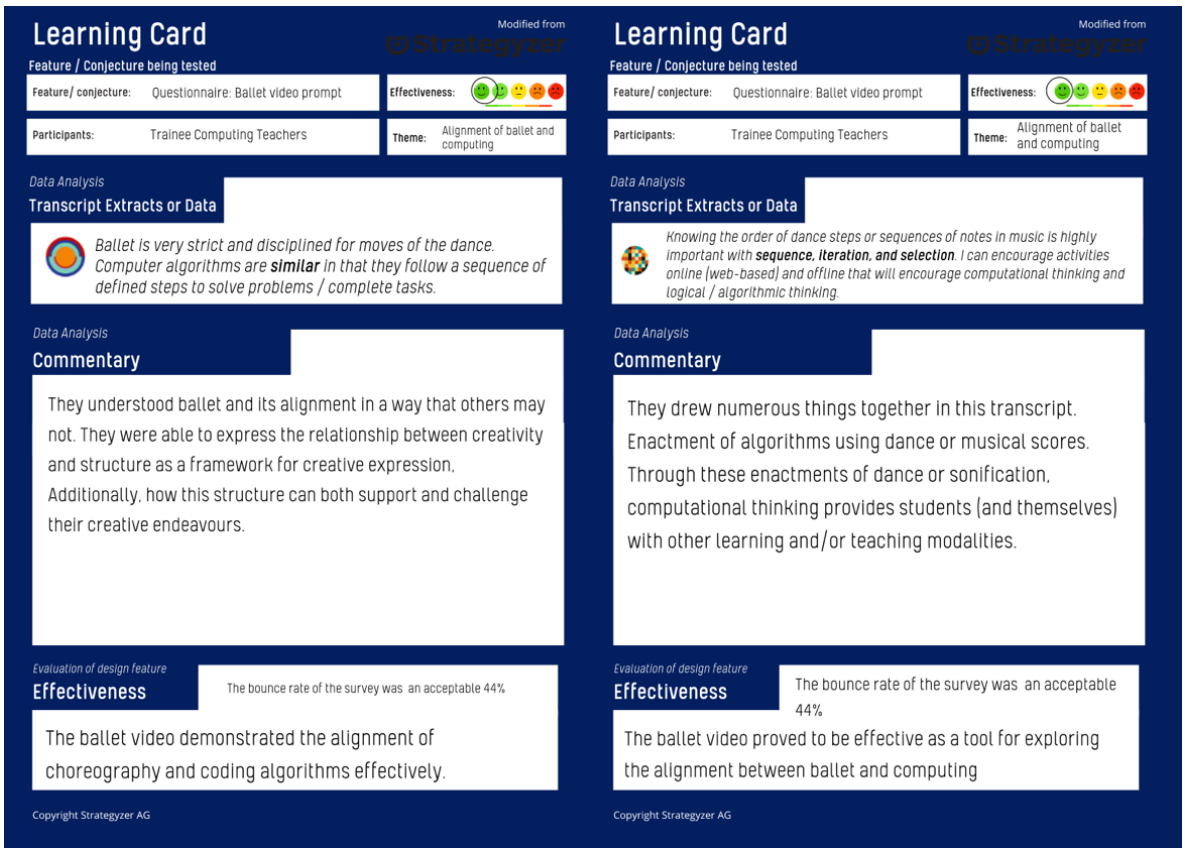
Overall, the response to the ballet algorithms video demonstrated that the PGCE cohort recognised the connection between dance and programming to some extent. The participants emphasised how ballet and computing have similarities and could be mutually beneficial in education contexts. Transcripts illustrates the alignment of the ballet and computing but did not go further in developing insights into broadening participant through classical ballet. This may be due to online modality or limited access or experience to ballet as part of the study.

Figure 8.5 *Learn Card—Alignment between Ballet and Computing* [*questionnaire text data*]



Figures 8.6 and 8.7

Learn Cards Experiential Theme—Alignment Between Ballet and Computing [questionnaire text data]



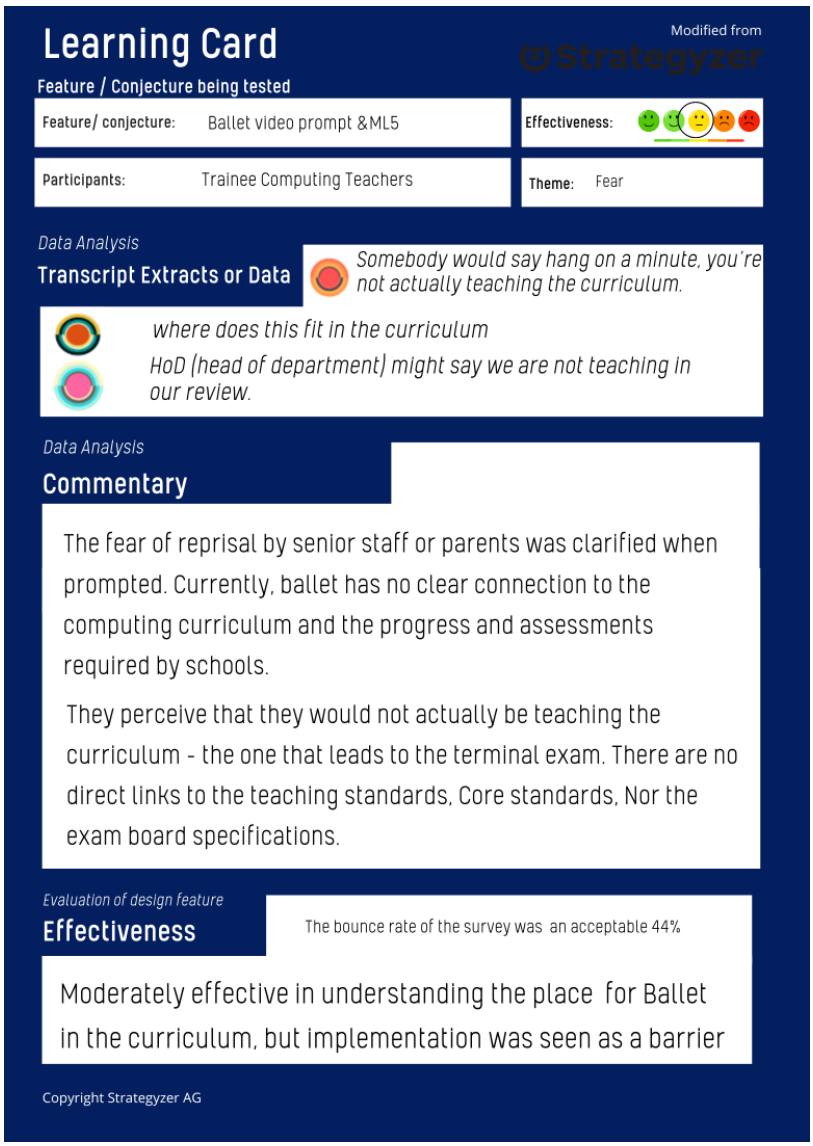
8.2.3 Fear

The transcript extracts below reflect apprehension about using innovative pedagogical approaches, such as ballet for computing or P5.js with ML in PGCE practices. This fear element ran parallel to the awareness of the alignment between ballet and programming throughout this stage. This apprehension could be because ballet was novel and unfamiliar to the participants in the computing context, and the connection had not yet been properly established with the goals and needs of their PGCE in mind. This apprehension was also evident when considering the cross-curricular connection to music (see the last extract in Fig 8.14, p.216). There was a particular concern of retaliation from senior staff who review and conduct PGCE assessments while on placement or, once employed as an NQT, their performance management reviews.

teachers' [ballet/dance] knowledge might be a hindrance in using these creative techniques. [voice]	Lack of ballet knowledge and competencies of individual teachers is a constraint to implementation but an opportunity for cross curricular collaboration.

This fear was also linked to trainee instructors' perceived lack of ballet subject knowledge. Indeed, a lack of ballet knowledge and competencies represented a constraint in the execution of ballet-based learning activities. This limitation, on the other hand, might be considered as both a task and an opportunity. The lack of familiarity with ballet **presented difficulties for incorporating ballet-based activities** into the computing curriculum and facilitating student learning in this area, but it also opened up further exploration of the **potential/possibilities for cross-curricular** collaboration, as teachers might seek out resources and experience beyond computing.

Figure 8.8 *Learn Card—Fear* [*voice data*]



Fear due to a lack of subject knowledge could also be handled by training, teaching materials, experimenting, and re-examining how trainee instructors see this constraint, thereby transforming it into an opportunity. The kaleidoscope lens may aid in refracting the perspective of what is ‘acceptable' in a computing classroom. Rotating through the various lens of the ontological kaleidoscope aided in the changing of roles educator-observer-researcher during the study.

8.2.4 Cross-Curricular EEG data

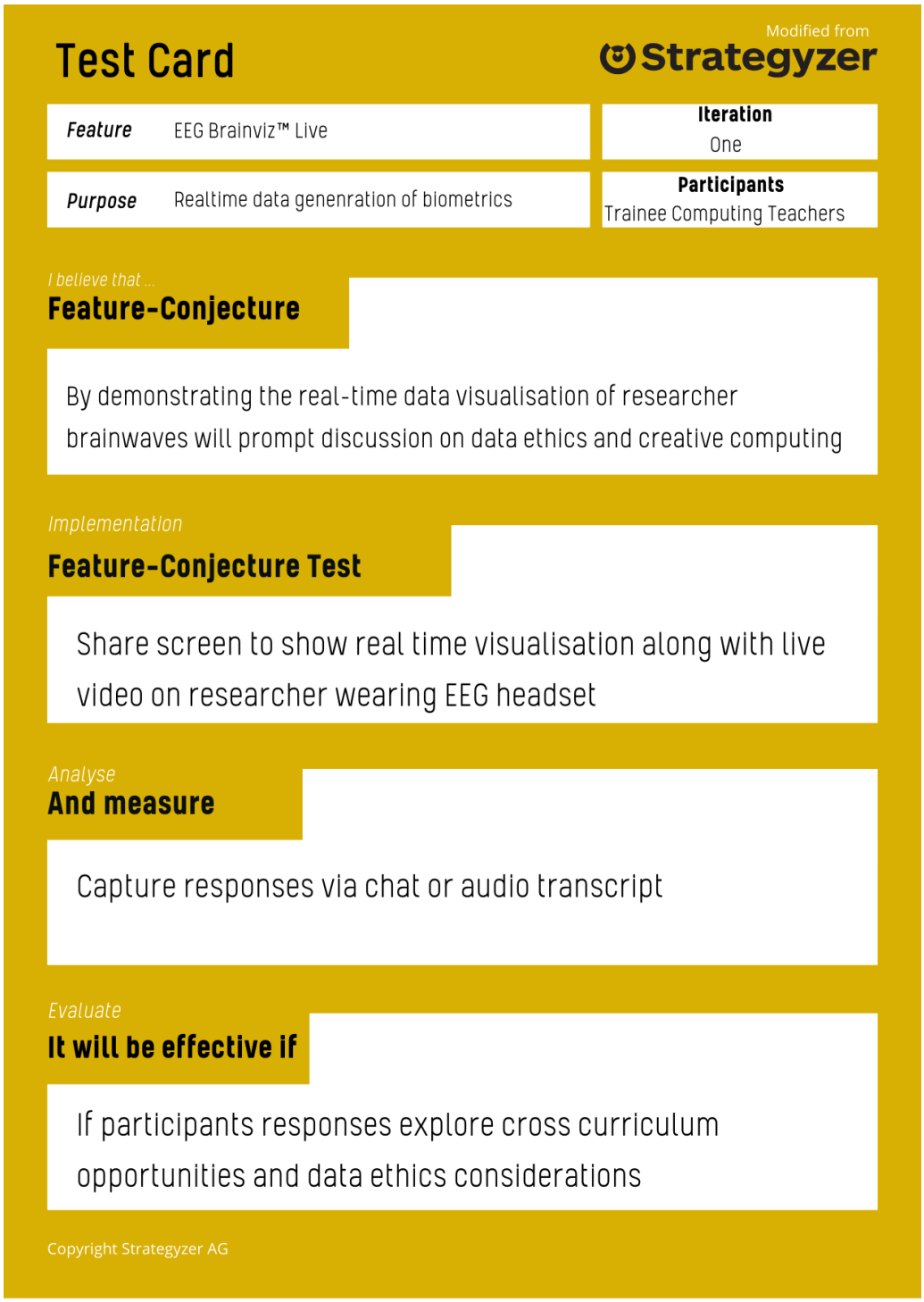
The use of the EEG brain visualisation as a feature, figure 8.9, below, for data-ethics prompted discussion on **broadening participation opportunities for data-ethics**.

Figure 8.9 *Dancer wearing Emotiv Insight running Brainviz™ software*

Several areas were discussed by the participants drawing on their own experiences and teaching practice. (i) cross-curricular, (ii) coding competency, and (iii) fear. First, they discussed (i) Literature and film, in addition to dance, were highlighted as significant vehicles for developing cross-curricular talks, with science fiction authors such as Aldous Huxley, Philip K Dick, and Hugh Howey being suggested. Participants believed that these media may be used to connect subjects like Media Studies, Business Studies, Personal, Health, and Social Education (PHSE), and potentially even English. While there is a predetermined reading list in the English GCSE curriculum, it was recommended that an investigation of information/data-ethics may be included into other year groups or themes. (i) Cross-curricular as theme is presented following the feature/conjecture card, figure 8.10.

Because of the nature of the BrainViz™, data as Art, the participants were able to go beyond their preconceived notions of what EEG data is and its position in the computing classroom.

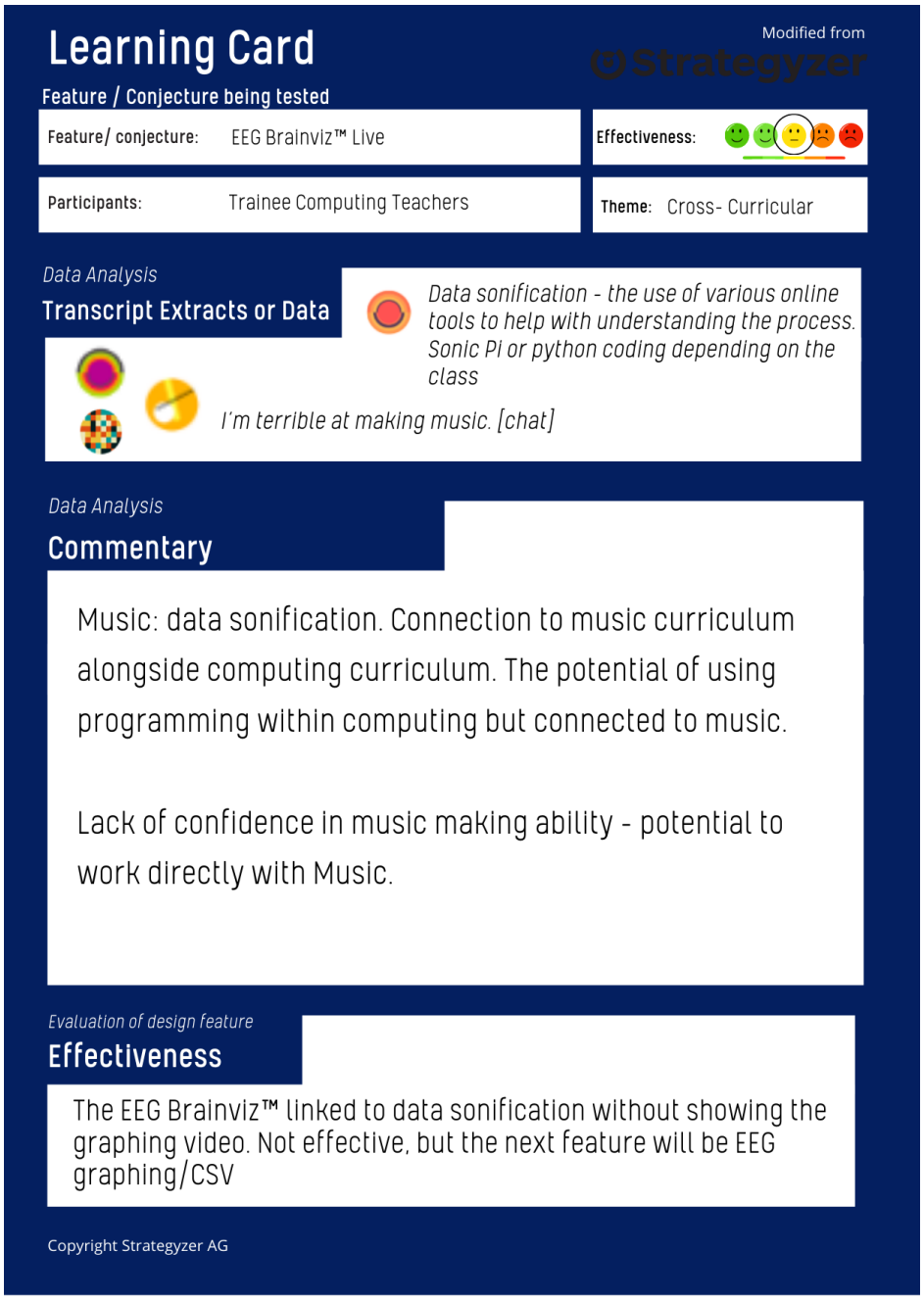
Figure 8.10 *Test Card—EEG Brainviz©*



Following the question of where data-ethics could be incorporated in other subjects, participants considered how music may be relevant to this discussion (see Figures 8.10 and 8.11). The extracts discussing the potential of using music in data-ethics education focused on a lack of confidence, however, but participants noted that visualising the EEG data in spreadsheet form did bring programming and music together.

Figure 8.11 *Learn Card—Cross-Curricular–Music* [*voice & chat data*]

Figure 8.12 *Learn Card—Cross-curricular Music* [*chat data*]

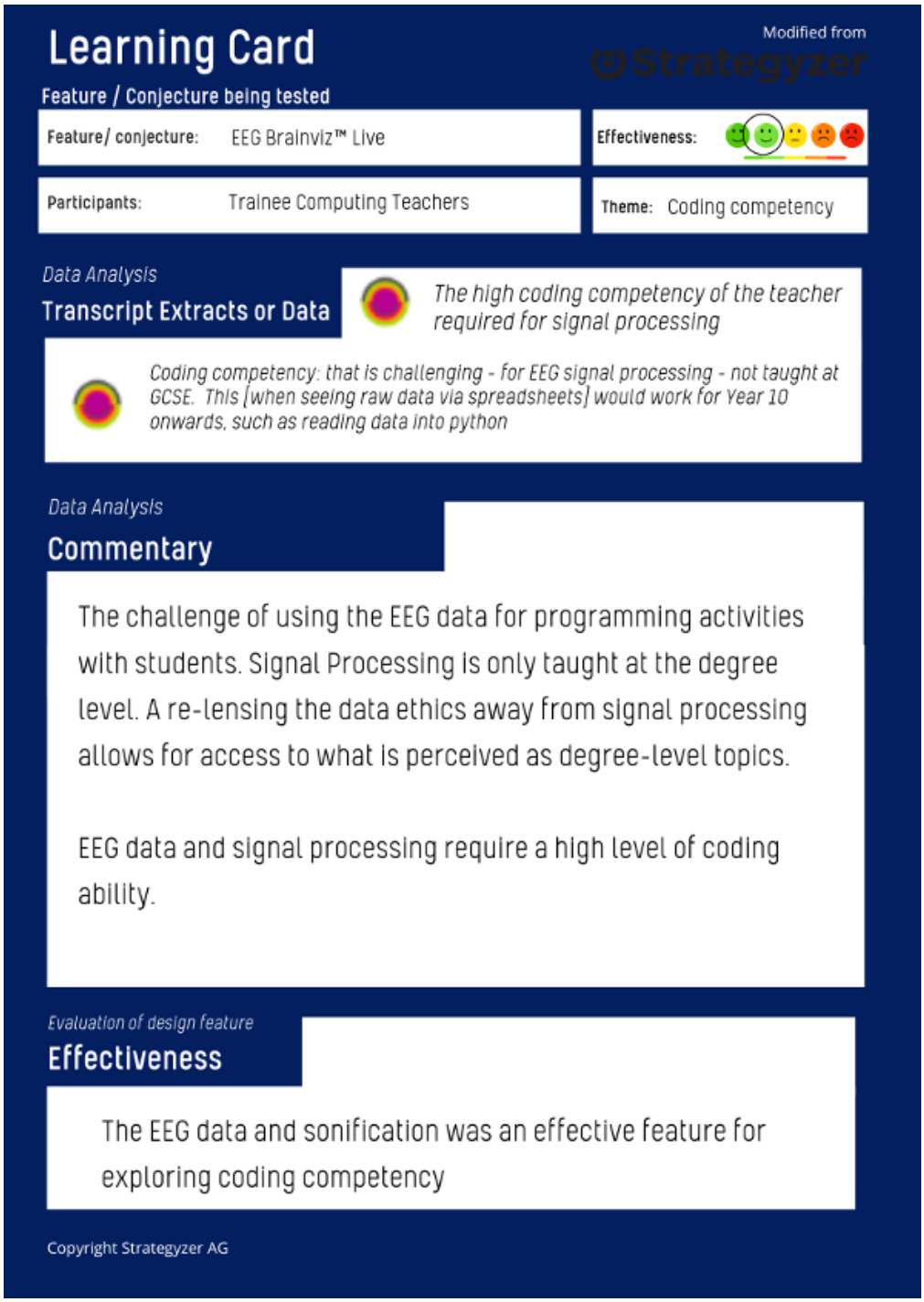


8.2.5 Coding Competency

Coding competency was the second area explored, and was tested through the questionnaire and in response to the EEG visualisation. It was important to understand the participants' prior experience with various coding languages in order to develop appropriate coding activities that raised awareness of data-ethics while aligning with the programming constraints of their curricula. The trainee computing teachers' coding competencies varied,

and some had limited prior programming experience. It was important to distinguish between their coding proficiencies as teachers and the coding competencies of their pupils, as learning and teaching programmes are vastly different, and this subject is particularly difficult to grasp (Guzdial, 2010).

Figure 8.13 *Learn Card—Coding Competency* [*voice data*]



The Learn Card and extracts, fig 8.13, reveal that participants tended to talk about [their] students' competency rather than relating it to themselves (trainee) as students or learners. This was in response to data sonification with EEG data.

Biometric data as form of employment or education access [voice].

The use of biometrics as a metric could lead to future damaging segregations that are not foreseen by Edtech companies developing these technologies.

The findings from the discussion of this theme highlighted the need to confirm, reiterate, and provide a demonstration in the next iteration that only code modification was required in the proposed study. This would not only fulfil the PGCE's coding requirements, but would also **provide opportunities to discuss data-ethics in detail**.

8.2.6 Classification and Categorisation

Following the demonstration of brain visualisation and Professor Farahany's cognitive liberty video (2014), the issue of classification and categorisation became evident during the AI/ML discussions. Concerns were raised that biometric data, such as facial recognition software or fingerprints, could be used to categorise children based on ability in the future. In response to the demonstration of EEG, the transcript extracts below (Figure 8.14) demonstrate the concerns voiced about access and the inclusion of biometrics in the computing classroom. These transcripts highlight the negative aspect biometric data and how it could potentially lead to categorisation, leaving students at a disadvantage or denying them future access to education or employment. The voice extracts and observations demonstrate how this issue could be **compounded by classifications based on biased or incorrect information**, which prompted more discussion about the need to raise awareness about data-ethics. The use of biometrics in the classroom, the participants found, could reinforce and perpetuate existing inequalities and discrimination, especially against SEND students (students with Special Education Needs or Disabilities).

Figure 8.14 *Learn Card—Categorisation/Classification* [*voice data*]

Another issue raised was the difficulty for students, particularly those with impairments, was the use of a User Interface (UI) and navigation of software, which were identified as potential barriers to progress. The participants elaborated that if navigation was not intuitive or user-friendly, students may find it frustrating or confusing, and their progress may be slowed or stopped. The EEG brain visualisations and neuroethics video data were effective prompts for discussions on data-ethics, including classroom implementation inhibitors from a coding perspective.

8.2.7 Dancing with P5.js

This section considers the coding competency theme and how it was discussed and tested throughout this stage of the research. The test of the P5.js skeleton tracking code activity, shown in Figure 8.15, brought up themes of participants lacking confidence or competency in coding and feeling apprehensive about using this tool in future lessons. P5.js was specifically selected to minimise barriers to entry, as even those without JavaScript experience could interact with it. ML5, the post-pose estimate model used P5.js and enabled online access to the coding environment. It presents a similar pipeline to the one used to develop the 3D model, but is also suitable for use in schools owing to its simpler structure.

Figure 8.15 *Test Card—P5.js*

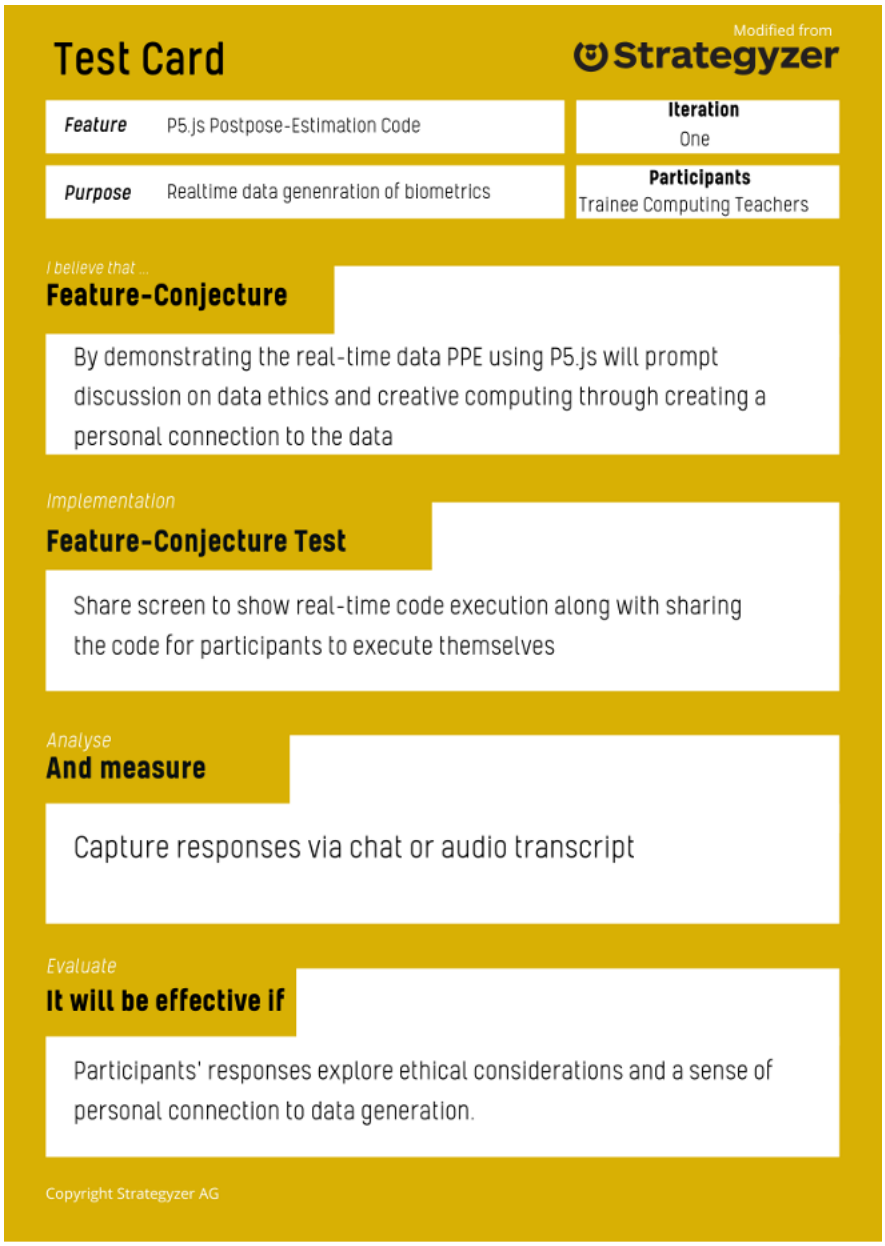
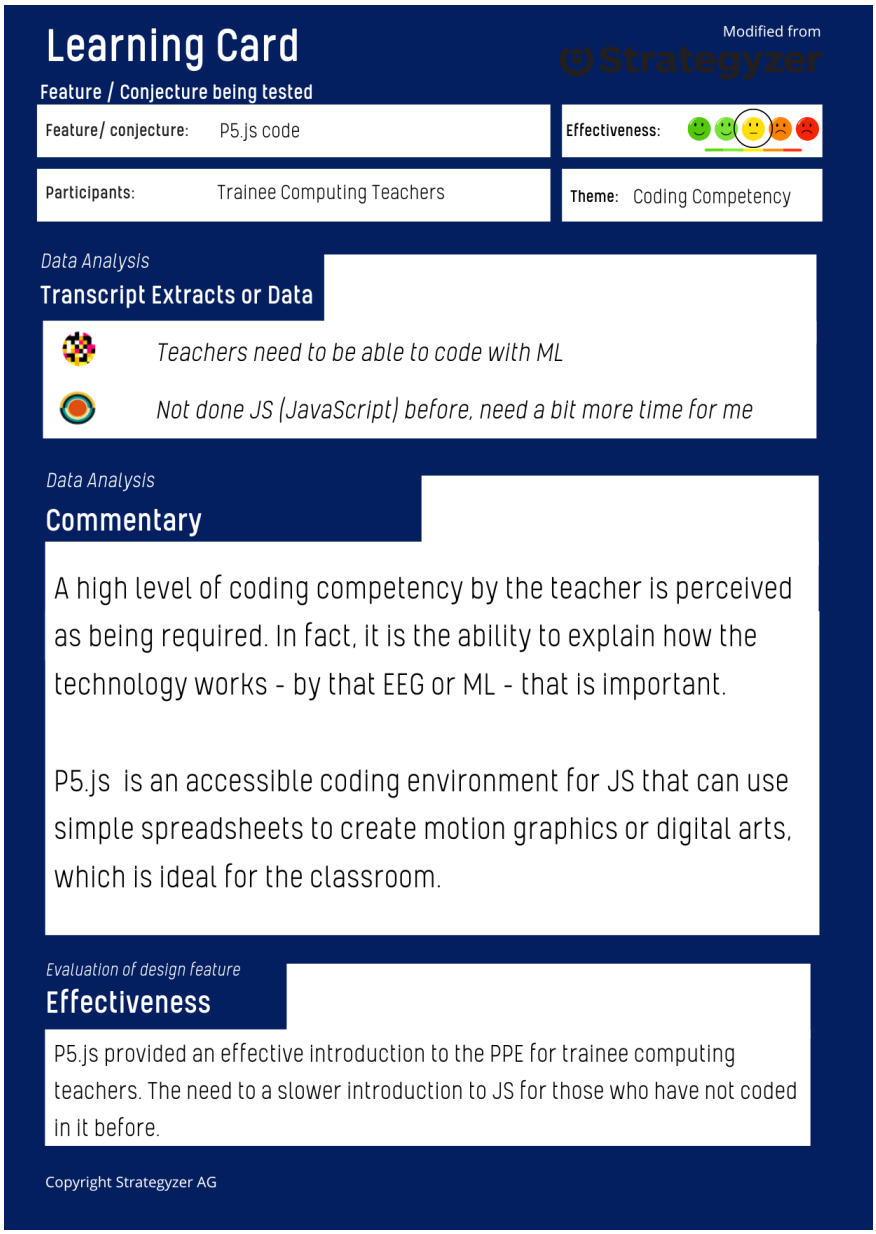


Figure 8.16 *Learn Card—Coding Competency* [*voice data*]



The participants often presented coding competency (questionnaire 8.2.1, transcripts) as a barrier, fig 8.16, owing to the perceived need for high-competency programming skills. In truth, however, the code only needed minor changes, and there was no need to code the ML model or code from scratch. When attempting to use these new forms of coding exercises to discuss data-ethics, this perceived level of ability and drawback created boundaries.

8.2.8 Time

The constraints of time occurred across multiple activities and was considered a huge factor in teaching and learning in the computing classroom in relation to ballet or using P5.js.

Participants noted constraints on time allocated for planning, activities, and logistics, as well as their own continued learning. The language used in the extracts below reinforces this perspective that time is a constraint in teaching contexts rather than an opportunity. The transcript extracts in Table 8.2 raise several relevant issues regarding the integration of ballet into the computing curriculum. These issues relate to the amount of time and resources needed to deliver the content effectively. One trainee expressed a desire to spend more time on this type of content and delivery method, but when discussing their teaching practice/placements, they noted that this approach would be limited by the timetable.

The time and effort necessary for educators to create ballet-based learning activities further complicated the integration of this cross-curricular approach into the computing curriculum. Time was an important factor for them because they had to develop lesson plans for all of their sessions, which implied that including ballet would require more time. These limitations impeded the aim to widen participation in computing education through enabling creative computing pedagogical alternatives.

Table 8.2 *Experiential Theme Time* [*voice data*]

Voice Transcript extract	***Commentary***
You'd want to spend more time.	The computing curriculum is (incredibly) dense considering time allocation in timetables is roughly 3-5 hours a week- especially at GCSE. This poses the question of how this would fit into teaching planning and teaching considering that their students have to pass exams.
Interesting for both teacher and student.	Time in the curriculum and lesson duration impacting ability to deliver.
Spend too much time on prep. [both said the same thing]	Time for Educator to prepare and plan for this topic

8.2.9 Summary

Section 8.2 illustrated the aim to **broaden participation** RQ2 in computing education for education in light of the alignment of ballet with programming, and also the limitations and constraints posed by time, coding competencies, and the risks of using **biometric data** RQ1 in classrooms, especially for SEND students. The participants demonstrated a nuanced awareness of the relationship between structure and creativity in ballet and programming

RQ2, and were able to draw parallels between these domains and other disciplines such as media studies and business studies. Teaching RQ1 **data-ethics** at PGCE level would help with the safe use of biometric data, and would help educators find ways of anonymising the data/not recording it fully for privacy and humanising the data.

8.3 Summary of Design One: Inspect and Adapt.

After considering the findings of questionnaire, IPA analysis, and workshops, led to the adaptation foe design two. These adaptations included altering the introduction of the P5.js and ML elements for design in order to alleviate the perception that a high level of coding competency is required when using biometrics and ML models for raising awareness data-ethics. Ballet proved to be an unexpected cross-curricular possibility that combines the dance curriculum with computing through the use of movement as a method of information and physical knowledge transfer (Loke & Núñez-Pacheco, 2018).

Design one's experiential themes demonstrate the critical necessity for learning opportunities within data-ethics as part of the PGCE curriculum. Figure 8.17 illustrates the effectiveness of each feature of Design One.

Figure 8.17 *Feature/Conjecture effectiveness*

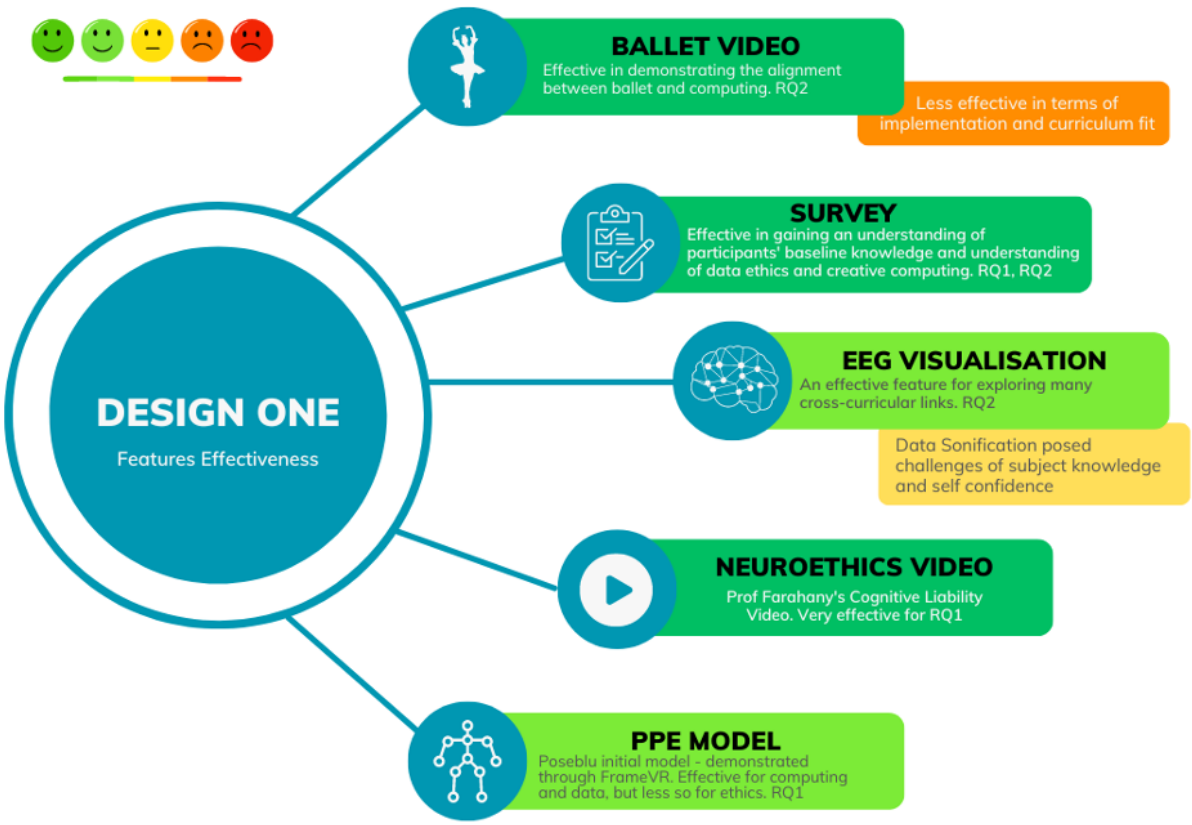


Figure 8.17 notes the feature/conjecture effectiveness which led to the key findings from this iteration. They suggest that the connection between dance and computing should be strengthened in order to (RQ2) broaden participation in computing education. The main restrictions to this approach were associated with the use of P5.js. As a result, the creation of resources with low or no barriers to entry is crucial (e.g., free opensource, working examples) in developing computing activities with the purpose of raising data-ethical awareness. Furthermore, the next design included the diversification of ballet resources (9.2.1) and expanded programming activities (9.2.4) to mitigate some findings from this iteration of fear, time, and coding competency. These improvements are intended to alleviate teachers' time limitations while using coding exercises and ballet materials in accordance with their PGCE or teaching practice work plans (schemes of work).

Chapter Nine: Implementation and Testing of Design Two

Figure 9.1 *Dalle.2 open.ai generated image: findings prompt 'dance, digital, self, and data'*

9 Introduction

Design Two provided a modified approach to investigating data-ethics and its connections to the computing curriculum, with an emphasis on practical application and cross-curricular integration, as informed by results from Design One. The objectives and values (design principles) for Design Two had the following focus: (i) how ballet could be used as a pedagogical tool in the computing classroom, and (ii) establishing awareness of data-ethics and its position within the pre-university computing curriculum.

Table 9.1 outlines the design and development changes from the previous iteration. The modifications included more detailed dancer narratives in an attempt to humanise the biometric data, as well as different ballet algorithm videos and P5.js code activities.

Table 9.1

Iteration and Development Principles—Changes from Design One to Design Two

Design One	Design Two
A need to establish clear links between classical ballet choreography and computer programming was identified. Participants should be able to form the connection between ballet choreography and programming languages/algorithm design. Participants should recognise what they currently know and understand about data-ethics. Participants should be cognisant that data-ethics is more than just its legislation and legal aspects. Participants should be able to expand data-ethics in the curriculum beyond sections on legislation and/or online safety. Participants should be able to explore cross-curricular opportunities within PE and other subjects.	A need to establish clear links between classical ballet choreography and computer programming was identified. Participants should be able to form the connection between ballet choreography and programming languages/algorithm design. Participants should recognise what they currently know and understand about data-ethics. Participants should be cognisant that data-ethics is more than just its legislation and legal aspects. Participants should understand what barriers they think there are for using ballet as a pedagogic tool within their computing classrooms. Participants should be able to explore cross-curricular opportunities within PE and other subjects. Participants should be able to expand data-ethics in the curriculum beyond sections on legislation and/or online safety. Participants should be able to link specific curriculum specification topics to practical activities for both programming and discussion.

9.1 Implementing Design Two

During feedback and reflection in Design One, participants asked for programming tasks/resources aimed at GCSE level students. The revised iteration design aimed to provide a more thorough grasp of data-ethics within the context of the computing curriculum, and provided opportunities for participants to engage with concepts in a range of contexts and locations. The goal of this second iteration was to ensure that the materials and exercises developed were understandable and relevant to the trainee computing teachers. Opportunities for advanced learners to increase their skills and knowledge were also highlighted.

Alongside the education cohort session, the technologist continued to develop the 3D model prototype, but met some severe challenges. It was critical to record not just the dancers' biometric data but also how they felt about the capture process and subsequent sharing of their personal biometric data during Iteration Two. The EEG headset, as well as a placement and cleaning protocol document, were provided to all dance participants prior to the collection of their biometric data. I held a brief instructional session before the data collection began on how to use the headset and the related software.

The dancers had access to two pieces of proprietary software: Emotiv Pro and Emotiv Brainviz™. The professional software captured raw brainwave data and downloaded them into a spreadsheet in CVS format. Brainviz is a real-time data visualisation tool that generates a live data video. Following a thorough explanation of the software, the dancers performed a specified piece of choreography while capturing raw data, and then performed this piece again using the visualisation tools, as the two pieces of software cannot operate concurrently.

During this increment, cross-functionality facilitated the exchange of various artefacts and stories among trainee teachers, technologists, and dancers about how they relate to their own disciplines. As a result, asynchronous interactions could incorporate different perspectives. This allow different perspectives to be included even when asynchronous interactions occurred.

9.1.1 Session Design and Delivery

The introductory session for Design Two, carried out with the education cohort, started with a reminder of the ethics protocols and the participants' right to withdraw at any time from the research. The session was delivered via Microsoft Teams, the education cohort's institutional mode of online learning which allowed for video, voice, chat, document sharing, and live

transcription. The structure of this session was similar to that in Iteration One, and focused on ballet, data-ethics, and then practical programming, with opportunities for discussion while coding. Preserving this same structure allowed me to see differences in process and product as the design changed. The first part of the session consisted of various ballet videos that drew choreographical inspiration from various methods and datasets. The second part included access to Farahany's works (2014, 2015) and the keynote speech video, both of which were made available prior to the session, as they were quite long. This also provided access to any participants who were absent from the session, and also gave me the opportunity to observe whether participants would adequately prepare for the session by reading through the material beforehand. The third part included practical and programming activities for P5.js, as well as a demonstration of the 3D model prototype via FrameVR™. The features outlined in Table 9.2 were tested and are discussed through IPA analysis in the rest of this chapter.

Table 9.2 *Design Two Features*

Feature(s) being tested	Conjecture/Purpose	RQ
Ballet video clip 'Protocols'	The older skeleton tracking video uses Kinect and C++ code to demonstrate links with data privacy/ethics of body-data, building on videos from Design One.	2
Article	The EEG Chinese study article should raise participants' knowledge regarding EEG in education and the ethical implications and challenges.	1
EEG Graphing Video Raw Data csv	Participants were able to visualise the hidden nature of biometric data introduced in Design One. Data generation of an EEG headset produces massive amounts of data. Participants' exposure to a simple spreadsheet tracking a person's EEG data made this process less daunting (image of dancer wearing headset with graph displayed).	1
P5.js Full body skeleton PPE code	The JavaScript coding activity aimed to create a personal connection to the real-time data.	1,2
PPE Model Hosted inside FrameVR	Demonstrating the working 3D PPE model of dancer (bluPose) hosted within a webVR environment will allow participants to see the connection between the human and 3D model. Additionally, the use of low-barrier entry AR tools	1,2

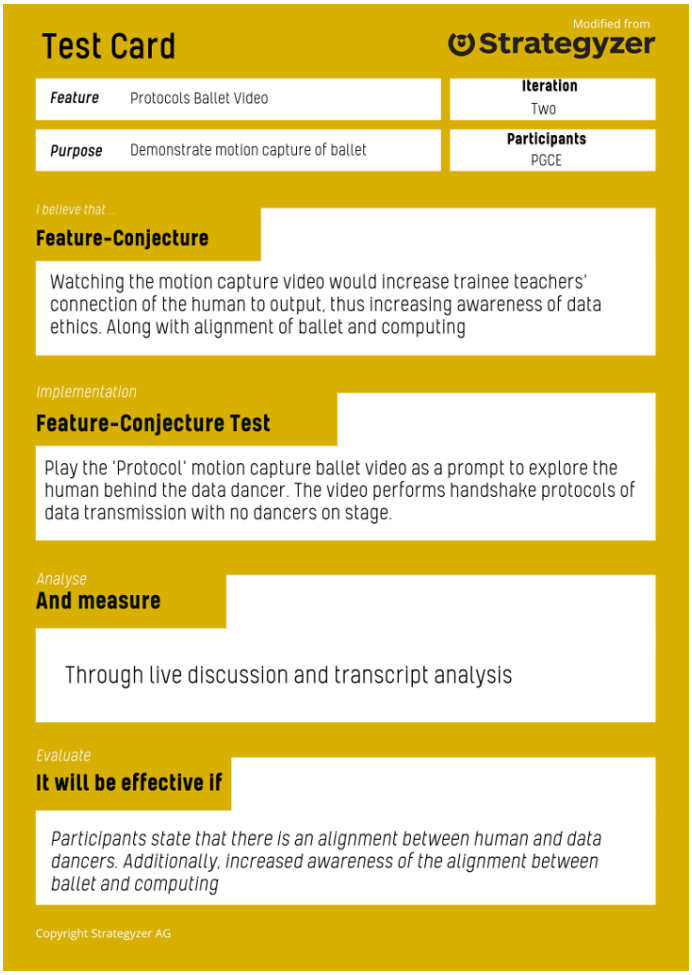
9.2 IPA Analysis

This section presents the analysis of all education transcripts under the following experiential themes: (i) precision, (ii) planning with and for technology, (iii) risk, (iv) assessment, and (v) legislation. I focus on extracts from trainee computing teachers and the PGCE programme lead, but also include findings from the dance cohort, extracted from transcripts of video sessions, text data, and Trello updates. The main themes for the dance cohort were: (i) non-conventional movements, (ii) technical challenges, (iii) digital representation, and (iv) liability. The first theme aligns with the technologist's concerns about tracking models which were not trained to pick up hands and feet specifically, as discussed previously, p.169. The dance cohort findings fed into the design and development of the education intervention.

9.2.1 Ballet Protocols Video(s)

The protocols ballet video used at this stage generated two distinct themes that were highlighted in the feedback from the education and dance cohorts: (i) precision and (ii) non-conventional movements. Figure 9.2 illustrates the feature test for the PGCE teachers.

Figure 9.2 *Test Feature—Protocols Video*



9.2.1.1 Precision

The excerpts included in Figure 9.3, next page, suggested that both ballet and programming precision provided further opportunities for the alignment of the two. This observation was noted during the discussion that followed the ballet video clips, algorithms, and the addition of protocols from [data]storm ballet. The participants had not previously watched the ballet insertion sort film, but they were familiar with dance and algorithms from the prior iteration, and they had been introduced to the folk-dancing bubble sort during their PGCE lectures. Other danced algorithms do not have the added choreographic layer of verifying and validating that the insertion sort ballet adds. Several interesting responses came from this discussion, including the majority of trainee teachers articulating the alignment between ballet choreography and programming in terms of precision or discipline needed.

Figure 9.3, below, outlines these responses, in which participants show a good understanding of how both ballet and computer algorithms rely on strict and disciplined approaches to achieve their respective goals. When discussing ballet, the trainee teachers noted that this manifested through specific motions and procedures that must be followed in order to correctly execute the dance. They suggested that the equivalent in computing was more abstract, but emphasised how algorithms, like ballet, follow the same predefined set of precision steps in order to solve issues or to complete tasks.

The extracts, figure 9.4, analysed continue the theme of precision and algorithmic performance, and draw upon Gagné's notion of performing rather than explaining a concept (1996, p. 85). A concept's performance identifies an object or distinguishes it from other objects. It is analogous to 'stimulus discrimination,' except that a class is differentiated in computing rather than a specific object.

Figure 9.3 *Learn Card—Precision* [*voice data*]

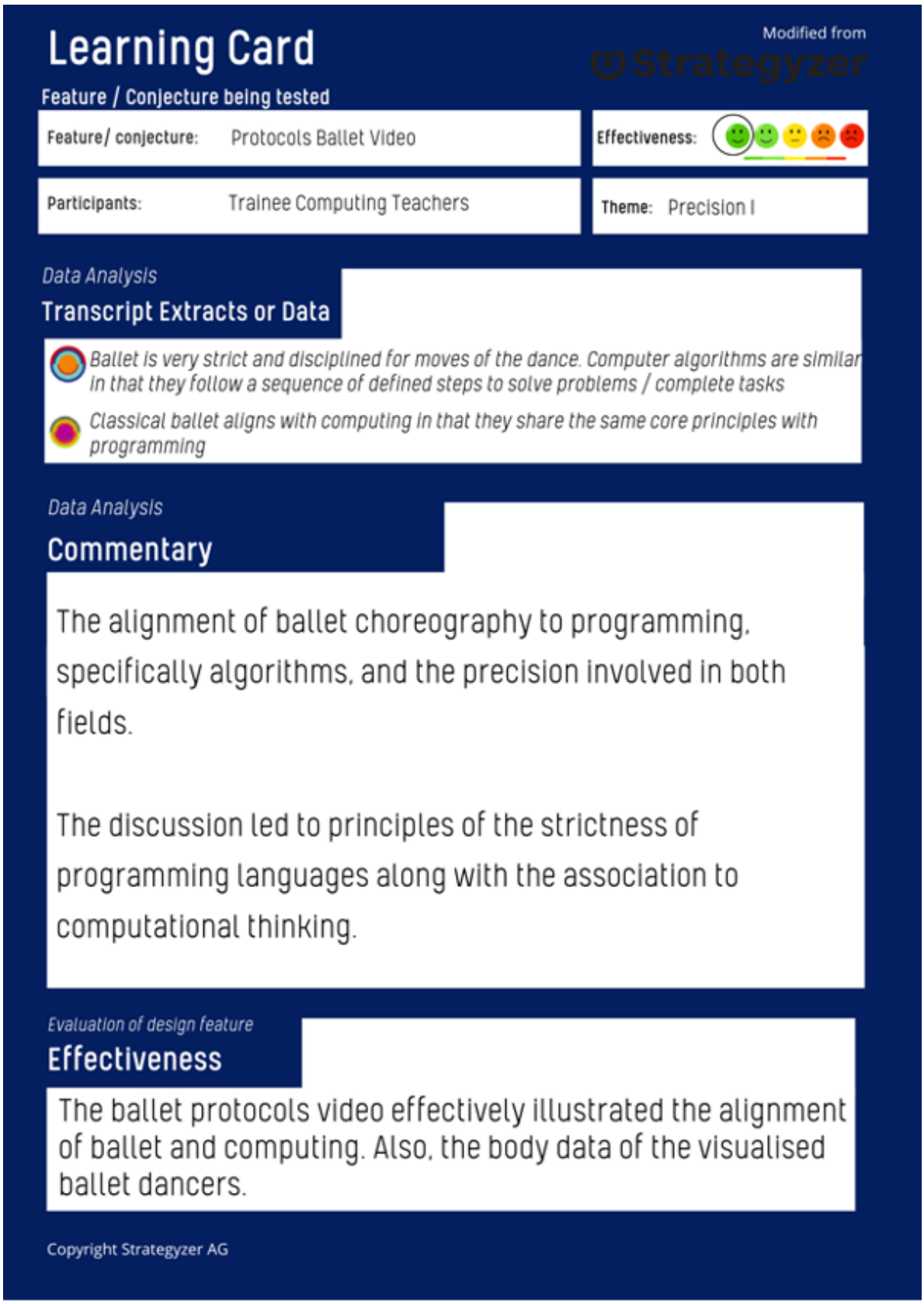
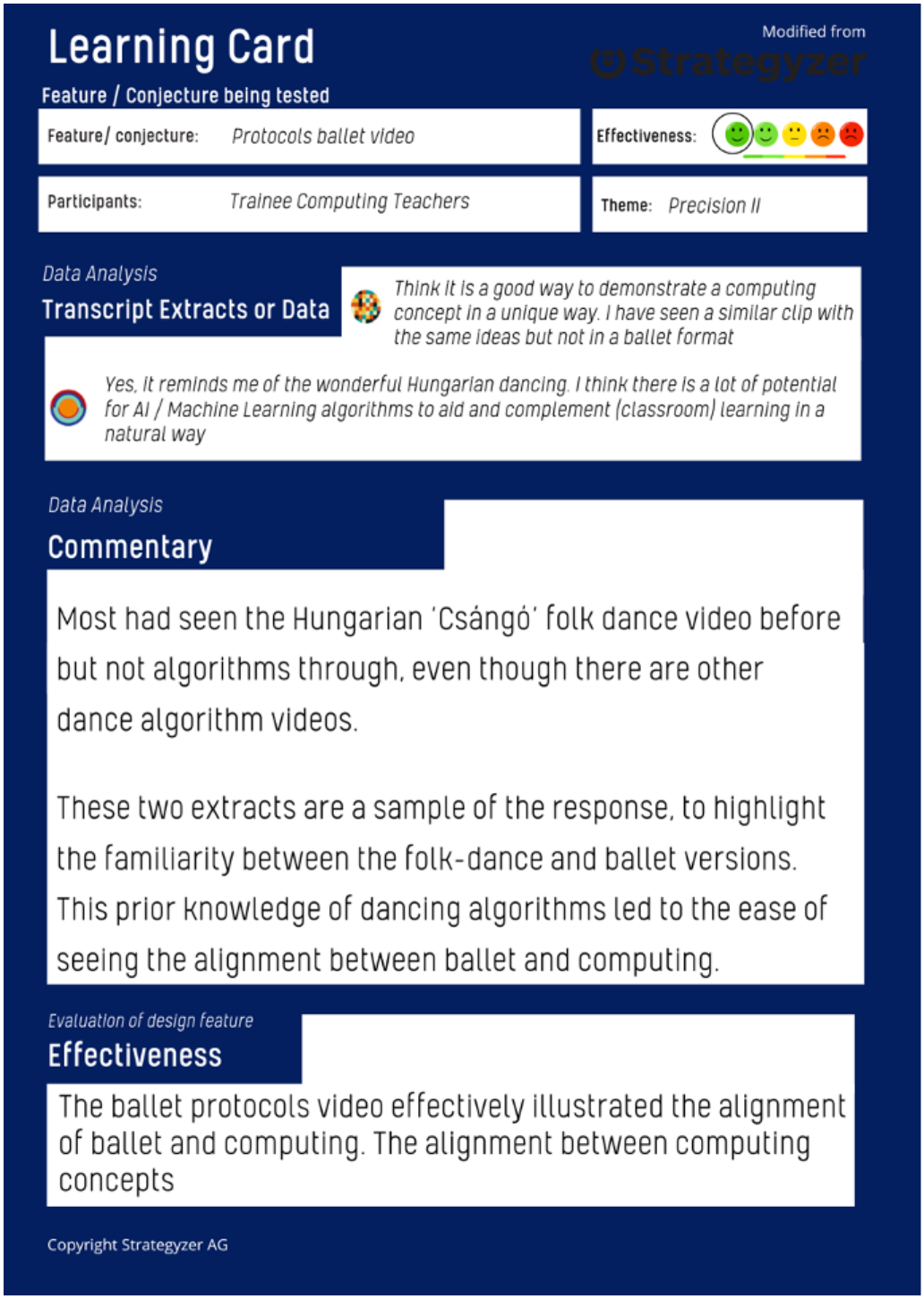


Figure 9.4 *Learn Card—Precision II* [*voice data*]



Ballet precision is used to demonstrate computing principles such as algorithm tracing, as seen in Figure 9.4's first extract. The second extract highlights the awareness of dance for computing extended to ML through the specific videos shown. The precision of ballet steps within adagios was easily understood by the dancers, and no explanation was required.

9.2.1.1 Non-conventional Movements

The dancers' extracts, highlighted in Figure 9.5, illustrate the complex interplay between ballet, technology, the data self, and ethics. Non-conventional ballet movements enabled an exploration of understanding through movement along with the possibilities afforded by XR technologies. Extracts one and two in Figure 9.5 demonstrate how the participants perceived dancing having watched the protocols video and envisioned their output for AR. They refer to notions of movement and creating non-conventional shapes with their bodies, which are then transformed into something different through the potential of AR.

The extracts suggest that the non-conventional movements of ballet increased technical challenges in this context. Ballet's distinct body placement and movement techniques posed challenges for replication using technologies not trained using ballet-specific data. Non-conventional movements offered an even larger barrier while recording dancer data, including not only EEG data but also genuine ballet moves. The third extract highlights how leveraging traditional ballet techniques and incorporating digital technologies makes it possible to generate movements derived from human input, but that these movements may not be physically feasible for human dancers to execute.

The technical challenges fell into the following categories: (i) keeping the whole body inside the recording frame, (ii) screen mirroring, and (iii) latency, or video delay. The extract below highlights these three areas, which were recurrent themes throughout the recording process.

Recoding the ballet while keeping the entire body in the frame was challenging when using both mobile and web technology. When videoing, the dancers repeatedly asked if their entire body was in frame. This brought a new dimension to online choreographic learning and performance.

I'm being conscious of recording, as it is not going to pick this up. [voice]

Figure 9.5 *Learn Card—Non-conventional Movements* [*voice data*]

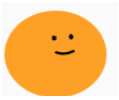
The second obstacle was spatial orientation when learning dances online. The participants noted that this method of learning differed from in-person sessions, as in the latter the teacher

would have their back to the dancers or dance on the incorrect leg, allowing the dancers to directly mimic the teacher's motions. The voice extracts below demonstrate the technological difficulties encountered while learning and recording ballet data from online choreography, which did not follow this familiar format.

I am struggling with the mirroring – is this on [zoom setting], which leg and direction is it?

Same for me

As each dancer was isolated in their own space with only a screen as the audience, latency was a critical concern. Because latency varied for each person during the session, the music and movements were not always synchronised between dancers. This was thought to be a distraction for the dancers when learning choreography online:



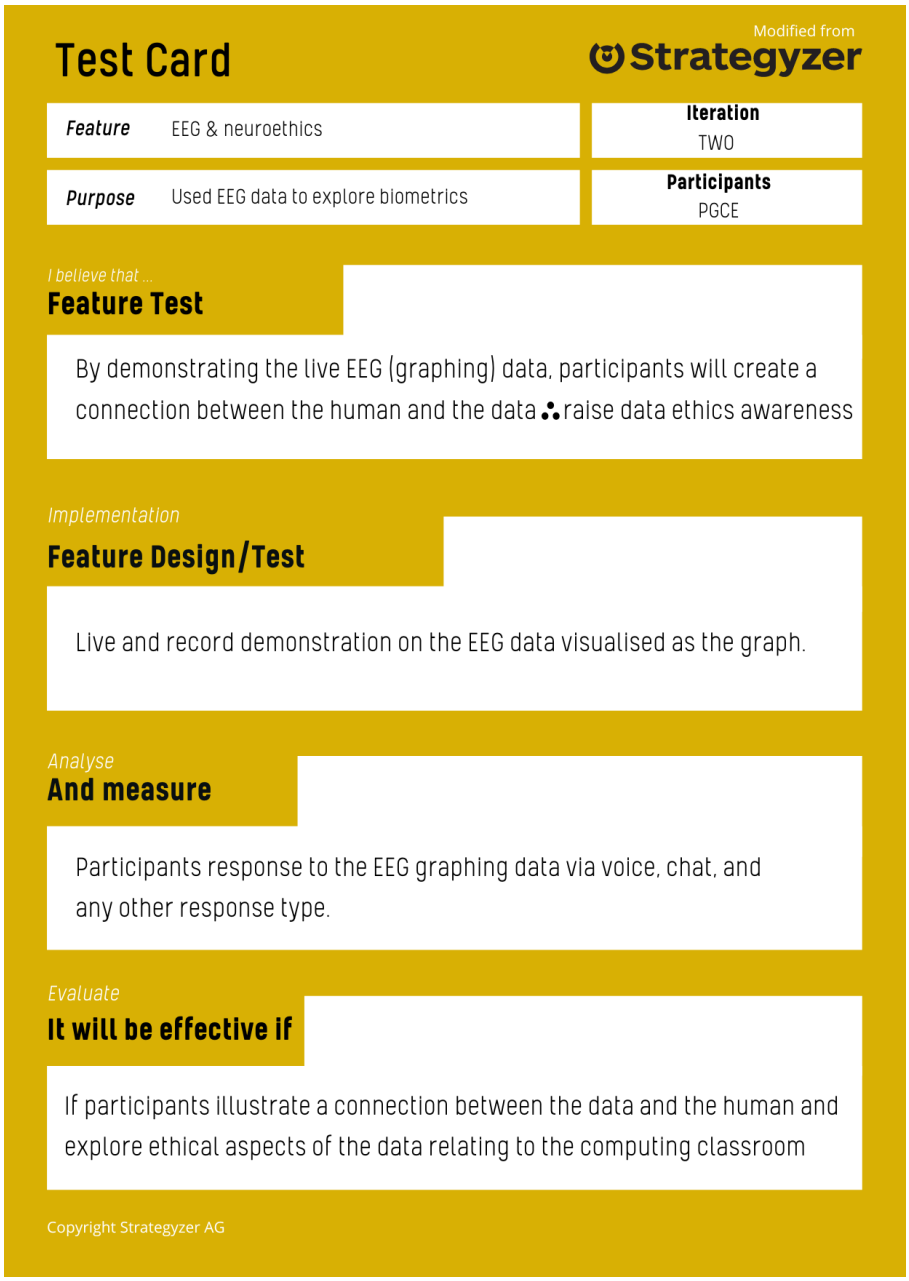
The delay [when using zoom] is annoying

The dancer stories included throughout these extracts humanised the biometric data, and offered an interesting perspective on the combination of the human with the data self. Additionally, shed light on insights into the pragmatic technical issues that could occur in a dance studio or computing classroom. Furthermore, the incorporation of technology into ballet contexts allowed innovative growth for ballet during the lack of contact that Covid restrictions necessitated. This online approach to learning ballet, the choreographer suggested, allowed for the discovery of new creative possibilities and the extension of the artistic boundaries of ballet's precise, non-conventional motions. These potentials/possibilities need further research that are beyond the scope of this study.

9.2.2 EEG (Graph) Test Card

The use of EEG graphing data feature explored the conjecture which different visualisation techniques created connection between the data and the human.

Figure 9.6 *Test Card—EEG and Neuroethics*



9.2.2.1 Planning with and for Technology

The two aspects of planning with/for technology following the use of the EEG graph and spreadsheet data outlined in Figure 9.6 that need to be considered are understanding the trainee as both a learner and educator. The first planning consideration uses technology as a tool to aid in lesson preparation and design, while the second uses technology to assist the teacher during the session. This dual theme emphasised the value of data-ethics when included as part of the planning and execution of computer education.

Figure 9.7 *Learn Card—Planning for and With Technology* [*voice data*]

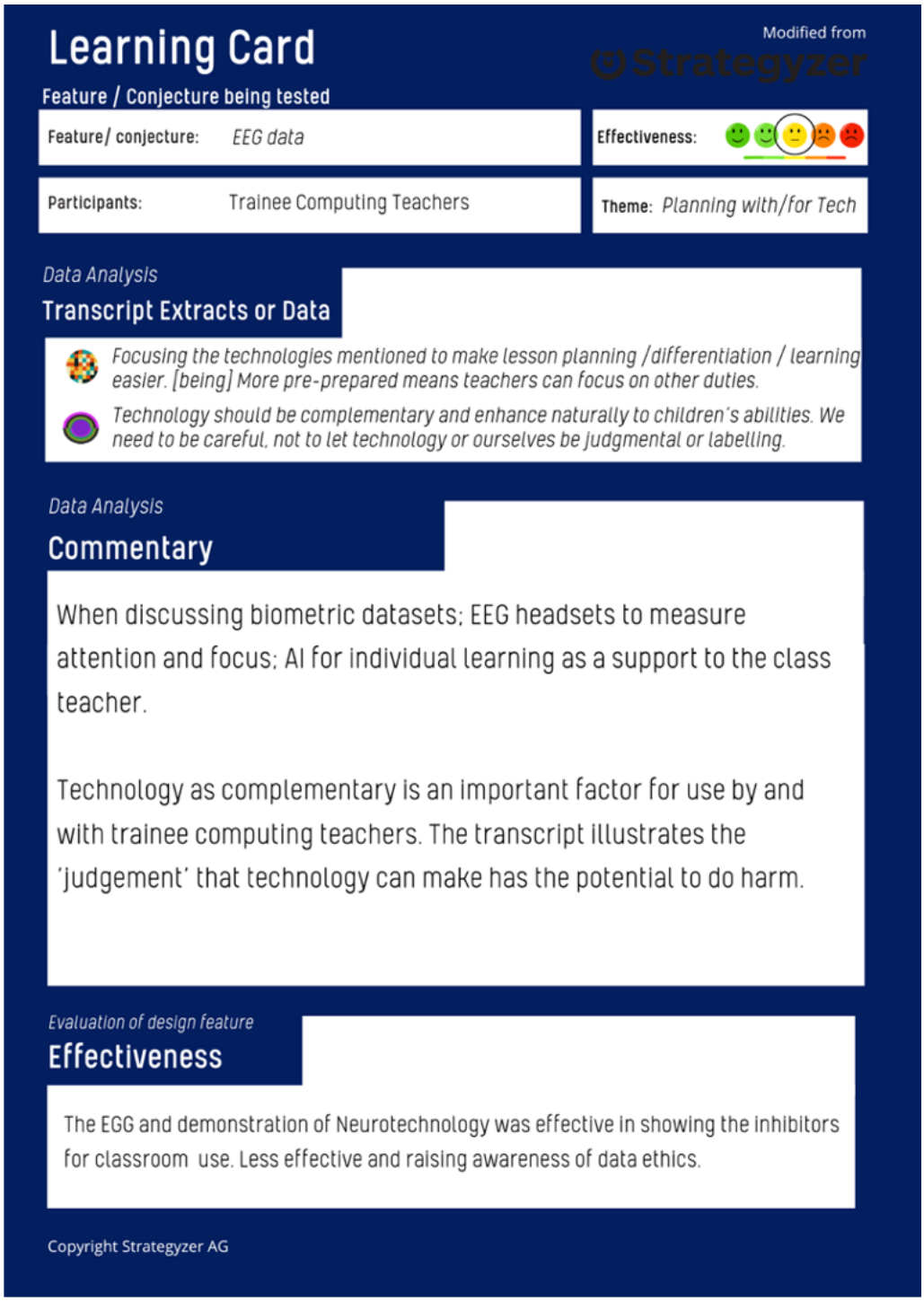


Figure 9.7, above, shows the experiential statements of trainee computing teachers, illustrating the possibilities and problems they could face when using neurotechnology. Biometric data, according to participants, could help learning in future classrooms by tracking brainwave activities that assess attention, focus, and even stress levels–similar to

Tang et al., (2023) EEG study measuring attention levels in blending CS university level classrooms..

They also proposed that by analysing an individual's brain activity, AI algorithms may uncover patterns and trends that could indicate areas of difficulty or misunderstanding and improve learning approaches accordingly. They also mentioned the lack of school policies or neuroethics of bringing BCI devices into their classrooms.

The chat feature provided further possibilities, such as the suggestion that emoticons could be used as a 'quick way to know if they [the students] are on track or lost.' The benefit of chat emoticons are that many students are accustomed to using emojis in everyday communication, and thus by including them into my study design, I linked by research to the familiar (Berges et al., 2021). Emojis were used as quick reaction gauges to discussions or activities, and they conveyed both negative and positive individual, real-time answers

From the choreographer's perspective, challenges included the generation of more digital dancers than human dancers. They also noted the unique nature of individual performances, which necessitated each dancer recording multiple versions of the dance piece in order to capture the sense of multiple human dancers:

There are only two physical dancers, but in my head, this choreography, there are four dancers. [voice]

Another area of concern was access to hardware/software inside the school environment for lesson planning, as well as the safety and risk factors associated with the given technology. The possible risks connected with using technology in the classroom, such as data privacy and security, as well as the implementation of appropriate measures to mitigate risk, were considered as follows.

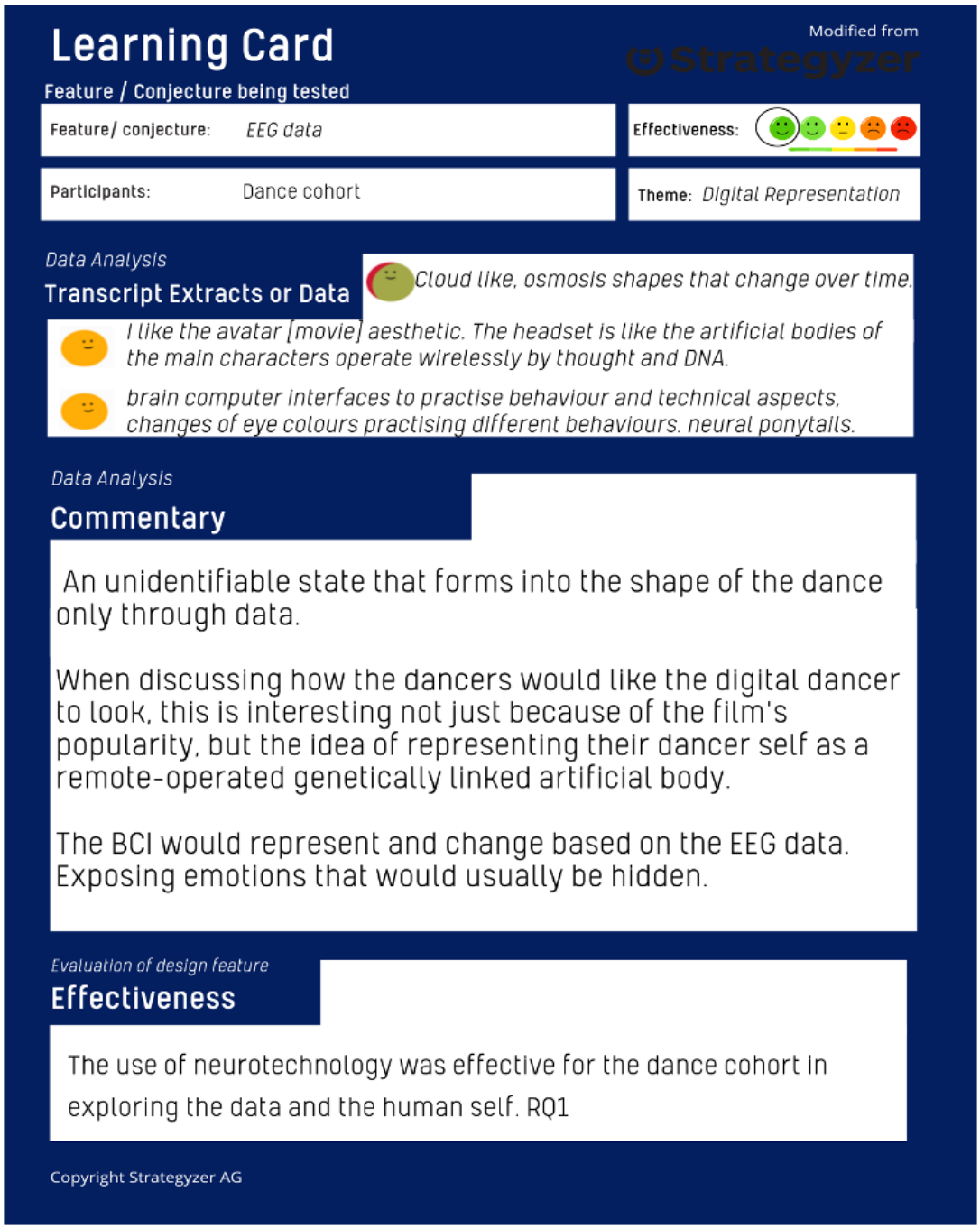
9.2.2.2 Digital Representation

Digital representation came in many forms for the dance participants, from watching their own brainwave data to the virtual representation of their dancer selves, shown in Figure 9.8. Although these ideas are distinct and separate, they were collectively spoken/written about in relation to digital/data representation of dance and data selves.

Figure 9.8 *Learn Card—Digital Representation* [*voice data*]

The dancers detailed their visual representations and how these changed throughout the study on Trello. The specifics covered how the biometrics could affect the virtual dancer's aesthetic effects. Each had a unique digital depiction, ranging from an unformed particle cloud to a character from the film *Avatar*. The extracts below relate to the visual, digital depiction of the dancers' digital data selves, specifically how their 3D model would appear as an AR character.

Figure 9.9 *Learn Card—Digital Representation II* [*voice data*]



The first extract, which suggests that the data embodies an unidentifiable state (the data self) until the dance begins, is particularly noteworthy. This concept touches upon the idea of representing one's dancer self as an osmosis cloud, continually changing and moving. The second extract draws on the idea of the artificial remote-controlled body, which is visually unidentifiable from the original dancer. This notion of the artificial body idea is linked to the movie *Avatar* and the concept of a wireless biped (Mitchel, 2003).

Participants noted their ethical concerns in revealing/sharing their hidden data selves, both in general and personal terms. The dancers' thoughts on ballet, along with their live EEG data, provided a deep and nuanced perspective on the link between the data self and the dancer self, revealing how these two states entangled and influenced one another.

9.2.2.3 Liability

In the interview with one dancer, concerns about insurance and liability as a self-employed dance teacher were raised, specifically in relation to dancer biometrics and the use of EEG devices. The participant was unsure whether their current insurance covered the use of this type of technology, and how this would affect the ability and cost of using this technology in dance studios generally).

I don't know if this is on my mind as ''ve just sorted out my insurance today but from an insurance point of view, like where does that money come in? Like as a [dance] teacher, you're responsible for your classes. How is that covered by insurance. [voice]

There are currently no clear insurance guidelines for dance teachers using biometrics. This concern is of utmost importance outside major enterprises or academic organisations, as liability and insurance constitute a significant cost of running a dance studio. This challenge could make using biometric technologies in these settings difficult, if not impossible.

9.2.3 Legislation and Control

Legislation and control are also critical concerns for trainee computer teachers, since they play key roles in the planning stages evaluated throughout the PGCE programme. Legislation and control considerations in connection to the teaching of GCSE or A-Level content, particularly when dealing with biometric data, were examined thoroughly. Although biometrics were not (currently) part of computing exams, participants indicated that an awareness of biometrics was significant in both their personal and professional lives. They mentioned scenarios ranging from unlocking personal devices using Live Facial Recognition (LFR) to fingerprint scanners used in some schools for logging into IT systems, libraries, and even to order lunch but not BCI devices. Figure 9.10 contains extracts that present both the

educational context and, to a lesser extent, the real-world context of these concerns and considerations.

Figure 9.10 *Test Card—EEG Education Study China*

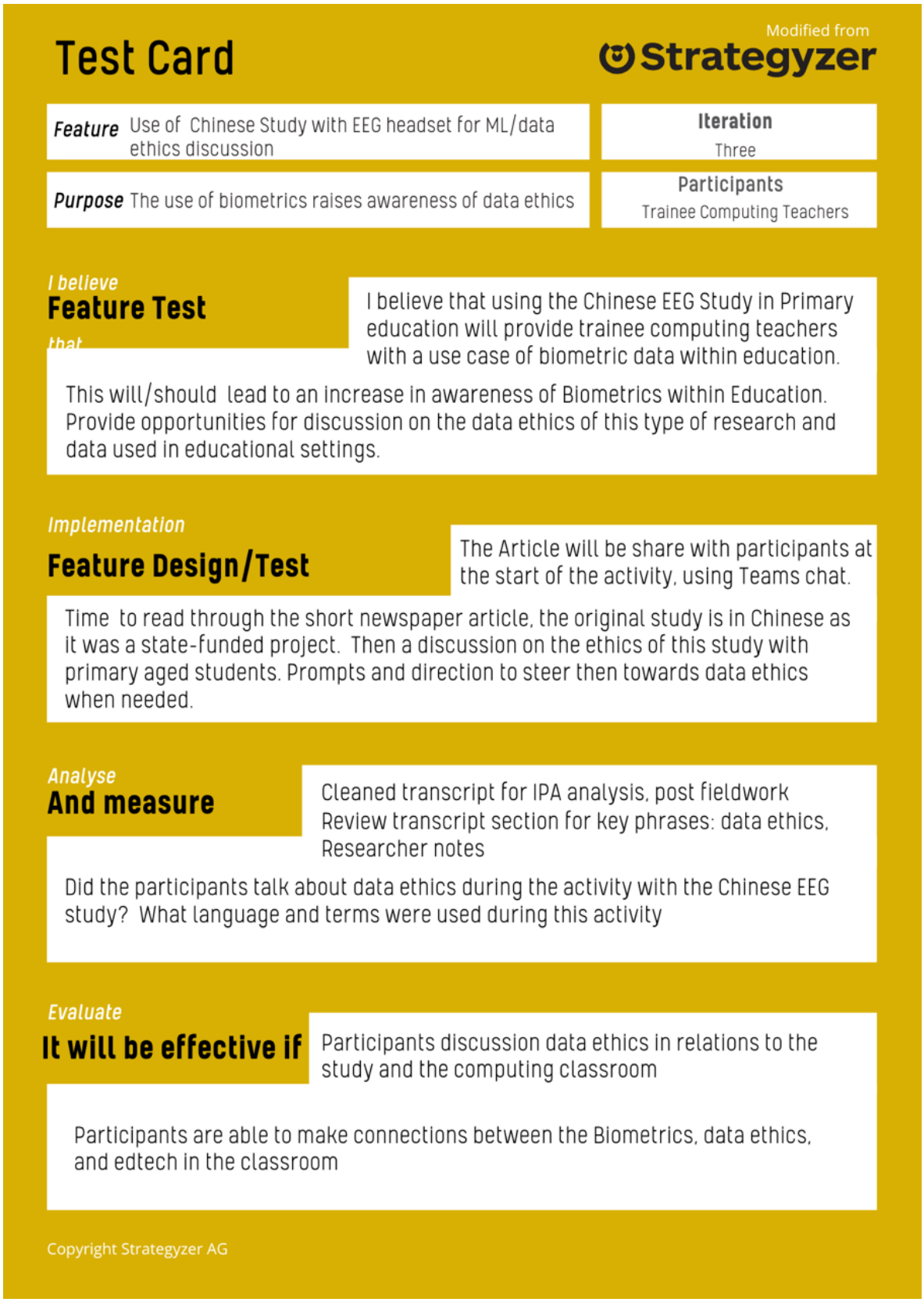
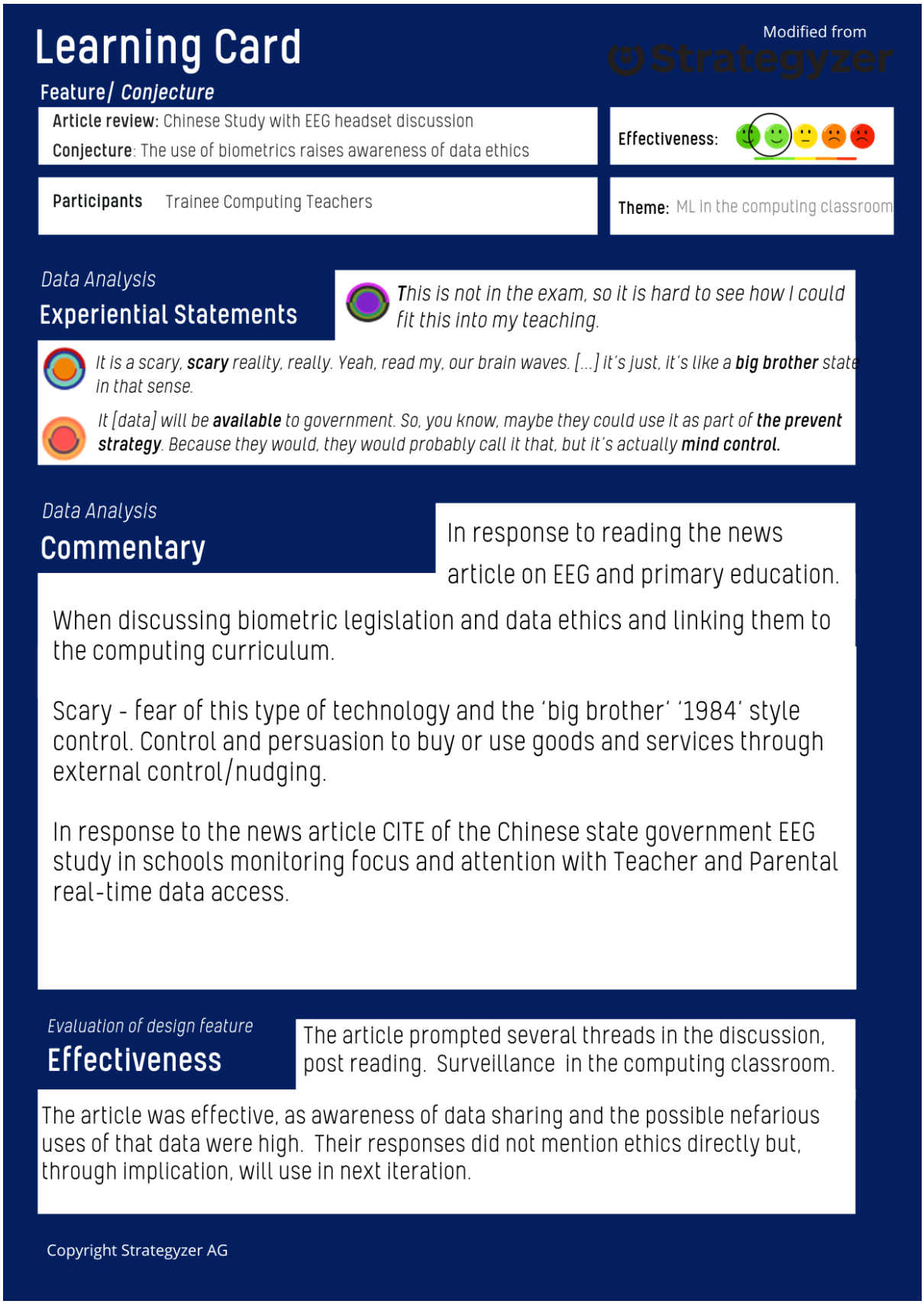


Figure 9.11 *Learn Card—Legislation and Control* [*voice data*]



The extracts in Fig 9.11 illustrate the importance of not only curriculum material but also the bigger issue of real-world biometric data or neuroethical challenges. There was a greater emphasis on the real-world ramifications beyond the curriculum in this iteration. One possible explanation for this was the allocation of resources prior to delivery provided more time for them to analyse their concerns. The past exposure from Iteration One could also have led to more in-depth thinking/discussion/engagement with data-ethics in computing in this subsequent iteration.

9.2.4 TEST 3D Model and P5.js

Risk is a recurring theme throughout both the personal and professional lives of trainee computing teachers. Risk assessment was viewed as an essential part of their professional duty as teachers, but taking risks, venturing outside one's comfort zone, and possibly feeling embarrassed were also mentioned when considering this theme.

Only one participant voiced the risk assessment issue, but the rest of the group swiftly agreed and emphasised the need to consider risk and undertake risk assessments when introducing new technology into the classroom. The first extract included below sets out a serious concern for all educators, but particularly for trainee computing teachers, who have less experience conducting risk assessments in an education context. Assessing any new technology may be their responsibility as computing experts in the school context. One participant reacted to the use of EEG equipment in the classroom as 'risk assessment hell,' following the discussion on legislation and control. The rest of the group responded mainly by emoticon or quick reaction response tools with the following emojis: with shock/surprise 😡😳😩😤 being the most frequently used emoji in the chat.

risk assessment hell [chat]

> The hardship and potentially damaging (to them as trainee teachers) use of EEG devices would need very careful and detailed risk assessment and parental consent to even have the device in the classroom. RQ1

Risk assessments are a regular aspect of practical lesson planning. This was highlighted when discussing risk assessments for biometric lesson planning, in which data privacy and ethical considerations were raised. Furthermore, risk-taking and **feelings of embarrassment** are important considerations when understanding the teaching contexts of these participants, who

taught teenagers. As educators, they should ensure that their classrooms are safe learning environments that encourage students to take calculated risks without fear of harm.

	I've run it. I'm just not. ***I'm not [admitting] danced around*** *though and admit to that.* [chat]	In relation to running the full body P5.js code. All participants were given a link access to the code to run individually. No one share their screen or had their cameras on. Refers to the idea of being embarrassed. RQ2

Despite the absence of an audience, the risk of embarrassment while dancing alone in the privacy of their own homes was a significant concern for the participants, which was surprising. Participants were invited to test the program individually to ensure that internet connectivity was stable, and that latency was not an issue, and to avoid the possible embarrassment of being asked to move around on screen in front of their peers. It was fascinating to note that these feelings of embarrassment persisted in private, justifying the necessity for supplementary coding exercises for Iteration Three.

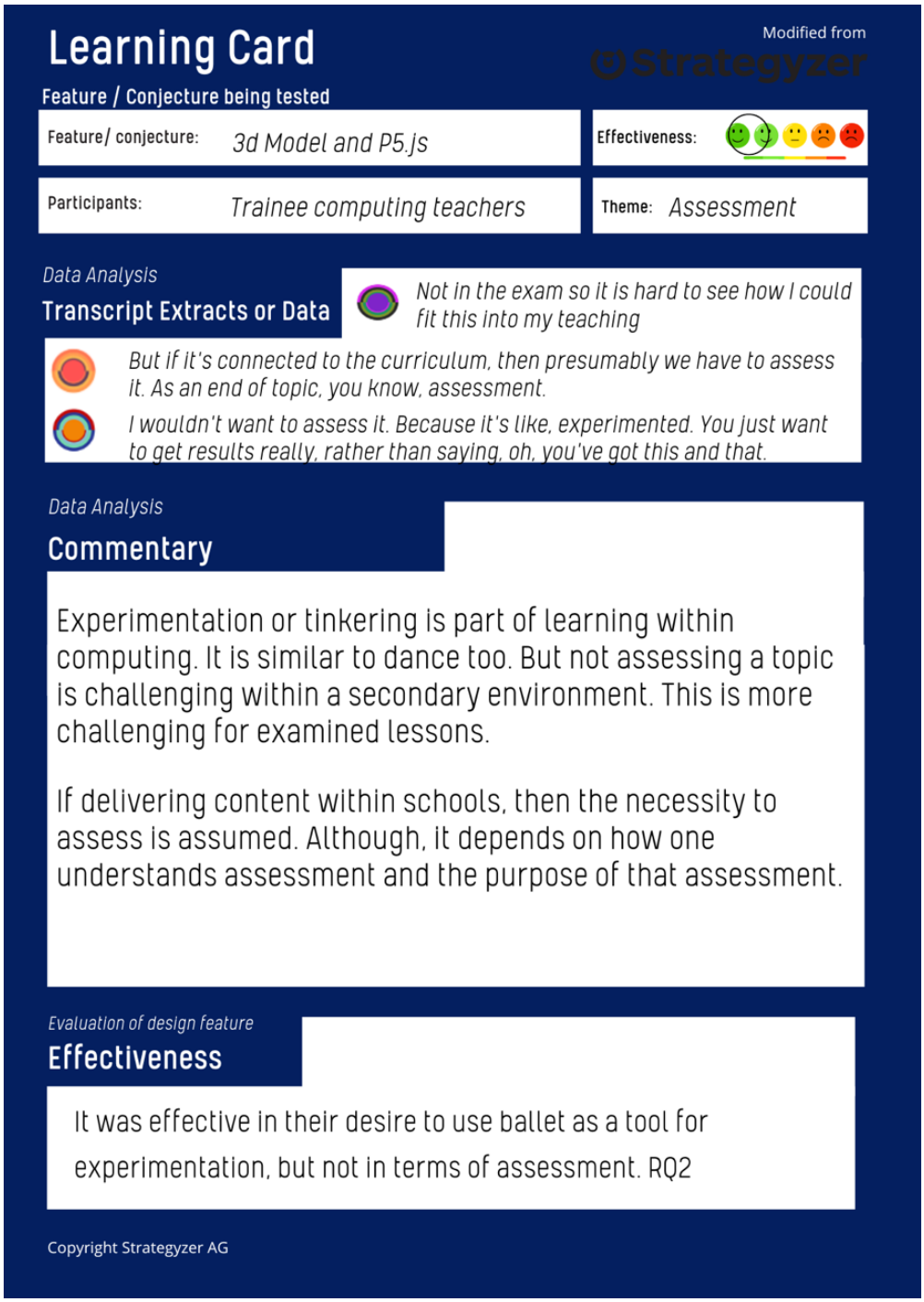
There were numerous concerns associated with biometric data monitoring, ranging from data protection to security. Furthermore, the participants suggested that biometric data could be used as a kind of assessment or to aid in assessment and progression in the computing classroom. Risk is an intrinsic aspect of being an educator in both cases. It was critical for trainee computing teachers to navigate these issues while dealing with biometric data, particularly when using non-conventional teaching and learning approaches and tools.

Risk was not covered when considering assessment themes, which was surprising. Participants spoke openly about curriculum, teaching, and learning connections, but not directly about assessment until prompted by me during discussion. I prompted the group by asking about assessment to help me understand what assessment meant to them. Although, assessing achievement is an essential element of their job as educators, they may have included assessment in their general thinking without overtly expressing it. The following excerpts in Figure 9.12, below, demonstrate the various reactions to assessment in both ballet and biometrics contexts.

The first extract shows the desire to use ballet as a tool for experimentation or tinkering, rather than assessment. This hands-on, exploratory method used in this iteration and

throughout the study as a whole, enabled more meaningful and interactive interactions with information, encouraging the formation of a stronger connection to data-ethics. However, the extracts show the 'need to assess' student learning in order to gauge progress and verify that academic requirements are met.

Figure 9.12 *Learn Card—Assessment* [*voice data*]



Participants viewed forms of assessment that involved biometrics or ballet as experimental. As a result, they might aid both teaching and learning by allowing students to demonstrate abilities in abstract/experimental ways or in ways that were indicative of real-world scenarios.

The findings from the education cohort, from the implementation and testing stages of Design Iteration Two, cover several themes: (i) legislation, (ii) planning with and for technology, (iii) risk, (iv) precision, and (v) assessment.

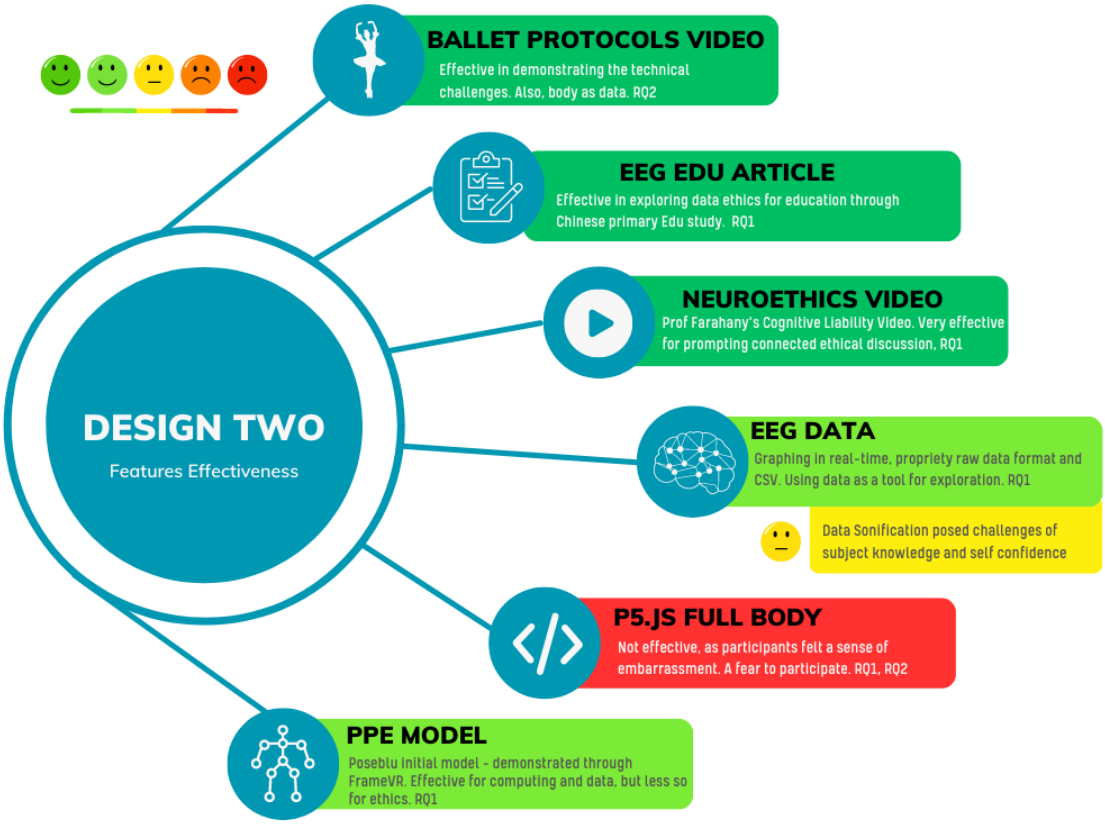
9.3 Summary of Design Two: Inspect and Adapt

The implications from these findings provided the aims for Design Iteration Three as follows: (i) to raise awareness of data-ethics by expanding curriculum opportunities within the topic of law and legislation, including liability; (ii) to reduce and/or remove the constraint of risk in terms of curriculum alignment and data recording; (iii) to build in opportunities for data-ethics discussions using digital representation from the dancer stories as part of the educator resources that work alongside programming activities. These led to new design principles for Design Three, see next chapter TABLE 10.1, born from feature/conjecture tests.

The embarrassment felt by educators, which presented a barrier to using technology in the classroom, needed to be mitigated, which led to the development of facial mapping code for the third iteration, to address this issue and to reduce/remove the constraint of technical challenges, which was identified as another barrier for trainee computing teachers. However, owing to external considerations such as internal network restrictions, time, and space, it is often difficult to totally remove technical constraints within the computing classroom.

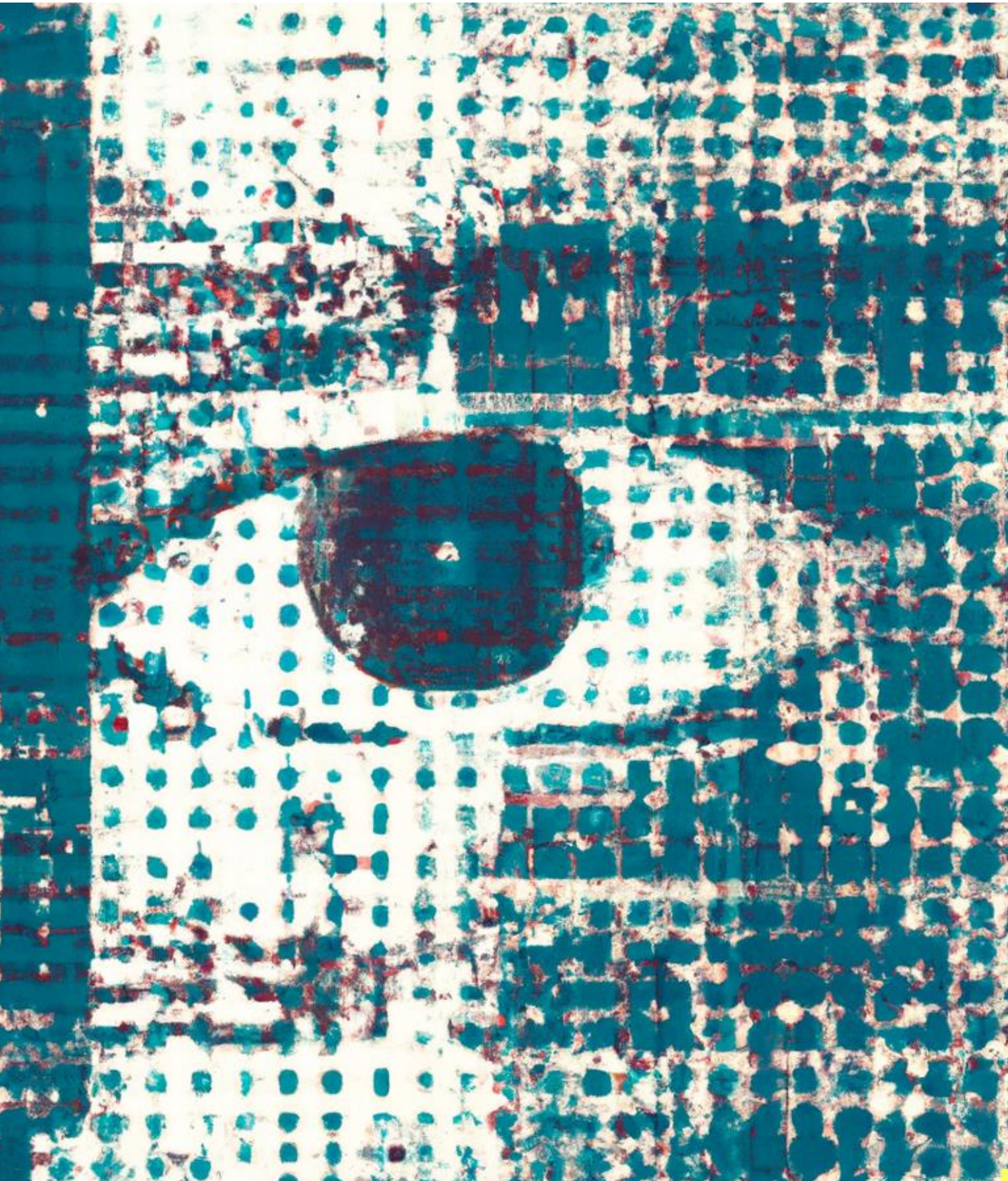
The key finding of this iteration are highlighted in Figure 9.13, which indicates the effectiveness of features and conjectures. The findings suggest that improvements and expansions are needed in the following areas: (i) including more dancer stories (related to RQ2) that incorporate programming activities to facilitate discussions on data-ethics in a computing context (related to RQ1); (ii) incorporating real-world ethical frameworks (related to RQ1,2); (iii) linking these frameworks to the law and legislation section of the GCSE exam specification; and (iv) making modifications to the programming activities.. The inspection and adaption process revealed that these changes were required in order to improve the overall design of Iteration Three. The next chapter presents the findings of Design Iteration Three

Figure 9.13 *Feature/Conjecture Effectiveness Design Two*



Chapter Ten: Implementation and Testing Design Three

Figure 10.1 *Dalle.2 generated image: findings prompt 'data-ethics, surveillance, education, future, abstract digital'*



10 Introduction

Iteration Three included new programming activities and expanded portions on data-ethics using real-world frameworks. Concurrent with the education cohort's workshop, there were several dance cohort sessions for learning the choreography and recording the performance for post-pose estimation. Biometric data were still used, but were modified to reduce the risk of embarrassment for participants. In this iteration, PGCE Computing teachers investigated the ethical implications of gathering data and analysing it in their computing classroom, alongside broader industry perspectives. They were able to identify applications of this knowledge in raising ethical awareness about data to some level. The main aim of Iteration Three was to explore and evaluate the iteration modifications and their influences on participants' awareness of data-ethics.

(i) The planning increment objectives and values (conjectures/design principles) for Iteration Three were: The use of biometrics leads to a **more personal connection** with data-ethics, neuroethics issues.

(ii) To investigate personalised biometric data and if it leads to **increased awareness ethical complexity** in terms of the dangers and distortions of computer algorithms.

(iii) To explore the potential of ballet as an **experiential pedagogical** approach to teaching and learning for some aspects of the computing curriculum.

Table 10.1 *Iteration and Development Principles Changes from Design Two to Design Three*

Design Two	Design Three
Need to establish clear links between classical ballet choreography and computer programming.	Need to establish clear links between classical ballet choreography and computer programming.
Should be able to form the connection between ballet choreography and programming a language, algorithm design.	Should be able to form the connection between ballet choreography and programming a language, algorithm design.
	Should be able to form the connection/identify that ballet choreography aligns with algorithms through a systematic sequence of steps for a given output, linking motifs with functions.
Should recognise what they currently know and understand about data-ethics.	Should recognise what they currently know and understand about data-ethics.
Should be cognizant that data-ethics as more than just legislation and legal aspects.	Should be cognizant that data-ethics as more than just legislation and legal aspects.

	Should be able to reflect on their own teaching and learning to develop new cross curricular links related to data-ethics and biometrics.
Understand what the barriers they believe exist in adopting ballet as a pedagogical tool in (their) computing classroom.	Understand what the barriers they believe exist in adopting ballet as a pedagogical tool in (their) computing classroom.
Should be able to explore cross curricular opportunities within PE and other subjects.	Should be able to explore cross curricular opportunities within PE and other subjects.
Should be able to expand places for data-ethics in the curriculum beyond sections on legislation and/or online safety.	Should be able to expand places for data-ethics in the curriculum beyond sections on legislation and/or online safety.
Should be able to link specific curriculum, specification topics to practical activities for both programming and discussion	Should be able to link specific curriculum, specification topics to practical activities for both programming and discussion.
	Engage in targeted programming activities that use biometrics without recording both for programming and discussion purposes.
	Should be supported to take risks and try (modify) new approaches/activities that aim to raise awareness of data-ethics

10.1 Implementing Design Three

Design Three continued to explore ways to raise awareness of data-ethics that were relevant to the computing curriculum. It also incorporated cross-curricular opportunities, programming activities, and teaching/learning experiences designed for PGCE Computing teachers. Due to the iterative and cross-functional nature this increment had a higher degree of specialised terminology and interdisciplinary comprehension. Dancers use of computing terminology within ballet context. There was a shared understanding between all participants, as the transition from studio to classroom context, knowledge, and settings. Trainee computing teachers explored into the possibilities and challenges of integrating ballet into a computing curriculum.

10.1.1 Session Design and Delivery

As with all previous iterations, the session started with a reminder of ethics protocols and the participants' right to withdraw from the study at any time, and that they could still participate in the learning if they chose to do so. As in Iterations One and Two, the session was

structured into three parts: the first section focused on ballet, the second on data-ethics, and the third on practical programming, with discussion opportunities throughout.

Alongside the session with the education cohort, there were several sessions with the dance cohort that aimed to capture additional biometric data and discuss the technical and ethical processes of participating in the initial development and prototyping of an AR ballet. The dance cohort's reflections on their participation in the study humanised the biometric data stories, making the study more personal and engaging.

The session with the education cohort began with a video starter activity that used ballet videos of skeleton tracking to emphasise the link between ballet and programming. This was coupled with the discussion prompt 'What are the potential consequences of unethical data practices when using biometrics?' Initially, this was a general discussion to encourage the trainee computing teachers to think beyond the constraints of curriculum or exam-board specifications.

The ballet segment of the education cohort's workshop emphasised skeleton tracking and XR by using still photos and short clips from the AR development. These videos and the ensuing discussions highlighted how the technology captured detailed data about dancers' movements and positions. This led to speculation in the discussions about how such technology could be used to collect data on individuals without their knowledge or prior consent, as an intrusion on privacy and/or an exploitation of personal data.

The second part of the session introduced the most current and publicly available data-ethics frameworks available at that time: the Gov.UK (2018) and the Open Data Institute (ODI, 2020) frameworks, developed by the ADAPT Centre for Digital Content Technology for the ODI. The data-ethics canvas itself is an adaption of Osterwalder's (2010) business model, which reflects the Agile processes and practices that are central to this study.

The concept of embarrassment arose from the discussions with the education cohort in Iteration Two, particularly when the full body mapping code was included. I developed the P5.js facial mapping to combat this sense of embarrassment. The body and facial tracking code was followed by data sonification which aimed to explore potential cross-curricular routes into education. Another P5.js activity I added in this iteration, paired microphone volume levels with simple shapes (see Appendix 10A). I chose full-screen over camera view

because the goal was to introduce additional coding activities as well as possibilities for discussing personal biometric data-ethics.

Data sonification of biometric data led to discussions about expressing emotions through sound using tools such as Sonic Pi™ or programming with Python (see Appendix 10B). Several participants were not familiar with Sonic Pi's coding language (Ruby) and therefore felt apprehensive about their coding competency. To address this issue, we moved back to coding within the P5.js environment and continued with the audio example mentioned above.

Throughout the discussion, I emphasised the relevance of the ethical implications of collecting and using personal data as educators. I urged participants to think critically, both as learners and educators, about how technology may be used to help society while still respecting individuals' privacy and autonomy. Coding excellence as a technique was never the end goal, but rather a mechanism that potentially addressed both the study and the participants' data-ethics and computing educational needs.

For this session the following features were tested and are discussed through IPA themes in the rest of this chapter, illustrated through the use of Test and Learn cards. Table 10.2 provides an overview of the features tested in this iteration and how these link with the central research questions of my study.

Table 10.2 *Design Three Features-Conjectures*

Feature(s) being tested	Conjecture/Purpose	RQ
PPE Model Hosted inside FrameVR	Same feature as Design Two, but to demonstrate errors and further explore webVR tools. Participants should be able to see opportunities for creative computing mitigating risks related to coding competency	2
MS Learn: Security Fundamentals Course	Through collaborative exploration of the Microsoft Security Fundamentals course, participants can establish a connection between computing education concepts and theories, leading to an improved understanding of data ethics awareness.	1
Coded Bias Video Clip	By watching Coded Bias clip, the participants will have a greater appreciated of human data surveillance, thus increasing their awareness of data-ethics	1
EEG Graphing Video Raw Data csv	Participants were able to visualise the hidden nature of biometric data introduced in Design One. Data generation of an EEG headset produces massive amounts of data. Participants' exposure to a simple spreadsheet tracking a person's EEG data made this process less daunting (image of dancer wearing headset with graph displayed).	1,2
P5.js Facial Mapping & Audio code	The JavaScript coding activity aimed to increase risk-taking by reducing embarrassment to create a closer personal connection to the real-time data. Also being playful with the code to increase engagment	1,2

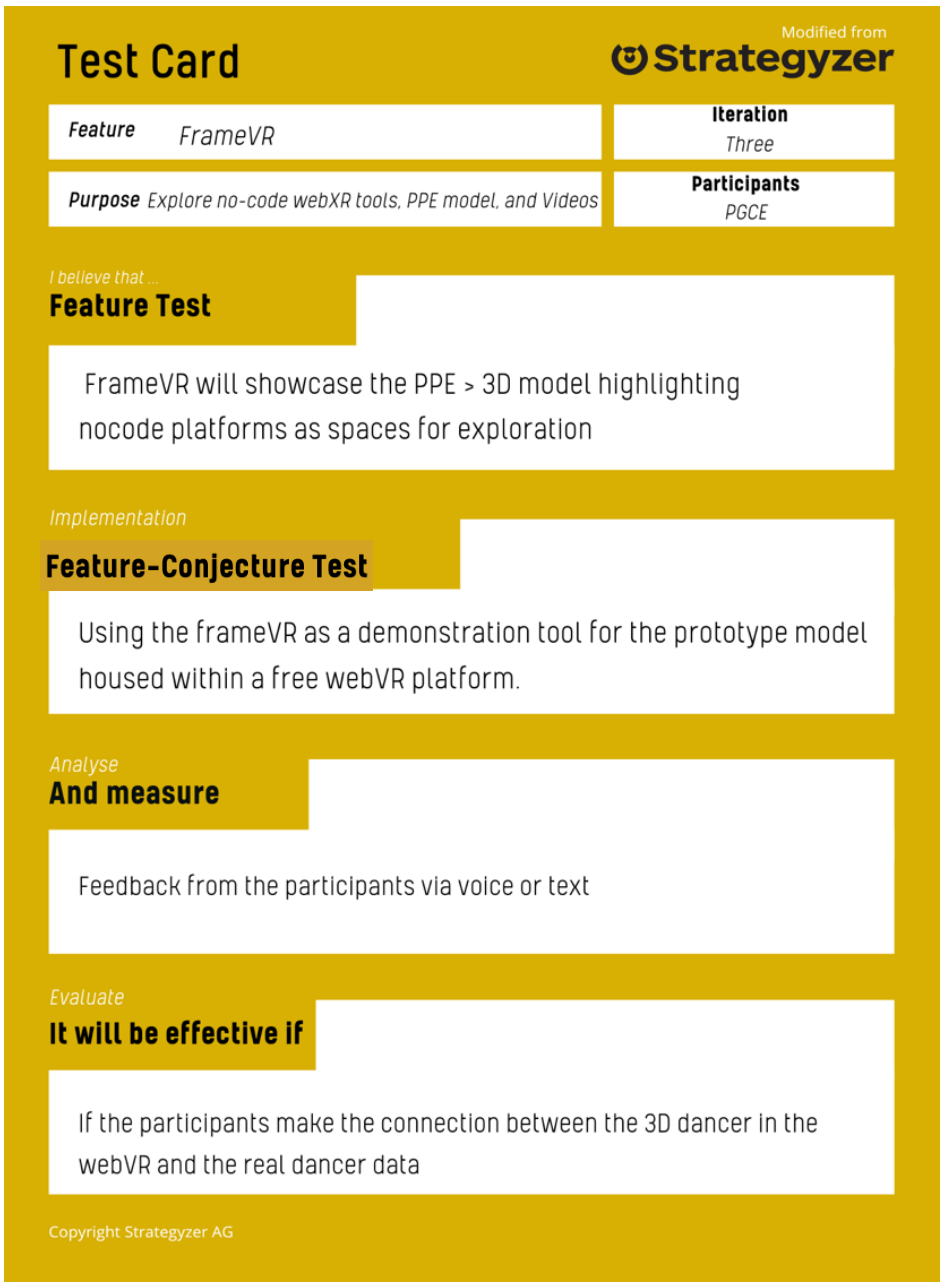
10.2 IPA Analysis

This section explains the findings from each feature of this iteration: (i) FrameVR, (ii) the MS Learn Online Course, (iii) neurotechnology, and (iv) the P5.js coding activity.

10.2.1 FrameVR Feature

The feature FrameVR presented several themes but access in terms of hardware and software was the main experiential statements.

Figure 10. 2 *Test Card—FrameVR*



The use of FrameVR in this iteration presented several challenges and discussion points, but the main issue raised was access, both in terms of hardware and software, particularly through the introduction of the EEG headset. Access to the appropriate technology was a fundamental design principle for the study from the initial scoping pilot and through each iteration, including the development and use of web-friendly tools. Using familiar technology enabled participants to interact with the study with ease, but engagement fluctuated as the study progressed. Though 16–18 PGCE teachers were logged in throughout the study, degrees of interaction varied across these participants

Access to technology and the digital divide were identified as barriers to implementing these types of technologies in schools, especially when considering the cost and the benefit to students (see Figure 10.3). Participants described poor or outdated hardware and software in several of the schools they visited during their teaching placements. The Covid context of the study added an interesting perspective on the cost issue outlined in these discussions, as remote distribution of teaching was a particularly pertinent issue at that time. Figures 10.3 and 10.4 depict participants' comments and reflections on the idea of making room for technology in reaction to a debate about Covid/access to teaching and learning. This debate led to a discussion about access in general for the computing classroom. Figure 10.4 illustrates the use of FrameVR as a way to share the 3D working prototype without the need for complex tools. The PGCE Computing course had already covered 3D modelling through the use of Blender ™. The discussion then moved on to the possibility of using opensource software to create the 3D model and its possible use in schools.

Figure 10.3 *Learn Card—Access* [*voice data*]

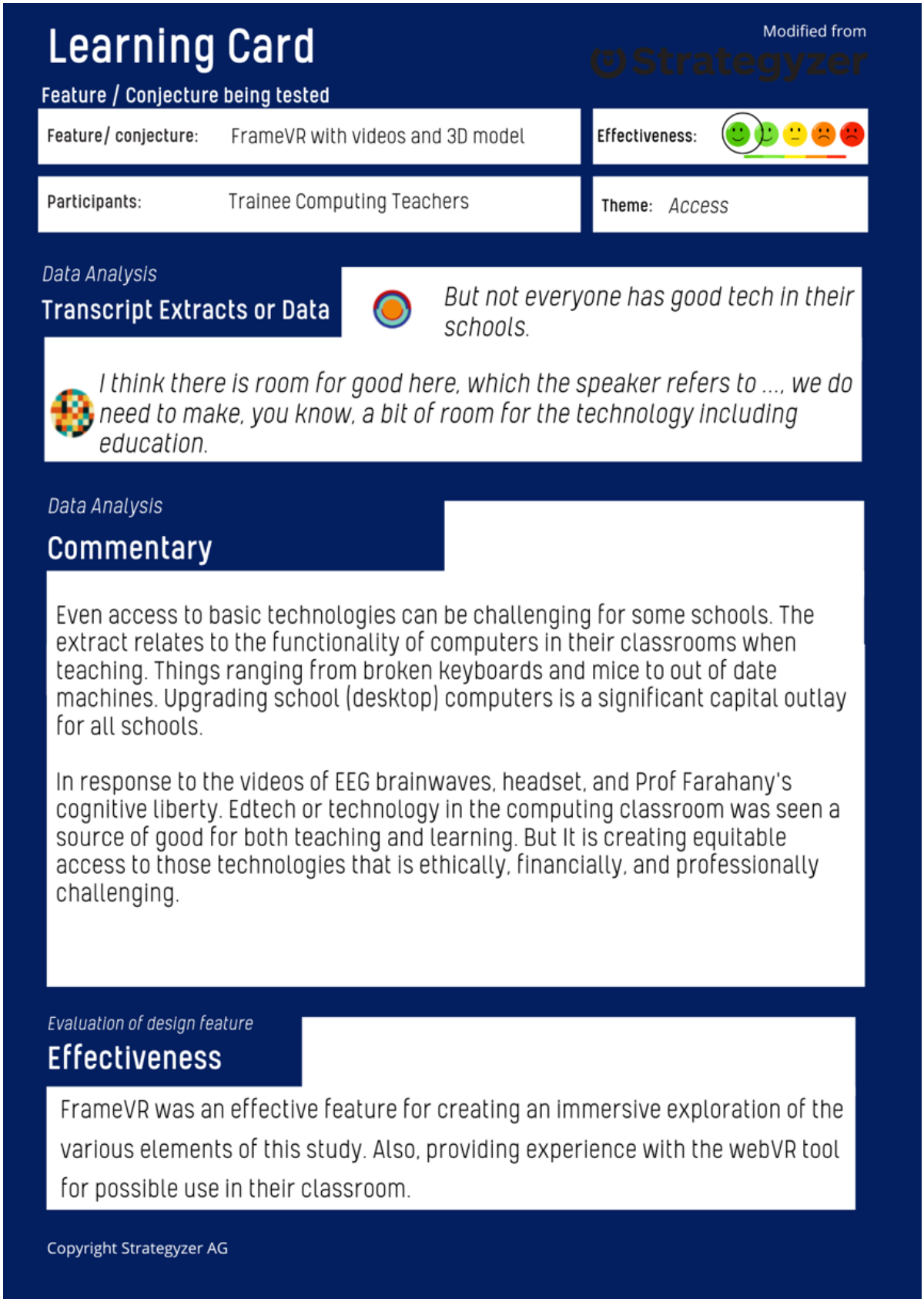
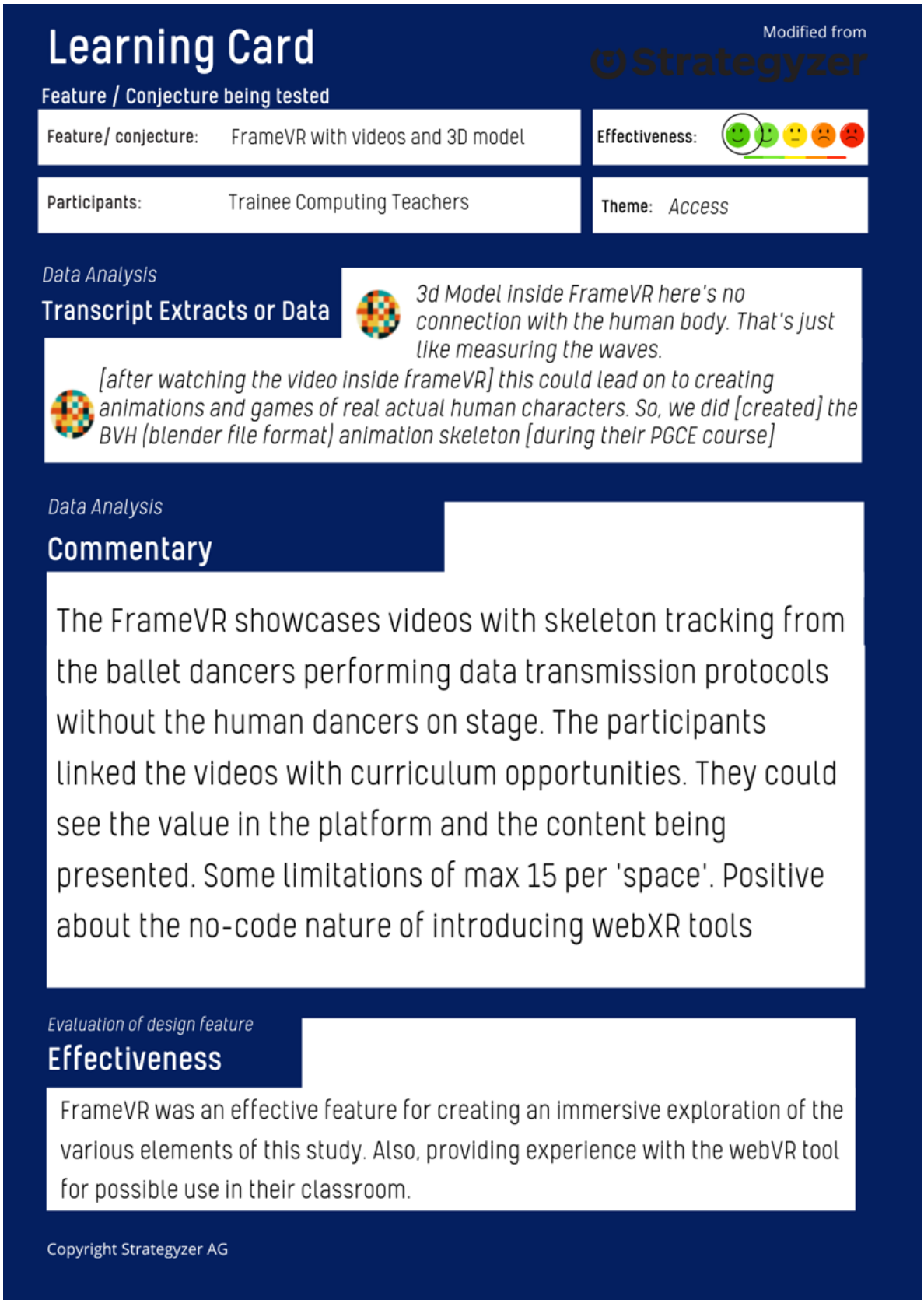


Figure 10.4 *Learn Card—Access II* [*voice data*]



One participant drew my attention to the limitations of access to software when they noted that their school did not allow the use of opensource. No reason was given for this limitation, but it does align with my personal experience of such restrictions in secondary schools, in which reasons included security risks, external access to students' data, and management of the software. This limitation of access to opensource tools could also include the PPE models used in this study, which is a significant obstacle to my research.

I examined these access limitations in light of wider concerns about digital privacy and surveillance under the umbrella subject of data-ethics. The participants suggested that raising awareness of data-ethics in and for computing would be difficult without access to teaching materials such as these.

10.2.2 Neurotechnology

This section explores the findings from the various EEG data features through the following themes: (i) understanding the brain, (ii) body becoming data, and (iii) the complexity of computing.

The theme of understanding the brain arose from the session, first when discussing cognitive liability and EEG data in a real-world context, and second when demonstrating the Emotiv™ headset with real-time, raw data and data visualisation softwares. PGCE Computing is not a neuroscience course, but educational neuroscience does have a significant role in this education. This role is, however, beyond the scope of this study.

Several sub-themes were identified within the theme of understanding the brain, as outlined in Figure 10.5: (i) a general understanding of how learning occurs in the brain for educators, leading to a greater awareness of how students think in real time; (ii) practical implications for teaching and learning; and (iii) the theoretical and conceptual implications of theories of learning, including teacher education. Methods for reflecting on and improving participants' teaching techniques or the resources utilised for lessons were also discussed.

Figure 10.5 *Learn Card—Understanding the Brain* [*voice data*]

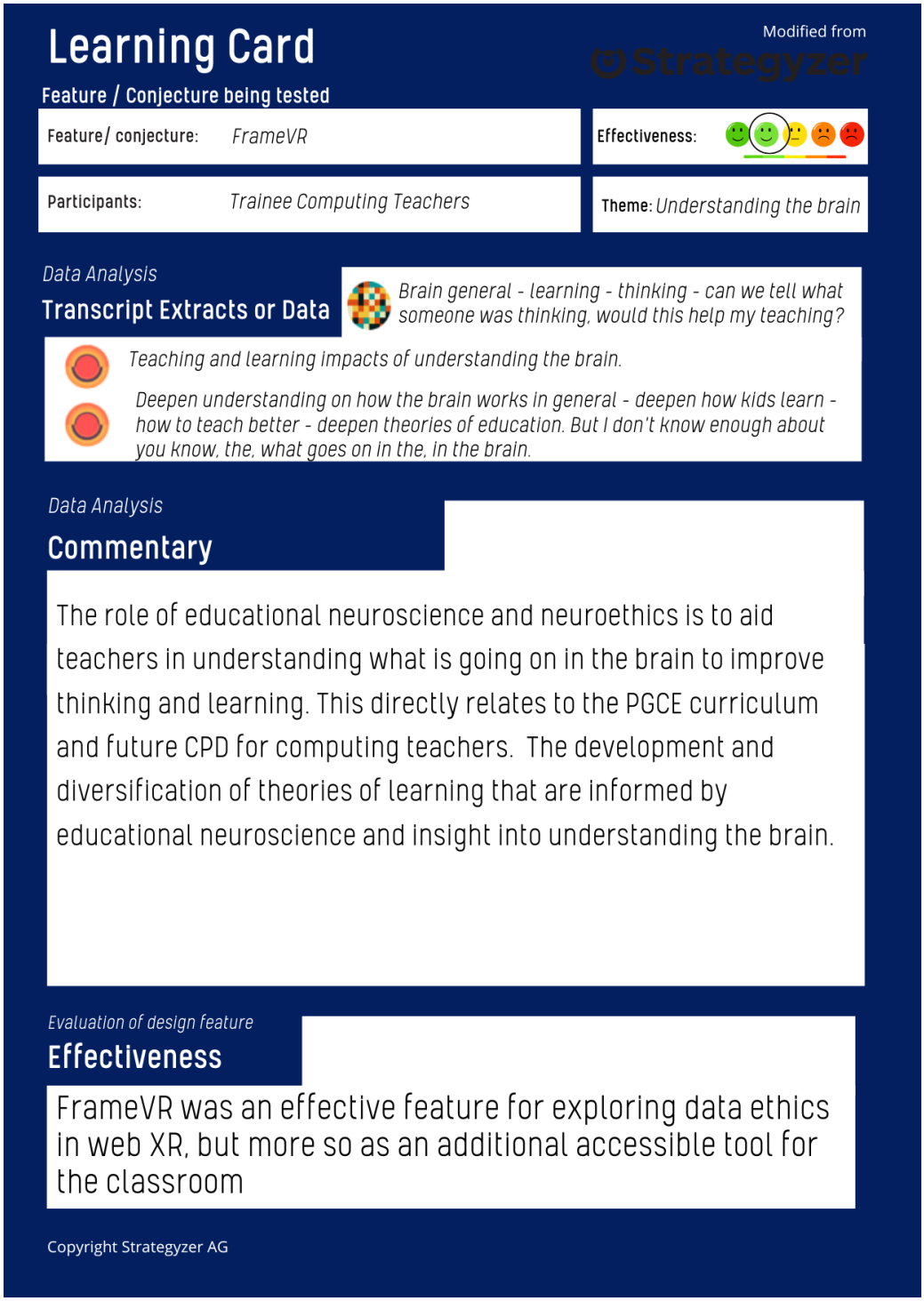


Figure 10.5 outlines how the practical implications of a wider awareness of the brain could inform the design and implementation of effective educational strategies and procedures. Participants suggested that understanding the brain could potentially provide insights into the cognitive processes underlying learning, leading to the development of more effective

classroom resources. Interestingly, they discussed the continuous professional development opportunities that were possible for qualified computing teachers, but not the possibilities for learning this content at PGCE level. The focus of discussions rested on the post-training phase of their careers rather than seeking to alter the PGCE curriculum itself.

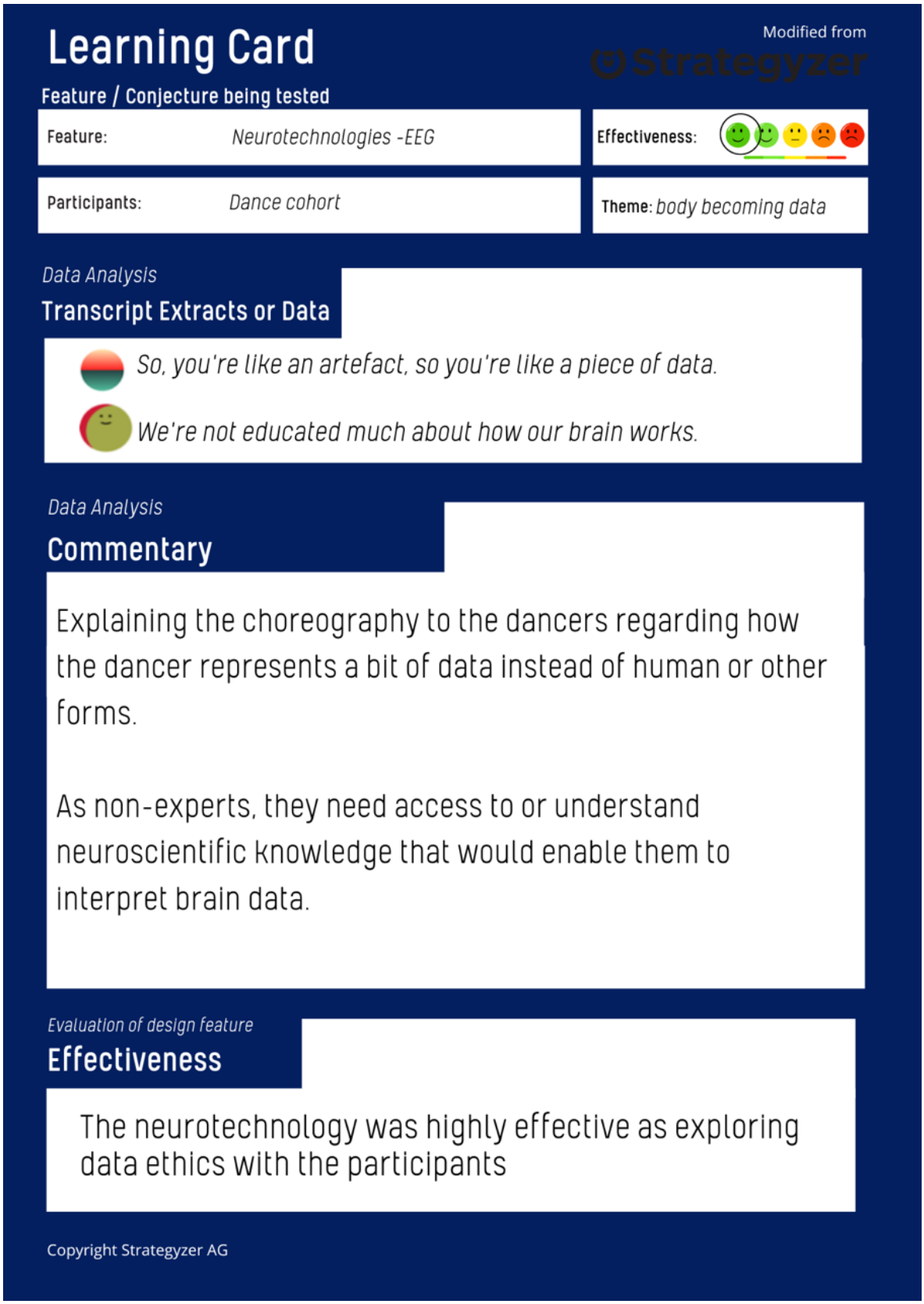
This theme of understanding the brain was connected to the potential future benefits of educational neuroscience. The last extract in the table above expresses that greater engagement with theories of neuroscience could contribute to the evolution of learning theories through expanding our understanding of how the brain processes and retains information. This feature is particularly important in learning to program. Disappointingly, there was very little expanded discussion on the ethics of understanding the brain in a neurotechnological context, other than establishing the need for guidelines and codes of practice. The third extract in Figure 10.5, above, indicates the link between knowing the brain and learning extension theories, but evidence of this knowledge is limited.

Body Becoming Data

The body as a data artefact was a recurring theme throughout most sessions with the dance cohort. Fitzgerald (2023) also observed 'body as tool' with their Ballet participants, similar to how body-data is a non-human tool, drawing on Bayley, 2018, see 3.2.1. Often this wording was used to refer to the ballet choreography and sometimes it was used to discuss ethical questions about the combination and coexistence of the human and data selves.

The dance cohort were able to fully experience the body becoming data, since they had access to the EEG headset, which they used to collect data during the study. The PGCE teachers did not have this access, and so the responses collected from each cohort are markedly different. The extracts, 10.6 below, track the dancers' experiences in relation to the theme of bodies becoming data/data artefacts, manifested through real-time data expressed in graph form or shown via the EEG headset.

Figure 10.6 *Learn Card—Body Becoming Data* [*voice*]



The choreographer used similar wording to the first extract in Figure 10.6 throughout the study. This similarity is expressed in the following [voice] extracts about transdisciplinary confidence:

the body as a tool, and as a data set [C49-50]
you're like an artefact, so you're like a piece of data [C44]
that is kind of the data but also the person at the same time [C12-13]

The following statement concerns the dehumanisation of personal EEG data represented in a spreadsheet.

[brainwaves] just comes out numbers in an Excel. Your brain data as well as your body becoming data, that's where the data-ethics discussion comes in.

After witnessing their own and each other's biometrics from EEG data, skeletal tracking, and eventually the AR prototype, ethical discussions of the body as data were instigated, especially when inaccuracies were noted in these data.

The **complexity of the computing** concepts driving the DDD project reflect the intricate ballet techniques that underpin the flawless, effortless aesthetic of the dance. The challenging and initially complex nature of recording the dancer data both in terms of learning the choreography and from the technology perspective also exemplify the hard work and iterative nature of both computing and ballet.

The first extract in Figure 10.7 depicts the body as pieces of data that are different but entangled and connected together. The extract also references the seemingly effortless movements of ballet that are in fact complex and challenging for novice dancers. The second extract mentions the 'crazy internal race,' referring to their reactions when viewing the EEG data while dancing. Furthermore, they spoke of ballet as an 'effortless façade' hiding the frenetic and complex EEG recordings. This duality of effortlessness and complexity was mentioned several times by the dance cohort during and after recording or when watching their own data.

Figure 10.7 *Learn Card—Aesthetics & Complexity* [*voice data*]

On watching the dancers' EEG data videos, the PGCE teachers carefully considered the potential risks and benefits of using biometrics in the classroom, especially in relation to EEG headsets. I am equally cautious about the potential of this technology within educational settings owing to the neurophysiology of the young and the future implications. Accordingly, there is a need for clear ethical guidelines for the use of neurotech in education. The

following discussion moved towards the potential implications of this technology in the computing classroom, and participants noted that they would 'approach with caution' any use of this technology owing to its potential to dehumanise, particularly when using the EEG data spreadsheets.

Just a number, Skynet here we come [chat].

The extract above jokingly refers to the popular cultural 'Skynet' technology, depicted in the film *Terminator*, which takes over the world and reduces humans to data and batteries. This response was met with agreement and positive emoticon reactions, which indicated the group's concerns about the disconnection of individual humans and humanity from data. Access to technology and digital communication tools were identified as a potential benefit to raising awareness about data-ethics for PGCE Computing teachers. Digital privacy and surveillance, two key areas of data-ethics, were discussed, especially external factors such as profit-driven surveillance and the monitoring and collection of student data. When discussing the possibilities of using biometric data, participants were quick to note the potential harms, particularly in relation to making decisions about individuals based on data collected in this way, and the need for informed consent. The use of ML in the computing classroom raised issues related to potential biases in data and algorithms.

The theme of understanding the brain occurred when considering how technology could enhance or alter human cognition. The ethical implications of collecting and using brain data were discussed alongside the disassociation of data from the individual and potential dehumanisation through data. Overall, the findings illustrate the significant gaps in data-ethics education for PGCE Computing teachers.

10.2.3 MS Learn and Coded Bias Clip

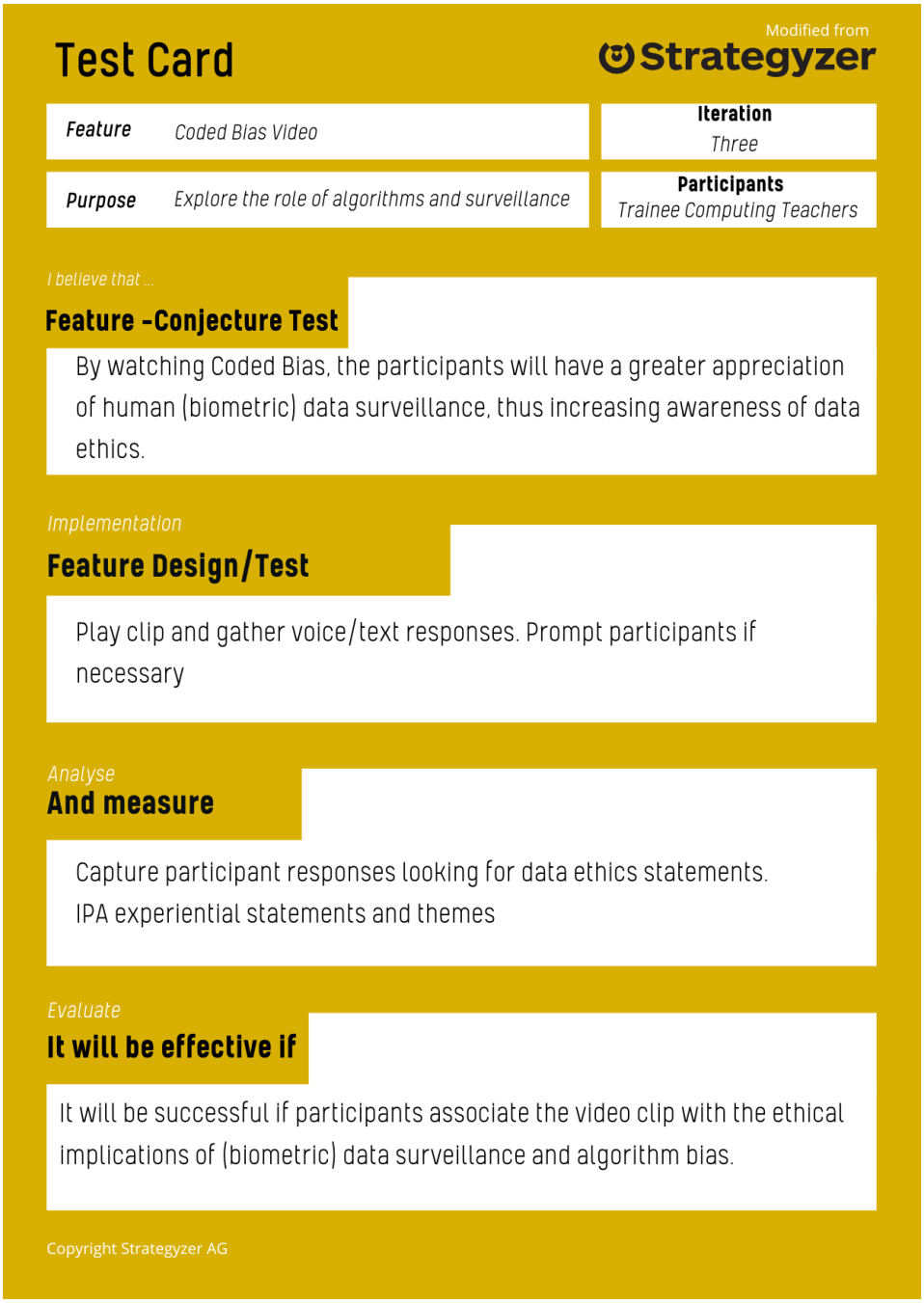
Microsoft's 'Security Fundamentals' online learning course was demonstrated during the session, and was followed by a short clip from *Coded Bias* which exemplified the racial biases inherent in facial recognition software. This video was very impactful, and sparked some very interesting discussions among the participants. The discussion around this session focused on: (i) real-world experience, in which the participants considered surveillance for profit, including motion and facial recognition data surveillance in public places (Figures 10.8 and 10.9); and (ii) classroom experience, in which participants considered their own experiences or predicted how these issues may impact their classrooms. The course prompted

discussions about surveillance, particularly when linked to the use of neurotechnology. Though the course was a useful source of materials, the participants noted that the surveillance information and learning was most beneficial for their data-ethics education.

Participants shared their experiences of external pressures surrounding data use, monitoring, and control, including pressure from the government and corporate organisations, as shown in the feedback in Figure 10.10. This led to 'classroom surveillance' that included student data surveillance, continuous monitoring, and data capture inside schools to test data that is linked and traceable to the individual.

Figures 10.8 *Test Card—MS Security Fundamentals*

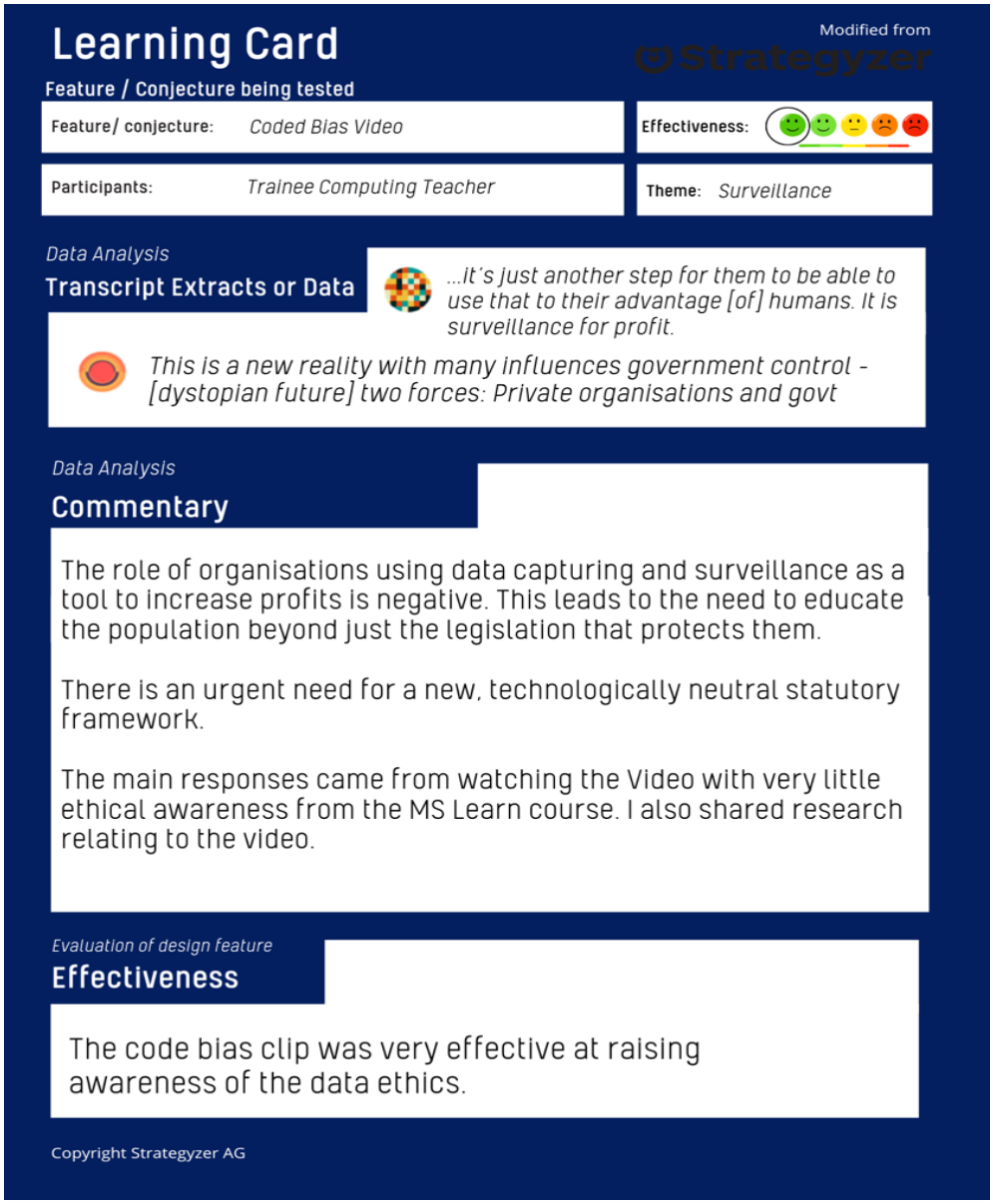
Figure 10.9 *Test Card—Coded Bias*



Participants reflected on the massive amounts of data captured in everyday society, and particularly for them as classroom teachers (chat, transcripts, see section 10.2.4). This increase in data generation and collection sparked serious concerns about privacy and the exploitation of personal information in their role as computing teachers. Subsequently, their understanding of data-ethics was clearer and affected the programming tasks and their perspectives on the dancer data after this session. In contrast, however, there was less ethical

awareness during discussions about surveillance. The next section discusses the biometric data capture features which also fall under the surveillance theme.

Figure 10.10 *Learn Card—Surveillance [voice data]*



10.2.4 P5.js Feature.

This section explores themes of surveillance alongside the ML/AI coding activities carried out in this stage, which used P5.js to consider the role of ML in creative computing. Using P5.js programming activities and the post-pose estimation software allowed for more nuanced and in-depth observations of the participants' digital/data environment, which could not have been accomplished by theoretical or legislative conversations alone. Interestingly, it

became obvious that the embodiment of these aspects of learning in programming and face mapping led to a closer link between individuals and their data-selves.

The PGCE teachers continued to discuss the theme of **surveillance**, as they were concerned about the issue of data capture and governance. The extracts below illustrate these concerns about the amount of data collected during these activities:

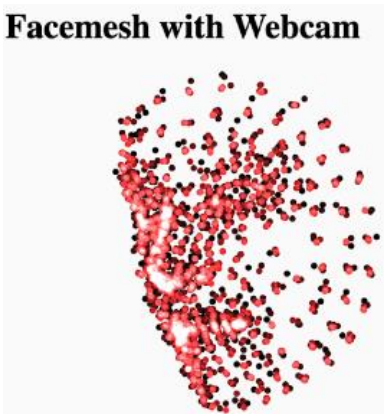
It makes you aware that you can never quite understand when your data is being collected [voice].

Companies already have LOADS of data on us [chat].

Surveillance is a broad term, and the participants used monitoring and data collection as examples of surveillance. The first extract exemplifies the negative element of surveillance, which they then demonstrated by using examples from CCTV and gait analysis in airports. Gait analysis links to somatic surveillance discussed earlier, see p.87 The second extract compounded this negative perception of data surveillance.

When participants explored the P5.js facial mapping algorithm, many of them stated how recognisable each face was if they knew the individual in question. The dots (as demonstrated in Figure 10.11) represent the large amount of facial data generated in real-time when mapping faces through this software. For data-ethics and privacy reasons, I used my own face in this figure to demonstrate this point to the participants. We then used two versions of this code, one with video and pulsating blue dots, see appendix 9A, to emphasise the biometrics, and another without video, fig 10.11 below.

Figure 10.11 *P5.js facemesh output*



I loaded it and got a load of dots on my face! ☺. Is this similar to the masks you get on snapchat? [chat]

The participant's tone and their use of the angered emoji in the discussion demonstrated their discomfort and urge to seek ethical consequences for this form of surveillance. The rest of the group offered no direct solution to this problem, but this was somewhat understandable given that this was a new topic for them. Many of the chat extracts about surveillance, monitoring, and data acquisition alluded to external factors, with only one remark about how educators collect and analyse large amounts of data. The following chat message sparked a discussion on when and where trainee teachers collected data during their teaching practice:

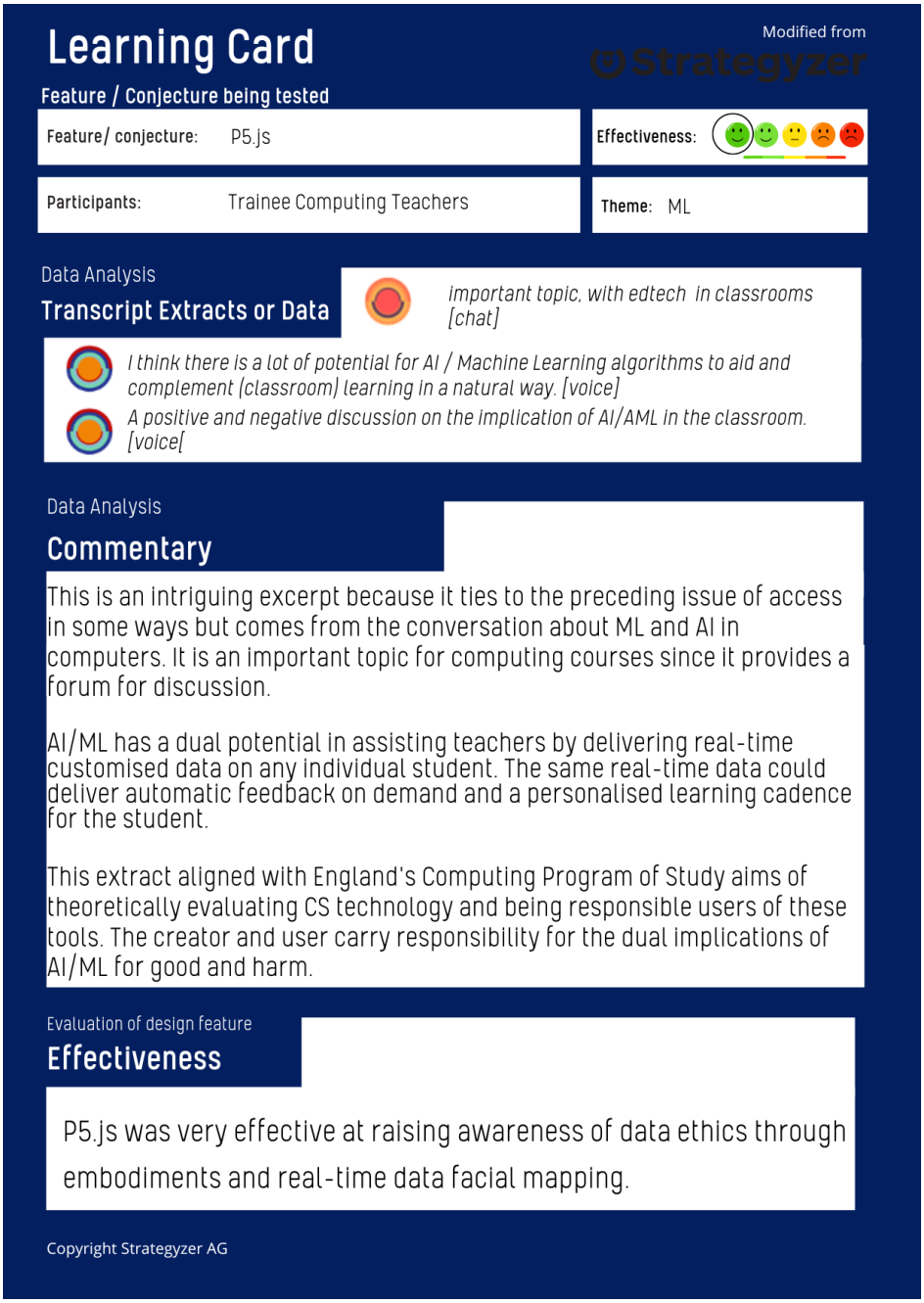
We have LOADS of data on our students [chat].

In pragmatic terms, this participant noted that the data collected was often little more than each student's attendance, assessment, and behaviour during lessons. An unexpected observation was how detached their data-ethics awareness felt from various forms of data production.

ML/AI were mentioned multiple times during the session: following the Chinese educational study using EEG headsets; during and after the explanation of the ML model used to create the 3D avatar; and when interacting with the P5.js code. In the participants' discussions, ML played a dual role as both a subject and a tool for use in the computing classroom. Participants also discussed how technology (EdTech) fits/integrates into the computing classroom, the potential of ML/AI to complement learning, encompassing both the positives and negatives of ML/AI within computing education.

The first extract in Figure 10.12 notes the '*important topic, [...] EdTech in classrooms*,' which illustrates the importance of this consideration for the group. The ensuing discussions not only exemplified how this related to the broader theme of educational resources, but also provided a valuable opportunity for exploring participants' own learning and teaching methods. The group considered ML and AI, reflecting upon the implications and applications of these technologies in the classroom in order to keep education current and relevant. Participants also noted the necessity of improving their professional practices to keep up with the rapidly evolving field of computing, although this content was not specifically part of computing assessment specifications.

Figure 10.12 *Learn Card—ML In and For the Computing Classroom through P5.js [voice & chat data]*



The second extract in Figure 10.12 illustrates how the group explored the potential of AI/ML to revolutionise education by providing real-time, personalised feedback for both teachers and students. They spoke about ML/AI as tools and forms of assessment automation, but did not mention AI generated learning materials, although admittedly access to these was limited at the time, and was much less sophisticated than present-day AI tools.

The group also considered the positive and negative duality of ML/AI for computing, as shown in extract three, and noted its importance not only for the potential benefits of these technologies, but also in relation to the potential for harm if not used responsibly within the computing classroom. As creators and users of these technologies, the participants outlined their great sense of responsibility and the need to carefully consider the dual implications of AI and ML when using them.

Throughout these discussions, the lack of any reference to the negative implications of AI for trainee teachers' future employment as computing educators was surprising, but this could simply be due to the fact that it was not raised at this particular session. Again, their focus was frequently directed to their pupils rather than themselves.

10.2.5 Postpose-Estimation and computing.

The postpose-estimation model used in this stage is presented through several themes: (i) licensing, (ii) frustration, and (iii) trans-disciplinary confidence, as explained below.

Licensing was a key area of discussion as the technologist attempted to fix the motion capture to 3D model development. There were two key constraints of the MocapNET model: the output, rigged skeleton character did not match industry standard tools such as Unity, and access to the neural network was not possible:

The rig is particular to MocapNET and Unity expects a more game-oriented rig, so we had to code a lot of our own BVH animation tooling. [voice]

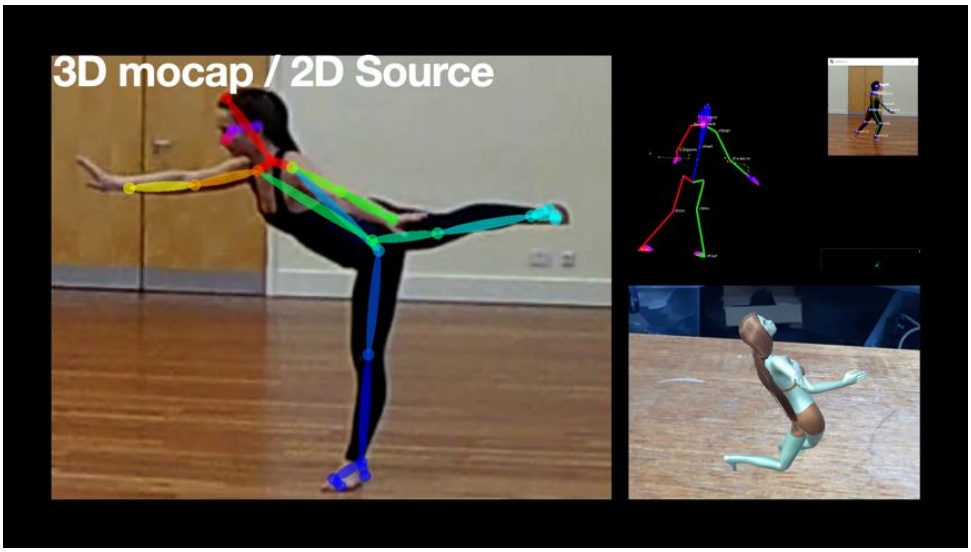
Some of the things we need are described in papers but not part of the open-source distribution. [voice]

These limitations led to a great amount of **frustration**, which was compounded by the limitations of recording human motion data via 2D videos and asynchronously, as noted below:

This is frustrating for the authors as well as us! [voice]

Figure 10.13 highlights the errors of the motion capture process that persisted throughout the study. The main square (left) is an example of perfect execution, which was somewhat rare. The image in the top right is discussed in relation to isolating the dance through video extraction, and the image in the bottom right corner is an example of the AR joint error connection.

Figure 10.13 *Postpose-Estimation Errors*



The top right square demonstrates the errors of joint attachment which the technologist attempted to mitigate through the addition of a video extraction:

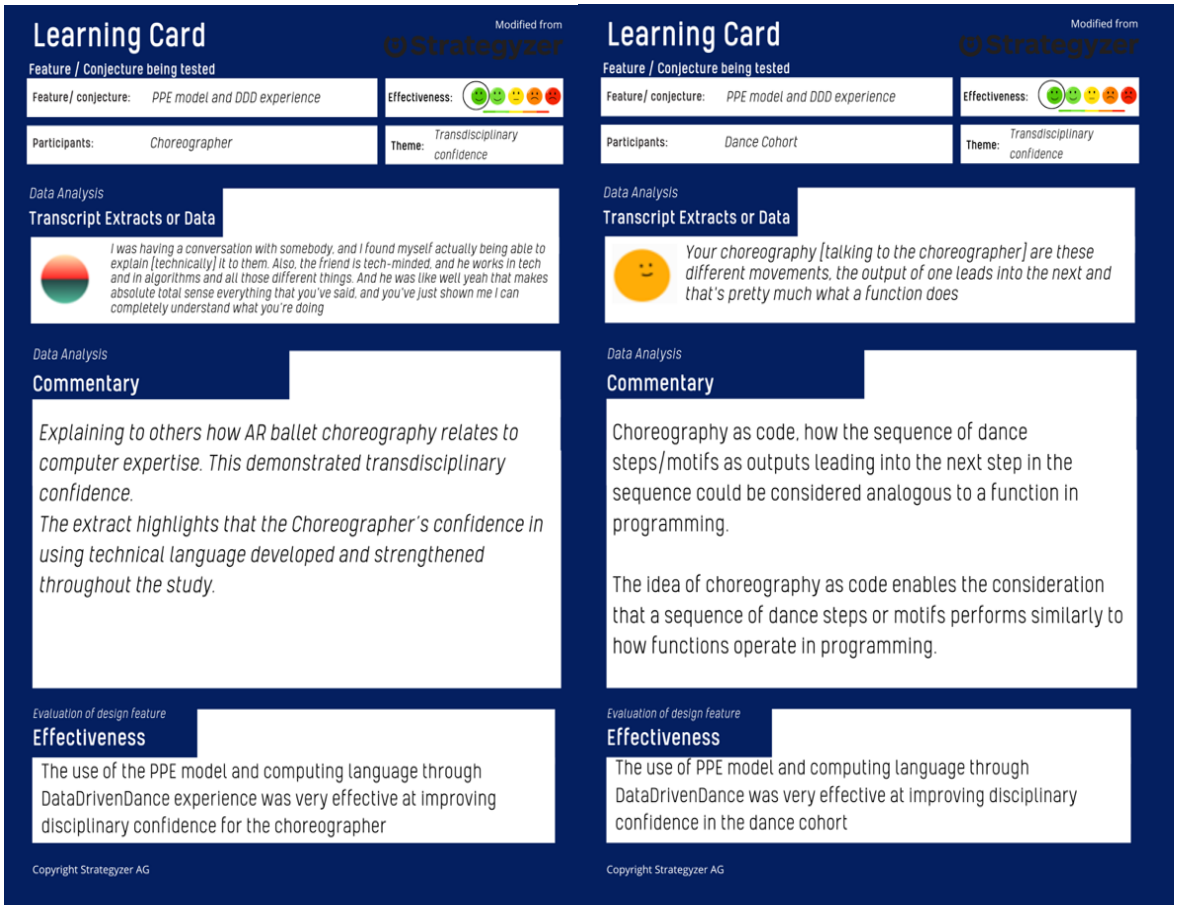
> *Needed to add [another tool] YOLOv5 as a way of pre-optimising the video and scaling it for open pose. [voice]*

YOLOv5 is an object detection model that enables the video to section out just the dancer in the frame to minimise what the post-pose estimation model examined. This added layer was a source of irritation, but also provided some improvements to the pipeline. The next extract highlights the challenges (additional layers of development) faced when creating a semi-functional 3D model. As the development of the AR model was designed specifically for this study, and was not a commercial product, the errors merely added to the research process, but they were a constant source of production obstruction.

> *Duct tape central, great for research, terrible for production*. [voice]

As a result of the MocapNET output, the AR character's body was not in the correct anatomical configuration, which was a constant source of aggravation and amusement for the technologist. The PGCE teachers sympathised with these frustrations, and shared their own experiences, demonstrating that failure is a natural part of the coding process at any stage of expertise.

Figure 10.14 *Learn Card—Transdisciplinary Confidence* [*voice*]



The theme of transdisciplinary confidence, Figure 10.14 above, spanned across both the education and dance cohorts. I have previously discussed the challenges faced by educators when integrating different disciplines and methods of learning into their subject of expertise. In this study, the dancers had to effectively navigate and communicate the complexities of computing technology and concepts through their engagement with DDD. Using choreography as code invited the comparison between the sequence of dance steps and programming functions which was a key component of my research. The dancers demonstrated a deeper understanding of the technical terminology associated with both fields and were able to explain the components of the choreography using computing language with

accuracy and confidence. Furthermore, the concept of effortless complexity, a crucial goal of ballet, can also be used to describe the computational principles that push DDD storytelling, and thus the two fields were brought together. Participants' transdisciplinary confidence improved over time through their experience of DDD.

Figure 10.15 *Learn Card—Transdisciplinary Confidence II* [*voice data*]

Choreography as a function of code was a particularly interesting finding in my research, as the first extract in Figure 10.15, above, highlights. This suggests the alignment of coding and choreography as a set of sequential movements or outputs that form a performance. The alignment between ballet and computing is clear but going further into broadening participant

is not (RQ2). Figure 10.15 demonstrates how the choreographer explained the choreography using computing language and the technical potential of AR.

The concept of data transmission as a source of choreography, discussed in the first extract in Figure 10.15, was explained as transmitting data through specific ballet movements and spatial relations. The second extract illustrates the potential uses of technology in ballet by demonstrating the choreographer's ability to confidently use computing language to discuss the nature and potential of AR ballet. The second extract continued, adding further detail regarding the participants' ideas about the AR output.

10.3 Summary of Design Three: Inspect and Adapt

Iteration Three highlighted a preliminary relationship between ballet and computing as a potential teaching and learning modality. This became more pronounced during the course of the iteration. The utilisation of unique ballet videos, code, and dancer stories aided in strengthening this connection. Protocols, dancer data, and anecdotes all helped to humanise the abstract biometric data (RQ2,1). However, owing to the study's necessary online structure, more evidence through in-person supplementary activities would be required to firmly demonstrate this link.

The inclusion of facial mapping and mic volume coding in this iteration was successful in establishing strong connections between biometric data and ethics (RQ1). This connection was not evident in the previous iterations owing to the participants' embarrassment or reluctance when using the full skeleton tracking code. Drawing back to the hybridisation of human and non-human (posthumanism) and sense-making (constructionism) gave rise to data-ethics awareness through iterative rotations and diffractions transforming perspectives in unexpected ways for the participants.

During this iteration, the levels of participant interaction and participation with the study varied, which was possibly a result of the lack of time given for the PGCE teachers to get to know me before we began the session. Iteration Three also occurred several days before the final submission of coursework for the PGCE, which may have influenced some participants' availability, engagement, and interaction with the study. Time a constant factor in this study (RQ2) from iteration one, 8.2.2.7; planning with technology 9.2.2.1.

The dance cohort offered a nuanced analysis of the interface between dance and computers, delving into issues such as transdisciplinary confidence, effortless complexity, and the body

as data. This emphasised the potential for employing technology to improve ballet performance, expanding new opportunities for dance, and raising awareness of the risks and advantages of using personal biometric data.

Through their participation in DDD, the dancers demonstrated their ability to traverse and explain the intricacies of computer technologies and concepts, and while they noted that the data collection method was demanding, they also found it interesting as a new method of understanding dance. Considering the body as a data source opened up new avenues for researching ballet movement and performance. The dancers regarded their bodies as a source from which to gather data and translate these data into useable forms, beginning with choreography, moving through skeleton data, visual representations, and finally 3D models. Throughout this process there were significant frustrations for the technologist regarding licencing and limitations of the software provided.

Figure 10.16 *Design Three Feature/conjecture effectiveness*

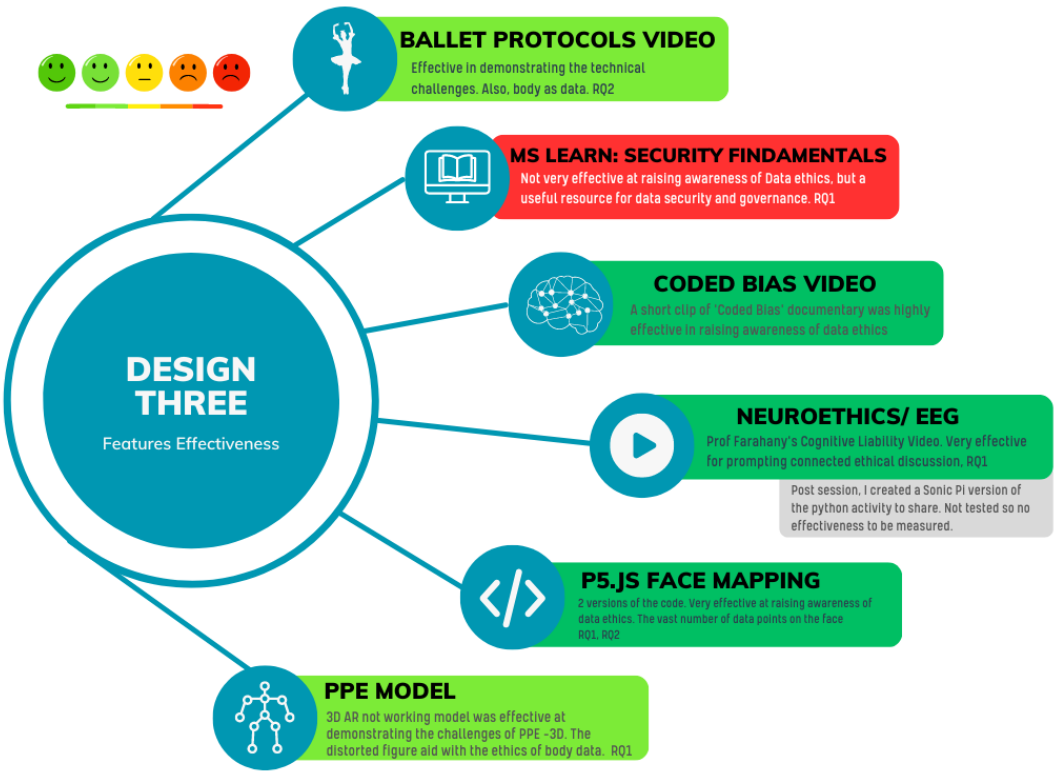


Figure 10.16 notes the feature/conjecture effectiveness which led to the key findings from this iteration. The findings were the continued alignment between ballet and computing demonstrated through the protocols video (RQ1, RQ2). The Coded Bias documentary (RQ2) raised ethical concerns about the use of personal biometric data (RQ1) in the computing

classroom. The MS Learn course was useful as a teacher resource, but it did not contribute to any gains for RQ1 or RQ2. EEG graphing provided an alternative way of viewing personal biometric data, increasing awareness of data-ethics. The P5.js Facial mapping was particularly effective for RQ1 because it provided a closer personal connection to the real-time output.

The findings presented in this chapter suggest the need to develop learning opportunities relating to data-ethics for PGCE Computing cohorts. The observations and extracts collected during this iteration indicate deeper levels of awareness of data-ethics than in previous iterations after participants had learned more about this subject and had the chance to discuss it thoroughly. The next chapter further discusses the implication of these findings.

Chapter Eleven: Discussion

Figure 11.1 *AI-imagery dalle.2 prompt from findings 'meaning through data, body becoming data, AR, ethics*

11. Introduction

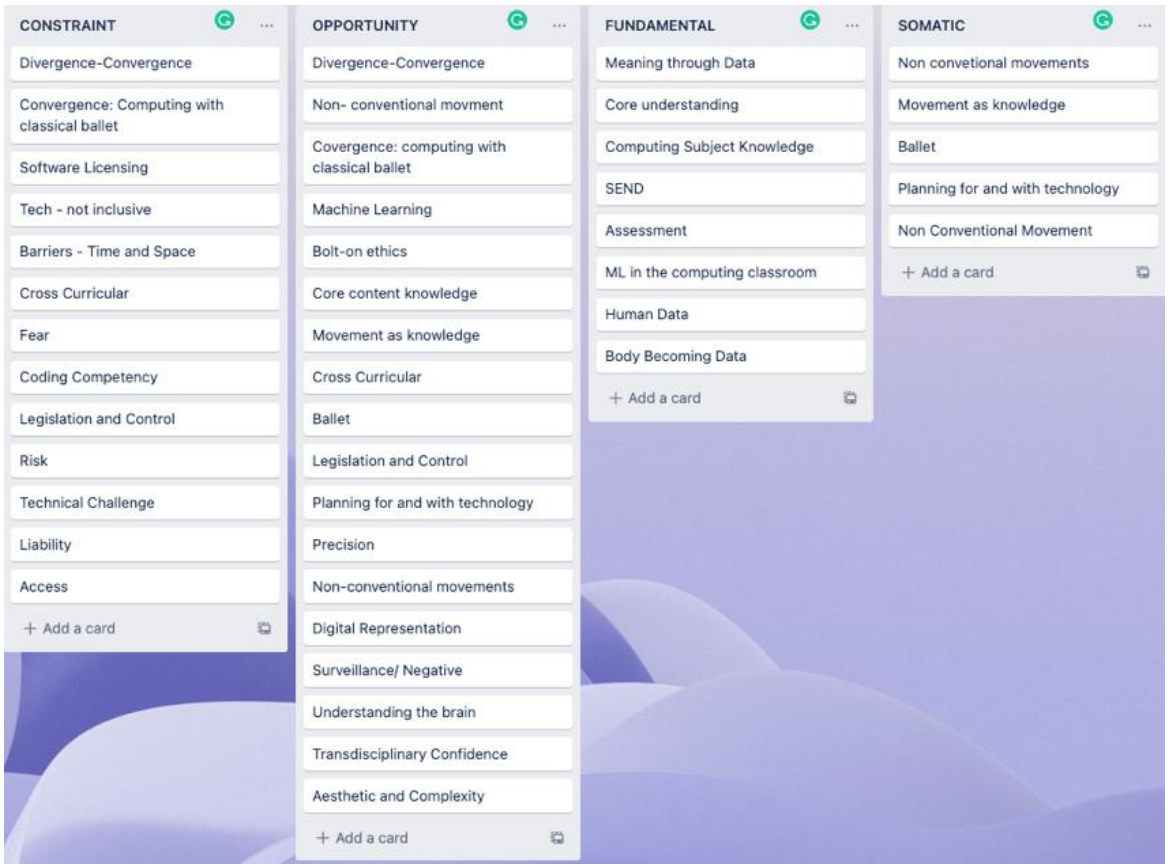
In this chapter, I discuss the findings from across the three iterations of this study, and examine how these findings relate to the larger discourse and current knowledge in the field, including recent literature that has shaped the post-fieldwork discourse. The previous chapters explored the use of biometrics, ballet, and programming as creative modalities for increasing data-ethics awareness in trainee computing education, see alignment of ballet and computing 8.2.2, 9.2.1.1; PPE and computing 8.2.7, 10.2.5; and EEG data 8.2.4, 9.2.2, 10.2.2. By incorporating these tools, I hoped to provide trainee computing teachers with a personalised, interactive learning experience that would help them understand the significance of data-ethics and its societal implications. Alongside this study, I developed educational resources for use in computing classrooms, informed by the participants' input and discussions.

The aim of this study was to raise trainee computing teachers' awareness of data-ethics when using biometrics, classical ballet, and XR as narrative tools or creative modalities in their classrooms. Ballet, as a highly structured and expressive form of dance, has been used as a teaching tool for a range of subjects, including maths, science, and history. I argue that ballet can also be a valuable tool for teaching data-ethics within computing, as it allows students to explore complex ethical concepts through the medium of movement and expression. I used P5.js, an open-source programming language for creating interactive visualisations and artworks, alongside programming and XR activities to demonstrate the advantages of ballet in computing education. Through the use of programming with biometrics, ML, and XR, trainee computing teachers were guided to understand the technical aspects of data-ethics, such as data collection, storage, and analysis, while remaining in line with the programming requirements of pre-university level computing specifications.

The following section analyses the findings from the iterations of the study, providing a holistic view of the advantages and disadvantages of my AgileDBR process. The purpose of cross-iteration analysis in IPA is not to create group norms from the study, but to highlight the shared and unique features experienced by all participants (Smith and Nizza, 2022). To then explore points of convergence and divergence, I initially used Trello to facilitate the rearrangement of groupings in a flexible and efficient manner. Trello's vertical format was useful when tracing cross-threads in the conversation, but I also wanted a non-hierarchical approach to examine the complex meshwork of the themes from the study, which is

illustrated in detail in Appendix 11A. Figure 11.2 displays the themes by 'design implication' and Grouped Experiential Themes (GETs) (Smith et al., 2022).

Figure 11.2 *Iterations Themes—Design Implications*



Within IPA, there is frequently a requirement to frame the findings generated in the analysis phase within the current literature (Smith et al., 2022, p. 116). Several data, AI, or ethical standards or frameworks had not been released during my fieldwork period, so my participants were unable to address connections to the topic(s) of computing curricular legislation.

After the conclusion of my fieldwork, three documents were published: (i) the Ryder Review (Ryder, 2022), an independent legal review of biometric data governance in England and Wales; (ii) IEEE Age-Appropriate Design Code (IEEE, 2021), often known as the Children's Code in the United Kingdom (ICO, 2021), which is a statutory code of practice that explains the obligations for adhering to the UK GDPR when offering online services likely to be used by children; and (iii) The IEEE neuroethics framework (IEEE Brain, draft 2023), including a subsection on 'Education,' which aligns with the Ryder Review recommendations. These documents highlight the ethical and legal aspects of biometrics, and also consider how data-

ethics may be taught at PGCE level. The Ryder review in particular has many detailed recommendations (Ryder, 2022, pp. 62–94), including four condensed recommendations that I considered the most urgent and relevant for inclusion in the computing/PGCE classroom.

Table 11.1 *The Four Recommendations from the Ryder Review for Computing Education*

Ryder Review – the four recommendations that relate to computing education (Ryder QC, 2022)
Recommendation 1: There is an urgent need for a new, technologically neutral, statutory framework. Legislation should set out the process that must be followed, and considerations that must be taken into account, by public and private bodies before biometric technology can be deployed against members of the public.
Recommendation 2: The scope of the legislation should extend to the use of biometrics for unique identification of individuals, and for classification. Simply because the use of biometric data does not result in unique identification does not remove the rights-intrusive capacity of biometric systems, and the legal framework needs to provide appropriate safeguards in this area.
Recommendation 4: A legally binding code of practice governing the use of LFR should be published as soon as possible. We consider that a specific code of practice for police use of LFR is necessary, but a code of practice that regulates other uses of LFR, including use by private entities and public-private data sharing in the deployment of facial recognition products, is also required urgently.
Recommendation 6: The framework envisaged by Recommendations 1 and 4 should supplement, and not replace, the existing duties arising under the Human Rights Act 1998, Equality Act 2010 and Data Protection Act 2018.

In addition, technological advances have also accelerated considerably since my fieldwork, including new motion-capture tools such as Rokoko Studio (Rokoko, 2022). These tools remove the need to develop additional joint translation software, are often run online, and some are even free to use. Similarly, data-ethics has become a much more prominent subject in the media and in research discourse than it was when I started this study.

11.1 Cross Iteration Group Experiential Themes

This study's retrospective stage includes a cross-iteration analysis, which aims to highlight the common and unique characteristics shared by all participants (Smith & Nizza, 2022). The following Group Experience Themes (GETs) from the cross-iteration analysis: (i) the role of AI and ML in computing education; (ii) generating meaning through data; (iii) PGCE curricula, including ethics; and (iv) ballet's convergence with computing, see Appendix 11A, 11B for further detail. In summary, the cross-iteration analysis covered several meshed,

interconnected, and sometimes disconnected themes, and provides a deeper understanding of the computing content, implications, and consequences of sharing and using biometric data, in order to raise participants' awareness of data-ethics. This was particularly important for the education cohort in my study, as they needed to consider the wider social and ethical implications of this research within the constraints of the computing curriculum.

11.2 Discussion and Review

This study investigated various techniques that could be used to raise awareness of data-ethics through the personalisation of biometrics. In addition, creative computing techniques such as dance and post-pose estimation for 3D modelling were used to illuminate widening participation through arts-based practices for trainee computing teachers. The sessions aimed to stimulate discussion, coding practice, and reflections, and I hoped to humanise the data through integrating personal stories from the dancers, the technologist, and the developer as the study progressed.

I now turn my attention to reviewing the different features of my study and the implications of the findings. I consider how each research question has been answered through my research, as follows: (i) data-ethics awareness in computing education was raised through teaching PGCE Computing teachers more about the subject and highlighting numerous critical challenges that must be addressed when teaching this subject; (ii) broadening participation in computing education through ballet and creative computing methods requires further research; and (iii) the AgileDBR approach was used with great success throughout the study design stages.

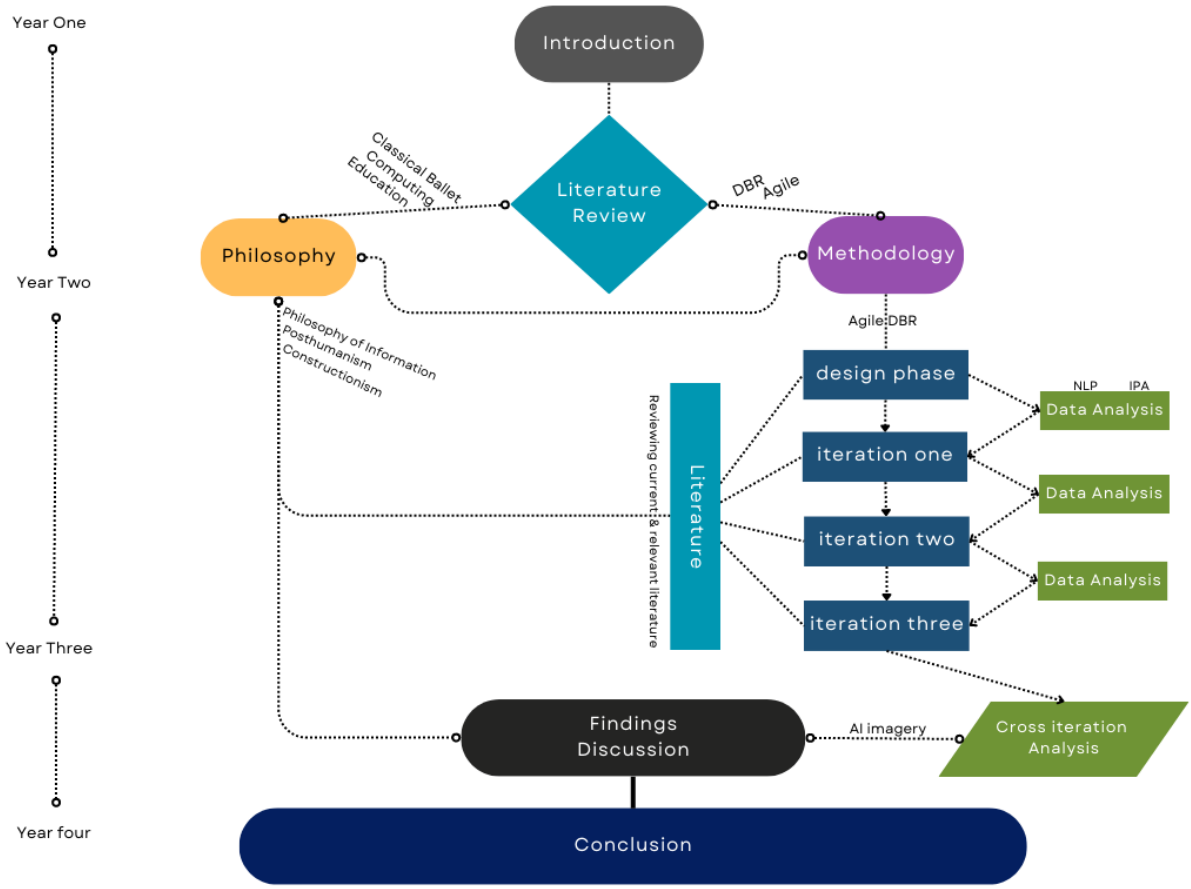
11.2.1 Reviewing the Development of the Intervention

The fieldwork was composed of a series of increments covering designing, developing, implementing, and testing the educational intervention centred around various mechanisms for raising awareness of data-ethics and widening participation in computing. Educational workshops with specific coding, discussion, and digital artefacts were developed in collaboration with the technologist and the dance cohort.

Figure 11.3, next page, highlights the overall study design with the full entanglement of literature, philosophy, and data. The design, implementation, and testing phases had two primary objectives: (i) conducting in-depth interviews with PGCE programme leads, Dancers, and Technologist to share their perspectives and comprehend the needs,

requirements, and opportunities for data-ethics within the PGCE curriculum. (ii) Technical development of a system to explore biometrics through PPE and create 3D prototypes for use in AR (with limited technology access). Given the need to record biometric data from dancers to generate 3D prototypes, technical development was deemed the first phase of the research. The virtual modality of the study required extensive research and review of post-pose estimation tools, which was a challenging task for both the technologist and myself, as numerous tools were excessively costly or not available for external use. The interviews with the PGCE programme lead provided me with a good background knowledge of the information covered in the current PGCE curriculum in relation to data-ethics and creative computing. By understanding this current landscape of computing education, I was able to use the information and opinions provided by the programme lead to design and develop the initial iteration in a relevant, productive way. The feedback about current teaching on the subject of data-ethics was that it was a bolt-on or ancillary area that was gestured to in other discussions but never given full attention as a standalone topic.

Figure 11.3 *High-level Study Design Diagram*



Increment three of the study encompassed three iterations, and focused on the development and use of various features for the educational intervention aimed at raising awareness of data-ethics and promoting wider participation in computing among trainee computing teachers. These features included EEG studies presented in news articles, ballet videos, neuroethics papers, keynote talks, and coding activities.

The different features provided diverse perspectives on the effectiveness of the intervention. For instance, several participants were too embarrassed to use the full body skeleton tracking code, which inhibited their willingness to take creative risks in computing. As a result, facial tracking code was developed, both with and without video display. Another way to mitigate this issue is the development of a 3D avatar prototype called 'Blue Dancer,' which has provided a novel way to investigate the complex interplay between data-ethics and technical considerations in the field of biometrics. Through the use of immersive virtual environments, participants have been able to visualise and interact with data and technology in a more tangible way (Flemisch et al., 2020), allowing a greater understanding of the potential impact and implications of using biometrics in computing education.

Furthermore, the use of this cutting-edge technology has facilitated a deeper understanding of the technical challenges that arise during the development of post-pose estimation 3D models. Through direct engagement with the avatar prototype, participants gained valuable insights into the practical considerations and limitations that shape the creation of these complex systems. The use of a 3D avatar prototype in FrameVR (a webVR platform) offered a dynamic and engaging space for exploring the intersection of data-ethics and technical design in digital modelling. As such, it has become a useful tool for advancing our understanding of these critical areas and generating new insights into the data-ethics of the 'Blue Dancer'.

11.2.2 Raising Awareness of Data-Ethics.

When seeking to raise awareness of data-ethics in computing education, one must consider: (i) the current understanding of data-ethics, including any sub-fields relevant to the specific context; (ii) access to technology necessary for using biometrics and human datasets, alongside the ethical and curriculum implications of this; (iii) the role of AI/ML within computing and data-ethics; (iv) neuroethics and EEG data; and (v) the place of data-ethics within the computing curriculum.

Data-ethics is discussed in this thesis through the pillars of the zero-trust methodology: privacy, security governance, and access, and adding AI/ML, neuroethics, and data-ethics for computing in order to understand my specific context. Data-ethics is a growing area of concern for computing educators as more and more data are collected and stored, and so it is important for educators to ensure that their students are aware of the ethical implications of working with these data. The use of current news articles and studies provided external evidence that these devices were and are being actively used in classrooms. The participants expressed their concerns about (categorisation 8.2.6, technology planning 9.2.2.1) teaching data-ethics, including the pragmatic elements of data privacy, data security, and data governance. The findings discussed in Chapters Eight to Ten suggest several places in which data-ethics may be included in the computing curriculum cross-curricular 8.2.4, technology planning 9.2.2.1, Legislation 9.2.3, which could increase awareness of data-ethics among pre-university students. Drawing back to Chappell 'the human and the non-human actants contribute to the emergent ethics of the situation' through (Chappell, 2018, p. 153). Data-ethics should not, however, be reduced to a single session/lesson or an isolated topic of study, and its integration into the wider field of computing education is key.

The role of government and legislation is an important consideration both within educational settings and when understanding access to technology outside the classroom. Ethical frameworks and legislation that deal with surveillance enabled trainee computing teachers to understand the technological and often negative implications for the computing classroom and wider society in discussions throughout my study. Surveillance of student data raised significant ethical concerns for the participants, see MS Learn/Coded Bias 10.2.3, within the realm of data-ethics, highlighting Salganik's statement that there are 'unanticipated secondary uses [of data]' (Salganik, 2017, p. 290). Ensuring ethical data management, use, manipulation, and privacy is of paramount importance in this field.

Data privacy was a major concern that was observed during each iteration of the study when using the P5.js feature with education cohort 9.2.4, surveillance 10.2.4 and when exploring dancers' brainwave data in relation to planning, representation, and liability 9.2.2 and less so with the creation of 3D avatars, see 3D model and PPE linked to risk assessments 9.2.4, errors, licensing, transdisciplinary confidence 10.2.5. This raised important questions about the uses of biometric data and the access to these data as teachers continue to collect more data about their students. These data are often collected by external bodies without knowledge or consent. The potential for using biometric data to track academic performance,

or to trace information about individual students through their academic career brings with it the potential to infringe upon privacy, but also to perpetuate systemic inequalities and biases, see categorisation 8.2.6. These key areas of tracking, categorisation, and monitoring were evident across the iterations, but need further investigation to combat these concerns. These findings may help to understand that through exposure to biometric data, trainee computing teachers were able to increase their awareness of data-ethics and lessen the risks of using such technology in their classrooms.

Data security is another vital consideration when teaching data-ethics, and differs from data privacy. Data security focuses on how collected data are protected from external and internal threats (Kleinman, 2018). There are countless news articles that present data breaches on both a global and local scale, and these provided adequate background to the study of data security and encryption for the education cohort in my study. The PGCE teachers suggested, see understanding the brain 10.2.2, MS Learn & Coded-Bias 10.2.3, that the constant monitoring and capturing of student data was considered problematic and a form of surveillance. Data security is frequently included in GCSE and A-Level computer specifications under legislation and GDPR, and many (but not all) participants were familiar with data security as a concept. As a result, the incorporation of biometrics and movement through personalised/humanised ballet data provided various discussion and coding opportunities to enhance awareness of data-ethics.

Data governance is also a crucial aspect of this study as data becomes more centralised. Through consulting the biometric datasets and exposure to Zero Trust methodology, see 2.2.2.1, EEG-graphing 9.2.3, participants understood that data governance is a key part of data-ethics, and includes ensuring that data are accurate and recent. Data governance also includes access to data privileges and levels of authentication, but it is important to note the difference to access to data and access to technology, which is discussed in further detail below.

Access to technology is a complex issue, as George and Petter emphasised back in 2016 when they argued that merely providing access to hardware and free data does not increase access or participation among low-income families (George & Petter, 2016). Since 2016, the Covid-19 pandemic has increased the need for access to technology owing to the increased emphasis on home learning, particularly for school-aged children. This has highlighted

broadband access as a determinant for social health and wellbeing alongside learning (Graves et al., 2021; Ramsetty & Adams, 2020).

As this study took place during Covid-19, the participants had a heightened awareness of the boundaries of access to technology (EdTech) as a benefit and a challenge faced by trainee computing teachers. Access to general EdTech was designed to be familiar, free, and simple, using platforms such as Microsoft Teams, Zoom, and Jitsi. If participants were not familiar with these tools, I selected tools that represented easy-to-use technologies that could be used in schools and picked up fairly quickly. I used video calling platforms that met my requirements as the researcher, and enabled me to record video and chat and allowed the participants to interact and engage with each other and me without the need for verbal interaction. These platforms also allow the collection of real-time commentary responses that might not be verbal/visualised in a non-virtual setting. The chat feature of these platforms is an additional channel of communication. The participants' voices were therefore heard across multiple forms of communications: orally, textually, and through imagery (emojis).

Moving beyond the familiar to EEG/biometric devices, this posed enormous ethical, financial, and professional obstacles. To fully realise the potential benefits/threats of biometric technology for the computing classroom, it is important to address these challenges first. The participants felt that there were no current policies that would enable them to ethically use BCI devices in their classrooms (see 8.2.6, 9.2.2.1). We briefly discussed the IEEE neuroethics draft framework (IEEE Brain, draft, 2023), which aims to provide a structure to ensure the ethical and future implications are met. This structure was only partially complete at the time, however, and did not provide much more than a discussion prompt. Before being actively employed in teaching and learning, the benefits and risks of access to this type of technology must be thoroughly explored.

AI/ML have a substantial role to play in education for both teachers and students. In my study, the teachers considered how ML/AI could serve as a tool to provide real-time data on individual students, enabling them to tailor their instruction to the needs and abilities of each of their pupils. This technology could also be used to optimise and/or personalise learning experiences for each student, possibly increasing the efficiency of the teaching process. Through post-pose estimation and 3D modelling, ML, with programming, the trainee computing teachers were able to map current curriculum/exam board specifications onto new methods of teaching, albeit in a limited fashion. ML/AL are, however, complex and require

prior knowledge that some trainee computing teachers did not have. OCED (2023) speak in terms ‘a new science of learning’, to ‘re-think purpose, design, and delivery’ for education (p.15). The ethical implications of AI/ML tools that access student data were only mentioned briefly in terms of data collection, see surveillance 10.2.4, not the future of teachers/educators. This is an area that needs to be researched further by and for trainee computing teachers.

For students, ML/AI can provide real-time feedback on demand, allowing them to track their progress and understand their strengths and weaknesses as the lessons continue. According to the trainee teachers, this may help to foster a more self-directed and autonomous approach to learning, as students would be able to take control of their own learning journey and set their own pace. From an ethical standpoint, the participants made no comments or mention of the future implications of these data or the potential impacts on the individual. Although in a classroom setting, real-time, personalised, en-masse feedback without ML technologies would be extremely time consuming and nearly impossible.

Overall, the participants’ discussion and comments on the use of AI/ML for education focused on the positive potential of these tools, and how they could enhance the learning experience for both teachers and students through their ability to provide personalised feedback and support in real time. The ML models used for facial/skeleton tracking provided both practical and ethical opportunities for raising awareness of data-ethics among the participants. Additionally, AI-imagery and the webVR provided additionally creative activities to explore data-ethics and computing, see appendix 11B.

A consideration of neuroethics alongside these potential uses of technology ensures that the application of this knowledge respects the autonomy and dignity of students. Overall, the integration of educational neuroscience and neuroethics has the potential to enhance teachers’ ability to facilitate learning and improve progress in their classrooms, see neurotechnology and understanding the brain 10.2.2, surveillance and ML/AI 10.2.3. When discussing the brain in relation to learning, some participants argued for the need to move away from the field of psychology and centre instead on education as the principal lens or a translational bridge (Rogers & Thomas, 2022). The trainee computing teachers also proposed that integrating insights from both educational neuroscience/neuroethics fields could lead to a deeper/broader understanding of the cognitive processes occurring in the brain during

learning. These reflections informed the design and implementation of more effective computing educational resources and practices.

The ethical implications of using a Brain–Computer Interface (BCI) within education to collect and potentially expose such personally identifiable data are considerable. Recording, representing, and reflecting an individual's EEG data into visualisations potential exposes them to data and data uses that would normally remain hidden or anonymous. This risk was a key component in raising awareness of the importance of data-ethics, especially in the use of biometrics see fear 8.2.3 and understanding the brain 10.2.2. As the trainee computer teachers are students themselves, the ethical responsibilities and duties of care for those running the PGCE programmes also need addressing.

EEG data and the development of educational neuroscience approaches to learning may provide access to and understanding of the complex neural mechanisms that underpin cognitive processes like memory, attention, and decision making. These advancements have the potential to broaden our theoretical understanding of learning, as well as the ethical implications of educational neuroscience for aspiring computer teachers. The practical implications for trainee computing teachers include teaching and learning about data-ethics using biometrics/EEG, which was not covered in the PGCE curriculum at the time of research. Without access to all PGCE curricula in England, it is difficult to say whether this is representative of all PGCE courses.

As data-ethics does not presently have a dedicated place in examined computing specifications (GCSE/A-Level/BTEC), future work within computing education is required. By exploring current and future opportunities within computer teacher training programmes, data-ethics could be integrated into the curriculum effectively and quickly, and participation in computing or computing-related subjects could be improved, as informed by relevant legislation and innovative education practices.

11.2.3 Broadening Participation

My discussion of exploring broadening participation within computing relates to the following areas: (i) arts practice —ballet, (ii) AR ballet, (iii) the dancer and the data self, and (iv) ballet and computing. It became clear over the iterations that classical ballet and computing possess striking levels of convergence in terms of formalisation, abstraction, and generalisation. These similarities are rooted in their mutual reliance on pattern recognition, and routine, and analysis, which are essential in shaping the learning experiences of students

in both domains. Given this alignment (convergence 8.2.2; precision 9.2.1.1; PPE 10.2.5), it is crucial to provide opportunities for students to apply their interdisciplinary knowledge in a practical setting to develop this link. This broadening in participation could be achieved through integrating cross-curricular activities and teaching/learning experiences into education, blending the two disciplines and providing students with further opportunities to explore this knowledge. As dance is already a part of the PE curriculum, there is definite potential for this to be implemented.

The integration of classical ballet into computing education presents a unique opportunity for students to investigate data-ethics in ways that map directly onto the computing curriculum and provide a creative approach. Some studies (Chen, 2001; York & Conley 2020) have demonstrated a degree of effectiveness in using artistic modalities as a way to engage students in ethical discussions and promote critical thinking. Chen (2001) found that using dance as a medium for ethical discussions resulted in increased student engagement and a deeper understanding of ethical issues. Similarly, York & Conley. (2020) found that using 'Creative Anticipatory Ethical Reasoning' in STEM education via design fiction served as an effective method to teach 'anticipatory ethical reasoning' (p. 2986) which they defined as an exploration of the ethical ramifications of the technology, including at the R&D stage. This aided students to develop critical thinking skills and promote a culture of ethical responsibility. This was also evident, to a limited degree, in the questionnaire data and responses from participants across iterations (cross-curricular 8.2.4, non-conventional movements 9.2.1.1) during my fieldwork.

The transdisciplinary approach of using AR ballet choreography developed for augmented reality combines the artistic expression of ballet with the computational knowledge of AR technology, resulting in a potentially unique and innovative form of artistic expression. Additionally, the protocols, tools and challenges of AR ballet experience are translated into the computing classroom context. A creative computing approach, explored through the integration of biometrics in XR/AR (see FrameVR immersive computing 10.2.1) worlds, gave rise to the exploration of both broadening participation and data-ethics education for both the education and dance cohorts. Within the constraints of computing education, the programming (using P5.js or C#) and digital futures discourse could be mapped onto the computing curriculum to widen participation by incorporating multimedia and creative coding skill development through immersive ballet experiences.

The incorporation of AR technology into ballet choreography has the potential to bridge the gap between dance and computing, allowing exploration of new forms of movement and choreography. Owing to the technical challenge imposed by Covid-19, only prototypes were developed, but this still shows the potential of AR choreographers to enhance the visual elements of their performances, creating immersive and interactive experiences through purposefully designed choreography. An example of this is the collaboration between Goh Ballet Academy, Canada, and Nextech AR, which developed ballet holograms in order to expand access and present a new, inventive way to learn dance (Nextech, 2021).

As new technologies develop, the technological barriers of programming and software deployment will become permeable and accessible to non-experts. Overall, the integration of AR technology into ballet choreography represents a significant advancement in the field of dance.

The posthuman tensions between the human-self and the data-self, the digital representation explored through the XR art and ballet, illustrated by figure 11.1, offered the unique ability to bridge the divide between the physical and the digital. The dancers, who were able to explore and be the data self and the human self simultaneously (see, humanising-data 7.5.2, precision 9.2.1.1, technology planning 9.2.2.2) as they moved through the visualised EEG data or 3D prototype models, interpreted and expressed complex ideas and emotions via creative computing. The ethical discussions that emerged from these activities concerned the data self and sharing data with others, and focused particularly on concerns about the longevity and permanence of their data existing without control or governance.

Combining ballet with computing, and understanding the alignment/collaboration between these two fields, could be developed and explored through further research and analysis, potentially leading to insights about the ways in which creative expression and structured processes can be integrated in both ballet and programming contexts. Owing to the fully virtual nature of the study, it was not possible to effectively explore this aspect. However, my use of multimedia and development of coding skills when using 3D model prototypes and AR ballet choreography provided unique opportunities for exploring the alignment of computing and classical ballet along with discussing data-ethics within the constraints of the computing curriculum. For dancers, the resulting experiences could foster an appreciation for the potential of AR technology to enhance and transform traditional art forms, while also developing essential skills for future careers in the digital age.

For PGCE computing, widening participation through cross-curricular subjects and interacting with external professionals meant that they were able to see the alignment of ballet with programming through both the video clips and the development of the choreography. The feedback was that teachers were likely to use the video clips (questionnaire, ballet) when teaching about algorithms and coding with ML, but were unlikely to explore ballet practice for computing themselves. This requires further research in a non-virtual study, and the possibility of working with PE faculty to integrate this approach more easily.

Both data and ballet can take written forms (albeit often symbolic for dance, such as Laban notation, Knust, 1979). Fabretti's (2015) *Software Theory: A Cultural and Philosophical Study* examines how software can be used to develop and test theories while also being informed by theoretical perspectives. This investigation ultimately leads to a deeper understanding of the relationship between technology and knowledge, including the role of software in academic knowledge production.

A written form of the choreography was generated/created by the choreographer using an adapted choreographic notation. Additionally, a storyboard of the ballet was created and shared via Trello. This was a collaborative, participatory, creative process, drawing on Csikzentmihalyi's (1994) domain field and the technique of ballet, as well as the culture of blending classical ballet, technology, and the individual dancer's live experiences together to create what Chappell (2006) refers to as 'creativity in relationship' between the choreographer and the dancer.

The ballet video clips were used to emphasise the alignment of ballet with programming. Participants were interested to explore the relationship between these two seemingly disparate fields in more depth. Through careful analysis, it was discovered that ballet could be interpreted as a visual abstraction of an algorithm, with each movement representing a distinct step in a larger process. The fluidity and precision required in ballet mirrored the attention to detail and structure needed in programming, providing a unique perspective on the similarities between these fields.

This alignment between ballet and programming opened up the possibility of utilising the principles of ballet to replicate other algorithms (see alignment 8.2.2). By breaking down complex algorithms into a series of smaller, distinct movements, one could use the same precision and attention to detail required in ballet to replicate these processes with some

degree of accuracy. This not only highlighted the interdisciplinary nature of these fields but also provided an innovative approach to solving complex computational problems.

Ballet may appear to be an unexpected candidate for the computing classroom, but when evaluated through the lens of information transfer, algorithm design, and programming, it becomes clear that the two share a lot of commonalities. Classical ballet movement can be viewed as a type of information transfer, with each gesture and step transmitting meaning and intent to the audience, and choreography as a form of programming/designing algorithms. Chip Heath and Dan Heath (2015), in Pavliscak's e-book *Data-Informed Product Design*, notes that 'Data are just summaries of thousands of stories—tell a few of those stories to help make the data meaningful' (Pavliscak, 2015); this study aims to tell the story of the humans behind the data.

11.2.4 Section Summary

Section 11.2 discussed the similarities between classical ballet and computing in their use of formalism, abstraction, and pattern recognition. I suggest that exploring the alignment/convergence of ballet and computing disciplines could potentially provide creative opportunities for students to apply their knowledge in a practical setting and investigate data-ethics. Classical ballet, in this respect, is a valuable source of somatic movement as knowledge transfer that could be integrated into the computing curriculum. This section also explored the use of artistic dance practice, AR ballet with biometrics, and the human and data self as ways to explore data-ethics in computing education. The potential of combining ballet and computing in further research and analysis to explore the integration of creative expression and structured processes in both contexts was explored, and I noted how awareness of data-ethics when using biometrics created both a humanising and more personal connection to the data.

11.3 Methodological

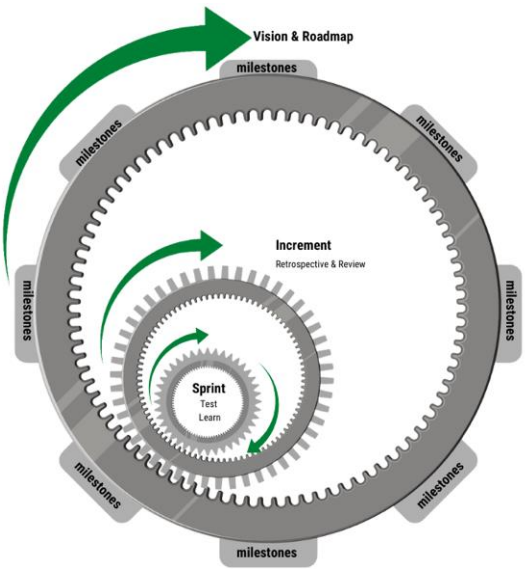
Another important element of this study was the methodological approach of AgileDBR, specifically designed to fit the needs of this study. This approach is discussed below, covering the successes of the approach, its potential for implementation in computing education research, and its use within broader methodological research. Agile is characterised by continuous delivery, as iterations present and refine results, and new projects are injected into the system. Modifications were made when combining Agile and DBR so that the new

methodology would align with the requirements of my research and fit into the limited time given to the fieldwork portion of this PhD study.

There are several key elements that have been adapted from Agile for use in my research. As Agile is primarily used in business to continuously deliver products, the iterative approach needed to be adapted to the finite PhD context. DBR in isolation did not provide adequate scaffolding or transparency upon which to build my study, and so combining the two enabled me to monitor the project and pivot, when necessary, with minimal disruption, using the most appropriate elements of both to further my research.

11.3.1 Did It Work?

Figure 5.1 *Research Engine–reposted for convenience*



As an educator and certified Agile Scrum master and Product Owner/Product Manager, I have been using Agile approaches to learning in my classroom to promote the use of creative technology and enhance students' learning. This approach allows students to deal with uncertainty, and teaches them how to readapt their research according to their findings/new directions that develop. What I refer to as the 'Research Engine,' of AgileDBR is the potential, reflective, and adaptable nature of the approach, which is achieved through the use of adapted documentation tools such as a vision board, roadmap, increment boards, a sprint board, and Test/Learn cards with milestones. These tools work in conjunction with Agile rituals and resources that provide an overview, snapshot, and routines through which to capture incremental changes and developments. AgileDBR combines theoretical and academic research feature requirements that are lacking from industry Agile methodology. The vision boards help me see the study as a whole, rather than just the features and conjectures being tested. Planning and reviewing my study through the use of the increment and sprint boards provided me with a scaffold to see how/if the processes and features benefited the design iteration. The Test/Learn cards illustrated the development, analysis, and review of a specific feature/conjecture, and were vital when reflecting on the successes and areas for improvement in each iteration.

PhD studies such as this are currently limited by time constraints set by ethics boards, which was a significant challenge for my research. AgileDBR's iterative nature, with continuous design, development, and data analysis throughout the fieldwork period, provided flexibility and the ability to pivot quickly as necessary. Trello was integral not only for planning in a traditional Agile approach, but also for analysis and theme development, as described in the introduction to this chapter.

11.3.2 Broader Educational Methodological Research

AgileDBR contributes to educational research enabling researchers to respond/pivot to shifting research questions, data sources, and other variables that may occur during the course of a study. Researchers can respond to new information more quickly and adjust their research by breaking down research projects into smaller, more manageable visible tasks using AgileDBR documentation and Industry practices.

Second, AgileDBR may facilitate collaboration among researchers, stakeholders, and other research participants. Researchers can ensure that their work is more relevant and applicable to its audience by involving stakeholders and end-users in the research process, similar to participatory design models. AgileDBR scaffolds, processes, structures, and outcomes with transparency designed to generate theory and actionable knowledge within educational settings. Although those unfamiliar to Agile would require time to acclimatise to AgileDBR tools, these are relatively simple and easy to use.

AgileDBR has the potential to improve academic research quality by encouraging researchers to take a more iterative, reflective, and documented approach to their work. Researchers can continuously improve the quality and rigour of their research by testing features/conjectures, analysing data, and iterating on their findings. Because research is built into the iterative learn-review cycle, both the output and processes of any given study/project are subject to research. The literature critiques DBR for a lack of rigour, and some suggest that it lacks cohesive standards and is vague (Dede, 2005), lacks argumentative grammar (Kelly, 2004; Sandoval, 2014, Kali & Hoadley, 2021), and that the duality of advancing both theory and design are unclear in many studies (Phillip & Dolle, 2006). Kali and Hoadley (2021) develop this critique, arguing that DBR does not present a clear switch between design and theory. The lack of agreed 'argumentative grammar' (Kali & Hoadley, 2021, p. 481) is a key issue identified by these researchers, who use Sandoval's conjectures to explain the pluralistic nature of iterative research.

Conjecture maps do not provide adequate information to replicate or follow a study's development in my own experience. This is where AgileDBR's Test/Learn cards offered a solution, as they provided a clear representation of the theories and features of my research alongside the effectiveness of these as they were used. Many AgileDBR tools were used in my study, and participants found them accessible and useful, even as non-experts. AgileDBR aims to illustrate that knowledge (design and theory) of a study resides in the personal, contextual, continually negotiated boundaries of real humans and their shared data-selves.

11.3.3 Section Summary

AgileDBR is a valuable approach that may be utilised across many academic disciplines. The approach provides several advantages that can improve the research process by breaking down and documenting projects into smaller tasks. This allows researchers to respond quickly to changes in research questions, data sources, and other variables. AgileDBR consults the macro (using vision boards) and the micro (using research sprints and Test/Learn cards) to enable individuals to visualise and monitor the study at every stage. Furthermore, AgileDBR can facilitate collaboration among researchers, stakeholders, and users, resulting in research outcomes that are more relevant to their needs, reflecting Agile's industry use. AgileDBR encourages a more iterative, reflective, and documented approach to academic research, which has the potential improve the quality and rigour of the work.

It is important to highlight, however, that AgileDBR may not be appropriate for all types of academic research, and that researchers should carefully assess the specific needs of their projects before adopting AgileDBR as a technique. While AgileDBR can be a strong tool for enhancing research outcomes, it is not a panacea, and researchers must still follow rigorous research standards and best practises to assure the validity and dependability of their findings in their field.

11.3 Summary

This chapter discussed the themes across all iterations of my study, consulting the research questions in order to discuss the successes and overall findings of the research. My study suggests that the combination of biometrics, ballet, and creative programming is an effective teaching strategy that raises awareness of data-ethics in PGCE Computing education. I provided trainee computing teachers with a hands-on and interactive personal learning experience through facial and skeleton mapping coding. These tools aided the participants'

development and understanding of the ethical implications of data and its role within the computing curriculum.

Humanising the dancer dataset and 3D models through including dancer stories led to deeper personal connections with the data, which in turn informed the dancers' awareness of data-ethics. The inclusion of these stories and reflections about data selves also enhanced the education cohort's awareness of data-ethics, particularly when they translated these experiences to their own or future classrooms. Using ballet provided an artistic perspective on computing, but also allowed participants to understand the algorithmic and programmatic aspects of ballet and illuminated alternative ways to explore certain aspects of the curriculum. For the dance cohort, exposure to DDD developed their understanding of the technology and allowed them to explore the creative computing possibilities for XR dance performances. The technologist facilitated the technical aspects of the study and shared key experiences with the PGCE teachers, as well as providing insights into the ethical implications of data and digital development.

In terms of methodology, Hoadley (2004) states that 'the promise of better alignment in research—certain and sure links from theories to hypotheses to interventions to data gathering activities to interpretation and application—should be a strong incentive to continue to pursue the design-based research approach' (p. 211). AgileDBR aims to provide a transparent framework for any educational research study's various epistemological approaches. As educational research could be viewed as 'research of the very particular' (Bertelsen et al., 2019, p. 35) AgileDBR allows for scalable, not necessarily generalisable, creative practice in both design and theory generation.

Chapter Twelve: Conclusion

Figure 12.1 *Dalle.2 image findings prompt: 'Convergence divergence non-conventional ballet movements. Movement as knowledge. Ballet convergence with computing*.'

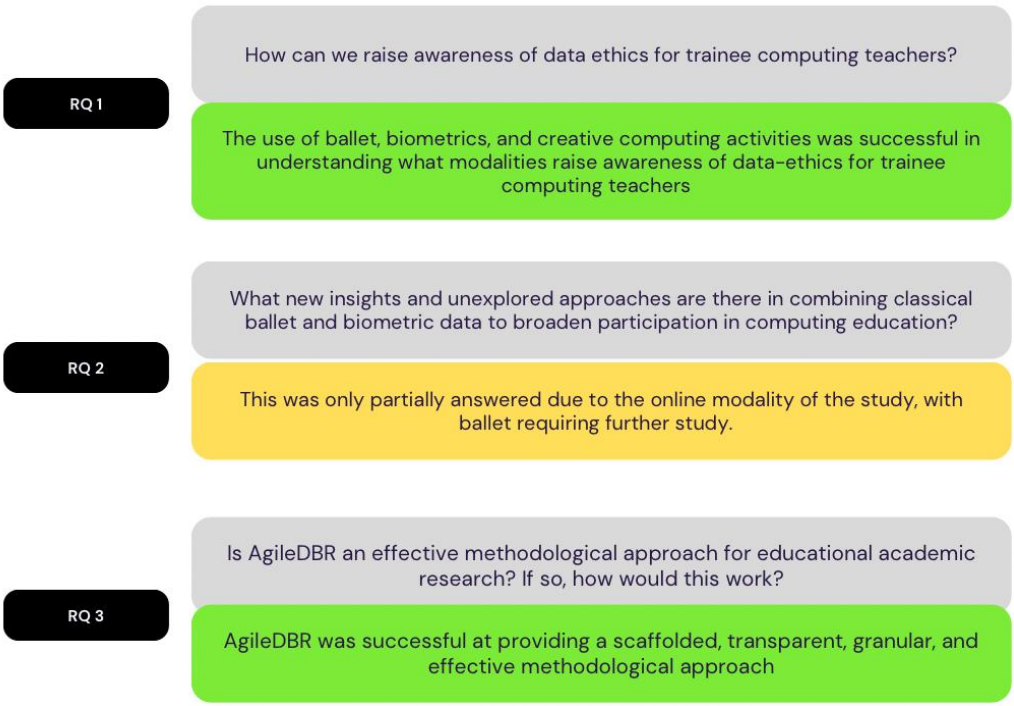
12 Introduction

This chapter summarises the primary findings from the study. It presents the study's contributions to the field. It illustrates the significance of its results, shedding light on the intricacies and uncertainties encountered during my research against the backdrop of a global pandemic. This chapter also outlines the nature and constraints of the research approach taken.

12.1 Summary of Findings

This study investigated if and how creative practices and biometrics could enhance awareness of data-ethics among trainee computing teachers' and how the inclusion of classical ballet may widen participation in computing education, see figure 12.2. An additional aim was to create and assess the efficacy of AgileDBR as a methodological approach for academic research.

Figure 12.2 *Answering Research Questions*



Through the collaborative efforts from three perspectives—education, dance, and technology, an iterative design, implementation, and testing model for an educational intervention was conducted. The findings support the use of biometrics and P5.js (ML) coding activities to explore data-ethics of biometric data through classroom-accessible tools and programming

languages. To achieve this, the ballet was employed as a storytelling technique which investigated computational principles through a very visual, interactive medium. It was also found that interactive, real-time, generative p5.js (a JavaScript library for creative coding with a focus on making coding accessible and inclusive for artists, designers, educators, and beginners) effectively raised trainee computing teachers' awareness of the ubiquity of personal data and its ethical implications. Additionally, the findings showed that incorporating EEG data and dancer narratives facilitated a humanisation of the datasets, thereby increasing trainee computing teachers' awareness of the individuals behind the data. This, in turn, heightened their awareness of data-ethics within a computing context and thus demonstrated the effectiveness of the approach. Consequently, this study yielded practical know-how for improving educational practice and research to raise awareness about data-ethics.

12.2 Limitations and Mitigations

Limitations are a critical aspect of the research process that must be acknowledged and addressed to ensure the findings are valid, reliable and relevant. The limitations of this research can be broadly classified into three areas: the study itself, the credibility of the findings, and the scalability of the study, including methodological issues.

12.2.1 The Study

The Covid-19 pandemic presented substantial challenges for this study, including losing the first PGCE cohort during fieldwork. The participants were grouped and acted as cross-functional teams, as each group addressed a different area of the study. The education cohort was n=17 PGCE Computing teachers, but the loss of access for the final session further disrupted this. The dance cohort (n=3) was small but appropriate for the needs of the study's DDD aspect. The overall participant sample size potentially limited the findings. Still, it enabled a close relationship with the participants and some excellent discussions about the key themes and issues raised in the study. This close relationship was vital to the methodology and enabled flexibility when certain aspects of the study were challenging or needed adaptation.

The use of an online platform for the study is not the traditional modality for teacher training and ballet. Thus, it limits the ability to generalise these findings from their specific context. This online environment also meant that the PGCE Computing teachers did not have access

to the EEG headset and so could not participate in this more active/practical aspect of the study. The use of the AgileDBR methodology enabled the identification and testing of critical features and pivot points, which served to bring the study to a successful conclusion and may do the same for other educational settings and modalities, despite unexpected challenges.

12.2.2 Credibility

As an educational researcher, my experience as a dancer, teacher, and lecturer provides internal and external perspectives on this research. Understanding the real-world challenges faced by computing teachers and dancers enabled me to create and modify the study to ensure participation was collaborative and authentic. Owing to the online nature of the study, the interactions had the potential to be recorded, but not all were. Applying a Zero-Trust (Microsoft, 2012) approach to using technology for recording video, audio, text, and transcription ensured that I followed strict ethical guidelines. The biometric data collection and management also followed these ethical guidelines and protocols in accordance with this study.

The data underwent a rigorous analysis, and I employed qualitative and computational (NLP) techniques using Agile analytics during the fieldwork stage. Subsequently, the data underwent a comprehensive reanalysis consistent with the methodology, which presented the participants' voices prominently through the use of IPA.

12.2.3 Scalability

The ability to generalise or scale research results is a common consideration in educational research fields. Given the specificity of this field and its focus on human variability factors, however, it is important to acknowledge the particularity of each study (Bertlesen et al., 2019). Using computational methods as a supporting analysis tool in this research aligns with Smith, Flowers, and Larkin's argument for 'theoretical transferability rather than empirical generalisability' (2022, p. 45).

AgileDBR contributes by allowing my study to be scaled to other comparable or dissimilar scenarios as it works in real-world, human environments, incorporating the local effectiveness and theory generation associated with DBR into my AgileDBR approach. The study was designed and developed iteratively, using transparent documentation and protocols/rituals. In contrast to Wang and Hannifin's (2005) claim that researcher involvement affects the study, I believe that being a constant presence in the study and

following precise, repeatable methods with insider knowledge was a benefit, not an inhibitor, as I was able to guide conversations and enlighten my participants about key areas of knowledge (such as the implications and risks of using personal data in an educational context).

12.3 Contribution to Knowledges, Practices, and Methodology

Despite the limitations mentioned above, there are several contributions to the field. This section presents the contributions of this research through four areas: (i) Knowledges, (ii) Practices, (iii) Policy and (iv) the methodological contribution of AgileDBR.

12.3.1 Knowledges Contributions and Recommendations

The study makes the following contributions to knowledge:

1. Demonstrating the value of **a pedagogical method** to achieve increased awareness of data-ethics: Through testing new methods, the findings demonstrate the effectiveness of interactive, real-time coding activities with biometric, personal data raises awareness of data-ethics among trainee computing teachers. The findings of this study suggest that these activities are an effective method to help trainee teachers develop a clear understanding of the implications of personal data generation, storage, and usage. The research addressed the need how to raise awareness of data-ethics among trainee computing teachers (RQ1). The effective increased data-ethical awareness of trainee computing teachers was achieved through **engaging in interactive, real-time coding activities involving ML and biometrics, the participants developed a clear understanding of the implications of personal data generation, storage, and usage**. This heightened awareness holds significance for the underpinnings of computing both for trainee teachers and in their future classrooms, ensuring adherence to ethical and data governance principles in today's datafied society.

2. Demonstrating the value of **a method for promoting understanding of ethical considerations in computing:** The study highlights the potential of interactive, real-time, generative programming (RQ1) as a mechanism for promoting ethical considerations in computing. By incorporating **dancer stories and datasets to humanise data, the trainee computing teachers enhanced their understanding and awareness of data-ethics**. This finding underscores the importance of

incorporating ethical dimensions into computing education and provides insights into pedagogical approaches for achieving this goal.

3. Implications for educational materials and pedagogy: The findings have important implications for the development of educational materials and pedagogical approaches aimed at promoting ethical and responsible data use in computing contexts. By **demonstrating the effectiveness of novel methods** of interactive, real-time coding and generative programming activities, the study offers practical insights for designing instructional resources **that foster ethical data practices**.

Overall, the study contributes to the field of computing education by addressing the need to raise awareness of data-ethics among trainee teachers and by exploring innovative approaches to promoting ethical considerations through ballet and biometrics. The findings provide valuable guidance for educators, curriculum developers, and policymakers in developing educational materials and pedagogical strategies that align with the ethical and responsible use of data in computing contexts.

12.3.2 Practices Contributions and Recommendations

The contribution of this study to teacher education practices can be summarised as follows:

1. Data-ethics awareness: The study focuses on raising awareness of data-ethics among Postgraduate Certificate in Education (PGCE) trainee computing teachers. By integrating creative computing practices and biometrics, the study **provided a unique approach to introducing trainee teachers to the ethical implications of sharing personal biometric data**. This contributes to the professional development of trainee teachers by **equipping them with the knowledge and skills needed to navigate the ethical challenges associated with data in the digital age**.
2. Innovative pedagogical approaches: The study introduced creative computing practices, such as ballet and biometrics, as narrative tools for teaching data-ethics. This innovative pedagogical approach goes beyond traditional methods of instruction, creating engaging and interdisciplinary learning experiences for trainee teachers. By **incorporating arts practices into computing education**, see appendix 11B**, the study promotes creativity, critical thinking, and cross-curricular connections**. These approaches can inspire trainee teachers to explore new ways of teaching computing and foster creativity in their own classrooms.

3. Development of accessible educational materials: The study used cognitive liability (Farahany 2012, 2023) and EEG data to develop accessible and reusable educational materials. These materials enabled trainee computing teachers to explore the realms of biometrics and data-ethics, providing them with **practical resources for incorporating ethical considerations into their teaching practices**.
4. Broadening participation in computing education: The use of creative computing practices and interdisciplinary approaches has **the potential to broadening participation in computing education**. By linking computing with other disciplines like physical education, dance, and music, the study only had limited success in expanding the appeal of computing to a broader range of learners through ballet. This contribution is particularly important in addressing the gender and diversity gaps in the field of computing. This **needs further research**, as it offers alternative entry points and encourages more inclusive participation in computing education.
5. Professional collaboration and networking: The study brings together stakeholders from different domains, including computing educators, dancers, and technologists, through purposive sampling. This collaborative, co-design approach allows for knowledge sharing, exchange of ideas, and professional networking. Trainee teachers can benefit from exposure to diverse perspectives and expertise, leading to a broader understanding of the role of data-ethics in computing education. This **contribution promotes a collaborative and interdisciplinary mindset among trainee teachers,** encouraging them to seek out partnerships and interdisciplinary collaborations in their future teaching careers.

Overall, this study's contribution to teacher education lies in its innovative approach to raising awareness of data-ethics, fostering interdisciplinary connections, and inspiring creative and critical thinking in trainee computing teachers. By equipping trainee teachers with the necessary knowledge and skills, this study supports the development of competent and ethically responsible educators in the field of computing.

12.3.3 Policy Contributions and Recommendations

The findings of this study have several implications for policy related to data-ethics and computing education:

1. Incorporating data-ethics education: The study highlights the limited opportunities for individuals to learn about the ethical implications of sharing personal biometric data.

Policymakers should consider **integrating data-ethics education into formal curricula, particularly in computing and technology-related fields**. This can help raise awareness and promote responsible use of personal data.

2. Promoting interdisciplinary approaches: The use of creative computing practices, such as ballet and biometrics, demonstrates the potential for interdisciplinary approaches in computing education. Policymakers should encourage **the integration of arts and creative practices** into computing curricula to **foster cross-disciplinary learning and engagement**.
3. Supporting professional development: Policymakers should **invest in professional development programs for computing educators**, specifically **focusing on data-ethics**. Providing resources, training, and ongoing support can help educators effectively teach and incorporate data-ethics principles into their classrooms.
4. Ensuring access to technology: The study uses digital tools and online settings for data collection and creative coding activities. Policymakers should **prioritise equitable access to technology infrastructure and resources,** particularly in underprivileged schools and communities. Bridging the digital divide can ensure all learners have equal opportunities to engage with computing education and explore data-ethics.
5. Privacy and data protection regulations: The study involves the collection and use of biometric data for research purposes. Policymakers should review and update existing privacy and data protection regulations to address new technologies and research practices involving personal data. **Stricter regulations and guidelines can help safeguard individuals' privacy rights** and ensure the responsible handling of biometric data. With **particular attention to pre-university educational settings**.
6. Research funding and collaboration: Policymakers should support **funding initiatives** and encourage collaboration between academia, technology industries, and creative sectors. This can promote further research and development of **innovative approaches, tools, and methodologies that enhance data-ethics education and computing participation**.

By considering these implications for policy, policymakers can take proactive steps to promote data-ethics education, interdisciplinary approaches, and responsible-ethical use of personal data within computing education.

12.3.4 AgileDBR as a Methodological Approach for Academic Research

AgileDBR (RQ3) has the potential to make a valuable contribution to the field of educational research by addressing the current critiques of DBR through iterative, transparent, and collaborative processes. Biesta and Burbules (2003, pp 107-108) note that theory and practice within educational research are distinct in their own right, and 'the relationship between educational research and practice is, in other words, not one of application but of cooperation and coordination'. AgileDBR offers this crucial cooperation and coordination of theory and practice.

Contributions of AgileDBR as a Methodological Approach for Academic Research:

1. Integration of Agile methodology principles with DBR: AgileDBR provides a unique framework that combines Agile methodology principles with Design-Based Research (DBR), allowing academics to **address complex educational issues in an iterative, flexible, collaborative, and transparent manner**.
2. Addressing complex educational issues: **AgileDBR enables academics to tackle complex educational** issues effectively by providing a **structured, adaptable and transparent approach**. It allows researchers to continuously iterate and refine their research processes, ensuring a more comprehensive understanding of the problem at hand.
3. Transparency and flexibility: **AgileDBR promotes transparency and flexibility** in the research process. Researchers can openly communicate and collaborate with stakeholders, including educators, learners, and other relevant parties, to ensure a shared understanding and involvement in the research.
4. Implementation in various educational environments: The findings generated through AgileDBR can be implemented in diverse educational settings. The methodology's **adaptability, collaborative, participatory nature ensure outcomes are applicable and relevant across different contexts**, allowing for a broader impact.
5. Co-design and co-creation: AgileDBR emphasises co-design and co-creation with educators, learners, and other stakeholders. By involving these key actors in the research process, the **methodology fosters meaningful engagement, enabling a more accurate representation of their perspectives and needs**.
6. Meaningful and sustainable impact: By incorporating Agile methodology principles, AgileDBR aims to create a more meaningful and sustainable impact on educational research practice. The iterative and collaborative nature of the approach **facilitates**

continuous improvement and ensures that research outcomes align with the evolving needs of the educational field.

7. Addressing critiques of DBR: AgileDBR addresses the current critiques of DBR by introducing iterative, transparent, and collaborative processes. This methodology responds to concerns that theory and practice within educational research are separate entities, offering a **cooperative and coordinated approach to bridge the gap between research and practice**.
8. Cooperation and coordination of theory and practice: AgileDBR recognises the importance of cooperation and coordination between theory and practice in educational research. It establishes a collaborative environment where researchers actively engage with practitioners, **promoting a reciprocal relationship** that enhances the applicability and relevance of research outcomes.

These contributions highlight the value and potential impact of AgileDBR as a methodological approach for academic research in the field of education.

12.4 Further Research

Future research in this field should focus on ethical discussions surrounding human data identity in the context of XR with biometrics, particularly as post-pose estimation toolsets continue to evolve. New tools such as Rokoko Video (Dec 2022) perform motion capture via webcam or video-upload, which is then used to generate a rigged character in minutes. It is essential to consider the ethical implications of these tools and their potential impacts on user privacy and data protection. Further study would develop a deeper theoretical understanding of data-ethics for immersive learning, exploring current and future tools for post-pose estimation and biometric identification.

The use of XR in education, particularly in computing education, is a key area of further research. As computing becomes increasingly important in our daily lives, it is important to ensure that students are trained in ethical computing practices. Using immersive (XR) learning environments can provide a valuable platform for exploring theories of immersive learning alongside data-ethics.

Continued collaboration with trainee computer instructors and training programs (PGCE) would be a positive step towards ensuring that future generations of computing professionals have the essential skills and ethical frameworks required. It may also be possible to establish

a more ethical and responsible computing culture through ongoing study and involvement with trainee computing instructors and PGCE training.

12.5 Conclusion

This research explored the potential of creative computing and art practices, specifically biometrics and ballet, as a means of introducing and raising awareness of data-ethics among trainee teachers undertaking a PGCE in computing. The study found that creative coding using biometrics and ballet was effective in raising awareness of data-ethics and expanding student participation in computing education. The research demonstrated the effectiveness of biometric coding activities in improving participants' knowledge of data-ethics, highlighting the unexpected connections between different fields of classical ballet and computing.

The study suggests that integrating such exercises into educational programmes could be a unique and effective way of enhancing awareness of data-ethics. The AgileDBR methodology was successfully developed and employed to examine how computing teachers could incorporate data-ethics into computer science classrooms. My approach also promoted cross-curricular connections between computing and other fields, such as PE, Dance, and Music, but these were outside the scope of this study and required further investigation.

Ultimately, the integration of creative computing with biometrics and ballet contributed to raising awareness of data-ethics in line with the aim of cultivating responsible, competent, confident, innovative, and ethical users of information and communication technology as outlined in the Programme of Study for Computing in England (Gov.UK, 2014). These findings suggest that creative computing and art practices have significant potential to enhance the development of future computing education programmes and that further research in this area is warranted.

I end by returning to the inspiration of Whitman and Barad's words:

> 'I listened to all sides and filtered them from yourself […] (Whitman, 2004)
>
> becoming 'an iterative reconfiguring of possibilities' (Barad, 2007)
>
> that developed into AgileDBR.

References

5Rights | Age Appropriate Design Code. (n.d). 5Rights Foundation. Retrieved 28 May 2023, from HTTPS://5RIGHTSFOUNDATION.COM/OUR-WORK/DESIGN-OF-SERVICE/AGE-APPROPRIATE-DESIGN-CODE.HTML

Aaron, S., Blackwell, A. F., & Burnard, P. (2016). The development of Sonic Pi and its use in educational partnerships: Co-creating pedagogies for learning computer programming. *Journal of Music, Technology and Education*, *9*(1), 75–94. HTTPS://DOI.ORG/10.1386/JMTE.9.1.75_1

Abbas, R., Michael, K., Michael, M. G., Perakslis, C., & Pitt, J. (2022). Machine Learning, Convergence Digitalization, and the Concentration of Power: Enslavement by Design Using Techno-Biological Behaviors. *IEEE Transactions on Technology and Society*, *3*(2), 76–88. HTTPS://DOI.ORG/10.1109/TTS.2022.3179756

Abhang, P. A., Gawali, B. W., & Mehrotra, S. C. (2016). Chapter 2—Technological basics of EEG recording and operation of apparatus. In P. A. Abhang, B. W. Gawali, & S. C. Mehrotra (Eds.), *Introduction to EEG- and Speech-Based Emotion Recognition* (pp. 19–50). Academic Press. HTTPS://DOI.ORG/10.1016/B978-0-12-804490-2.00002-6

Abrahams, J. (2018). Option blocks that block options: exploring inequalities in GCSE and A Level options in England. *British Journal of Sociology of Education*, *39*(8), 1143–1159. HTTPS://DOi.org/10.1080/01425692.2018.1483821

Ackermann, E. K. (2004). Constructing knowledge and transforming the world. In M. Tokoro & E. Steels (Eds.), A learning zone of one's own: Sharing representations and flow in collaborative learning environments (pp. 15–27). IOS Press.

Ackerman, E. (2021). How Boston Dynamics Taught Its Robots to Dance–- IEEE Spectrum. IEEE Spectrum: Technology, Engineering, and Science News. HTTPS://SPECTRUm.ieee.org/automaton/robotics/humanoids/how-boston-dynamics-taught-its-robots-to-dance

ACM Code TaskForce. (2018). *acm-code-of-ethics-and-professional-conduct.pdf* (p. 10). ACM. HTTPS://WWW-ACM-ORG.EZP.LIB.CAM.AC.UK/BINARIES/CONTENT/ASSETS/ABOUT/ACM-CODE-OF-ETHICS-AND-PROFESSIONAL-CONDUCT.PDF

Adams, D. (1979). The Hitchhiker's Guide to the Galaxy by Douglas Adams. Pan Books.

Adrian, E. D., & Matthews, B. H. (1934). The Berger rhythm: potential changes from the occipital lobes in man. *Brain*, *57*(4), 355-385.

Ainsworth, A. (2009). Neurobiology and ballet. *The Journal Of Undergraduate Research*, 1–12.

Aitken, M., & Briggs, M. (2022). Engaging children with AI ethics. *Raspberry Pi Foundation Research Seminars, 3*(13)

Akkerman, S., Bakker, A., & Penuel, W. (2021). Relevance of Educational Research: An Ontological Conceptualization. *Educational Researcher*, 0013189X2110282. HTTPS://DOI.ORG/10.3102/0013189X211028239

al-Rifaie, M. M., & Bishop, M. (2015). Weak and Strong Computational Creativity. In T. R. Besold, M. Schorlemmer, & A. Smaill (Eds.), *Computational Creativity Research: Towards Creative Machines 7*, pp. 37–49. Atlantis Press. HTTPS://DOI.ORG/10.2991/978-94-6239-085-0_2

Alaman, X., Mateu, J., & Lasala, M. J. (2016, April). Designing virtual world educational applications. In *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1134-1137). IEEE.

Alaoui, S. F. (2012, June). Evaluating an interactive installation for dance pedagogy: The Case study of Double Skin/Double Mind. Dis '19 Companion: Companion Publication of the 2019 ACM Designing Interactive Systems Conference.

Alaoui, S. F., & Matos, J.-M. (2021, May). RCO: Investigating Social and Technological Constraints through Interactive Dance | Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. Yokohama, Japan. HTTPS://DL.ACM.ORG/DOI/ABS/10.1145/3411764.3445513

Alismail, S., & Zhang, H. (2019). Exploring and Understanding Participant: Perceptions of Facial Emoji Likert Scales in Online Surveys: A Qualitative Study. *ACM Transactions on Social Computing*, *3*(2), 12:1-12:12. HTTPS://DOI.ORG/10.1145/3382505

Altunian, L. (2019, September 12). Touring Turing—Invertigo Dance Theatre's Formulae & Fairy Tales-Filled Love Letter to History's First Computer Scientist. *L.A. Dance Chronicle*. HTTPS://WWW.LADANCECHRONICLE.COM/TOURING-TURING-INVERTIGO-DANCE-THEATRES-FORMULAE-FAIRY-TALES-FILLED-LOVE-LETTER-TO-HISTORYS-FIRST-COMPUTER-SCIENTIST/

Amiel, T., & Reeves, T. C. (2008). Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda. *Journal of Educational Technology & Society*, *11*(4), 29–40.

An, T., & Oliver, M. (2021). What in the world is educational technology? Rethinking the field from the perspective of the philosophy of technology. *Learning, Media and Technology, 46*(1), 6–19. HTTPS://DOI.ORG/10.1080/17439884.2020.1810066

Anantrasirichai, N., & Bull, D. (2022). Artificial intelligence in the creative industries: A review. *Artificial Intelligence Review*, *55*(1), 589–656. HTTPS://DOI.ORG/10.1007/S10462-021-10039-7

Andrews, T., Dyson, L. E., & Wishart, J. (2015). Advancing ethics frameworks and scenario-based learning to support educational research into mobile learning. *International Journal of Research & Method in Education*, *38*(3), 320-334.

Apache License, Version 2.0. (2004) [Computer software]. Retrieved 30 March 2022, from HTTPS://WWW.APACHE.ORG/LICENSES/LICENSE-2.0

AQA. (2019). *GCSE Dance (8236) Specification For teaching from September 2016 onwards For exams in 2018 onwards.* AQA AQA Education. HTTPS://FILESTORE.AQA.ORG.UK/RESOURCES/DANCE/SPECIFICATIONS/AQA-8236-SP-2016.PDF

AQA (2020) *GCSE Computer Science(8525) Specification For teaching from September 2020 onwards For exams in 2022 onwards.* AQA Education. HTTPS://WWW.AQA.ORG.UK/SUBJECTS/COMPUTER-SCIENCE-AND-IT/GCSE/COMPUTER-SCIENCE-8525/SUBJECT-CONTENT

Archer, B. (1969). The structure of the design process. In G. Broadbent (Ed.), *Design methods in architecture* (pp. 76–102). John Wiley and Sons Ltd.

Awad, M. A. (2005). A comparison between agile and traditional software development methodologies. *University of Western Australia*, *30*, 1-69.

Axelrod, R. (1997). Advancing the art of simulation in the social sciences. In *Simulating social phenomena* (pp. 21-40). Springer Berlin Heidelberg.

Azanha, A., Argoud, A.R.T.T., Camargo Junior, J.B.d. and Antoniolli, P.D. (2017), *Agile project management with Scrum: A case study of a Brazilian pharmaceutical company IT*

project, INTERNATIONAL JOURNAL OF MANAGING PROJECTS IN BUSINESS, Vol. 10 No. 1, pp. 121-142. HTTPS://DOI.ORG/10.1108/IJMPB-06-2016-0054

Babbage, C. (1840s/2011). THEATRICAL EXPERIENCE. In *Passages from the Life of a Philosopher* (Cambridge Library Collection–- Technology, pp. 251-258). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139103671.021

Babineaux, R., & Krumboltz, J. (2013). *Fail Fast, Fail Often: How Losing Can Help You Win*. Tarcher Perigee. HTTPS://WWW.PENGUINRANDOMHOUSE.COM/BOOKS/314667/FAIL-FAST-FAIL-OFTEN-BY-RYAN-BABINEAUX/

Baer, J. & Kaufman, J. C. (2005). Bridging generality and specificity: The Amusement Park Theoretical (APT) model of creativity. *Roeper Review, 27*, 158–163.

Baer, J. & Kaufman, J. C. (2008). Gender differences in creativity. *Journal of Creative Behavior, 42*, (pp. 75–106).

Baer, J. & Kaufman, J. C. (2017). The Amusement Park Theoretical model of creativity: An attempt to bridge the domain specificity/generality gap. In J. C. Kaufman, V. P. Glăveanu, & J. Baer (eds.), Cambridge handbook of creativity across different domains (pp. 8–17). New York: Cambridge University Press.

Bakker, A., & van Eerde, D. (2015). An Introduction to Design-Based Research with an Example From Statistics Education. In A. Bikner-Ahsbahs, C. Knipping, & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education* (pp. 429–466). Springer Netherlands. HTTPS://DOI.ORG/10.1007/978-94-017-9181-6_16

Bakker, A. (2018). *Design research in education: a practical guide for early career researchers*. Routledge.

Balanchine, G. (1958). A Word from George Balanchine. *Dance Magazine*, *32*(1), 34–35.

Banerjee, D., Cronan, T., & Jones, T. (1998). Modeling IT ethics: A study in situational ethics. *MIS Quarterly: Management Information Systems*, *22*(1), 31–54. HTTPS://DOI.ORG/10.2307/249677

Barad, K. (2003). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. *Signs*, *28*(3), 801–831. HTTPS://WWW.JOURNALS.UCHICAGO.EDU/DOI/10.1086/345321

Barad, K. (2007). *Meeting the Universe Halfway Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press. HTTPS://WWW-DUKEUPRESS-EDU.EZP.LIB.CAM.AC.UK/MEETING-THE-UNIVERSE-HALFWAY

Barad, K. (2014). Diffracting Diffraction: Cutting Together-Apart. *Parallax, 20(3),* 168–187. HTTPS://DOi.org/10.1080/13534645.2014.927623

Barbieri, D., Caisl, J., Karu, M., Lanfredi, G., Mollard, B., Peciukonis, V., La Hoz, M.B.P Reingardė, J., & Salanauskaitė. L. (2020). *Gendered patterns in use of new technologies*. Publications Office of the European Union. DOI:10.2839/076536

Bares, W., Manaris, B., & McCauley, R. (2018). Gender equity in computer science through computing in the arts – a six-year longitudinal study. *Computer Science Education*, *28*(3), 191–210. HTTPS://DOI.ORG/10.1080/08993408.2018.1519322

Bares, W. H., Manaris, B., McCauley, R., & Moore, C. (2019). Achieving Gender Balance through Creative Expression. *Proceedings of the 5^{0t}h ACM Technical Symposium on Computer Science Education*, 293–299. HTTPS://DOI.ORG/10.1145/3287324.3287435

Barhorst-Cates, E. M. (2019). Spatial working memory is enhanced for movement experts in traditional and embodied tasks. *Spatial Cognition & Computation*, *19*(1), 69–91.

Barker, L., Garvin-Doxas, K., & Roberts, E. (2005). What Can Computer Science Learn from a Fine Arts Approach to Teaching? *ACM SIGCSE Bulletin*, *37*(1), 421–425.

Barnstaple, R. (2020). *An applied neurobiological model of dance, why it matters, and how it heals* [York University, Canada]. HTTP://130.63.180.190/XMLUI/BITSTREAM/HANDLE/10315/38198/BARNSTAPLE_REBECCA_E_2020_PHD.PDF?SEQUENCE=2&ISALLOWED=Y

Barton, E. E., Ledford, J. R., Lane, J. D., Decker, J., Germansky, S. E., Hemmeter, M. L., & Kaiser, A. (2016). The Iterative Use of Single Case Research Designs to Advance the Science of EI/ECSE. *Topics in Early Childhood Special Education*, *36*(1), 4–14. HTTPS://DOI.ORG/10.1177/0271121416630011

Batchelor, T. (2020, 12). Government advert encouraging ballet dancer to retrain in IT is 'crass', admits minister. *The Independent*. HTTPS://WWW.INDEPENDENT.CO.UK/NEWS/UK/POLITICS/CORONAVIRUS-GOVERNMENT-ADVERT-BALLET-DANCER-RETRAIN-IT-CYBER-OLIVER-DOWDEN-B987403.HTML

Bateson, G. (2000). Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology. (reprint). University of Chicago Press.

Bateson, G. ([1970] 2015). Form, substance and difference. etc: *A Review of General Semantics, 72*(1), 90–104. HTTP://WWW.JSTOR.ORG/STABLE/24761998

Baudrillard, J. (1994). Simulacra and simulation (English Translation). The University of Michigan Press. HTTP://HDL.HANDLE.NET/2027/MDP.39015037473249

Baudrillard, J. (1996). *The system of objects* (J. Benedict, Trans.). Verso.

Bayley, A. (2018). Posthuman Pedagogies in Practice: Arts based Approaches for Developing Participatory Futures. Springer.

Bayley, A. (2023, March 27). *AI-Otherwise #ED2123*. DEFI annual event: AI and Creativity, Cambridge. HTTPS://WWW.DEFICAMBRIDGE.ORG/EVENTS/ED2123-THE-DEFI-ANNUAL-EVENT/

BCS.org Subject Knowledge Enhancement Course in Computer Programming | BCS. (n.d.). Retrieved 30 August 2022, from HTTPS://WWW.BCS.ORG/QUALIFICATIONS-AND-CERTIFICATIONS/TRAINING-AND-SCHOLARSHIPS-FOR-TEACHERS/BCS-SUBJECT-KNOWLEDGE-ENHANCEMENT-COURSE-IN-COMPUTER-PROGRAMMING/

Beauchamp, T., & Childress, J. (2019). Principles of Biomedical Ethics, 5th edn. | Journal of Medical Ethics (8th ed.). Oxford University Press.

Beckwith, L., Burnett, M., Grigoreanu, V., & Wiedenbeck, S. (2006). Gender HCI: What About the Software? *IEEE Computer Society Press*, *39*(11), 97–101. HTTPS://DOI.ORG/10.1109/MC.2005.375

Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational psychologist*, *39*(4), 243-253.

Bell, P. (2004b). Chapter 4 Design-Based Research in Education—Internet Environments for Science Education. In M. Linn & E. Davis (Eds.), *Internet Environments for Science Education*. Lawrence Erlbaum Associates Inc. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/INTERNET-ENVIRONMENTS-FOR/9780805843026/XHTML/CH0004.XHTML

Benington, H. D. (1956, June 1-14). Production of large computer programs. *Symposium on Advanced Programming Methods for Digital Computers: Washington, D.C., June 1-14 1956.*

(U. S. N. M. C. A. Panel, Ed.). Office of Naval Research, Department of the Navy. https://play.google.com/books/reader?id=tLo6AQAAMAAJ&pg=GBS.PP14&hl=en_GB

Benington, H. D. (1983). Production of large computer programs. *Annals of the History of Computing*, *5*(4), 350–361. https://doi.org/10.1109/MAHC.1983.10102

[BERA] British Educational Research Association (2018) *Ethical Guidelines for Educational Research*, fourth edition, London. https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2018

Berger, J. (2008). Ways of seeing. Penguin. https://www.vlebooks.com/Vleweb/Product/Index/661959?page=0

Berges, S., Martino, S., Basko, L., & McCabe, C. (2021). "zooming" into engagement: increasing engagement in the online classroom. *Journal of Instructional Research*, *10*.

Berghmans, S., Cousijn, H., Deakin, G., Meijer, I., Mulligan, A., Plume, A., Waltman, L., Rushforth, A., de Ricjcke, S., Tatum, C., Tobin, S., & van Leeuwen, T. (2017). *Open Data Report: Researchers perspective* [Elsevier]. https://www-elsevier-com.ezp.lib.cam.ac.uk/__data/assets/pdf_file/0003/1073046/Open-data-report.pdf

Bergson, H. (1913/2018). Time and Free Will: An Essay on the Immediate Data of Consciousness (F. L. Pogson, Trans.). George Allen & Co. https://www.gutenberg.org/files/56852/56852-h/56852-h.htm

Bergson, H. (1946/2007). *The Creative Mind: An Introduction to Metaphysics* (M. AndisonL., Trans.). Dover Publication Inc.

Bergson, H. (1950). Time and Free Will: An essay on the immediate data of consciousness (F.L. Pogson, Trans.). George Allen & Unwin Ltd. https://chilonas.files.wordpress.com/2018/11/time-and-free-will-bergson.pdf

Berners-Lee, T., Cailliau, R., Groff, J., & Pollermann, B. (2010). World-wide web: the information universe. *Internet Research*, *20*(4), 461–471. https://doi.org/10.1108/10662241011059471

Bers, M. (2012). Designing Digital Experiences for Positive Youth Development. Cary: Oxford University Press.

Bertino, E., & Crampton, J. (2008). CHAPTER 3–- Security for Distributed Systems: Foundations of Access Control. In Y. Qian, J. Joshi, D. Tipper, & P. Krishnamurthy (Eds.), *Information*

Assurance (pp. 39–79). Morgan Kaufmann. https://doi.org/10.1016/B978-012373566-9.50005-7

Bertelsen, O., Bødker, S., Eriksson, E., Hoggan, E., & Vermeulen, J. (2019). Beyond generalization: research for the very particular: *Interaction*, *26*(1), pp.34–38. https://DOi.org/https://doi.org/10.1145/3289425

Best, J. (Ed.). (2017). Colour Design Theories and Applications. In *Colour Design (Second Edition)* (p. iv). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-101270-3.09993-8

Bhadeshia, H. K. D. H. (2021). *Theory of transformations in steels*. CRC Press.

Bhadeshia, H. K. D. H. (2023, March 10). *Isolation of Atomic Mechanisms: The Choreographer at Play–- Professor Sir Harry Bhadeshia*. Darwin College Lecture Series, 2023, Cambridge, U.K. https://www.youtube.com/watch?v=kpJklRSlXJw

Bielaczyc, K. (2013). Informing design research: Learning from teacher'' designs of social infrastructure. *Journal of the Learning Sciences*, *22*(2), 258-311.

Biesta, G., & Burbules, N. C. (2003). *Pragmatism and educational research*. Lanham, MD: Rowman & Littlefield.

Billingsley, B., & Hazeldine, L. (2020). Shattering the Subject Silos: Learning about Big Questions, Working Scientifically and Epistemic Insight. *Impact: Journal of the Chartered College of Teaching, 9* (Summer). https://repository.canterbury.ac.uk/download/12b1a24abd21ce9245aa07edc571078094ed21c1c2a3b02ee3a9812ea08dcafd/334100/impact-article-epistemic%20insight-13March20-clean.pdf

Bingham-Hall, J., & Cosgrove, E. (2018). Choreographing the city: Can dance practice inform the engineering of sustainable urban environments? *Mobilities*, *14*(2), 188–203.

Bishop, J. M., & al-Rifaie, M. M. (2017). Autopoiesis, creativity and dance. *Connection Science*, *29*(1), 21–35. https://doi.org/10.1080/09540091.2016.1271399

Blackwell, J. (2018). Applied Visual Metaphors in Organizational Management. In S. Griffith, K. Carruthers, & M. Bliemel (Eds.), *Visual Tools for Developing Cross-Disciplinary Collaboration, Innovation and Entrepreneurship Capacity:* (pp. 409–416). Common Ground Research Networks. http://doi.org/10.18848/978-1-86335-117-1/CGP

Bland, D. J., & Osterwalder, A. (2019). *Testing business ideas: A field guide for rapid experimentation*. John Wiley & Sons.

Blokdyk, G. (2019). *Domain-Driven Design a Complete Guide.* 5starcioks. Retrieved 12 June 2023, from HTTPS://WWW.WATERSTONES.COM/BOOK/DOMAIN-DRIVEN-DESIGN-A-COMPLETE-GUIDE-2019-EDITION/GERARDUS-BLOKDYK//9780655512042

Boddington, G. (2021). The Internet of Bodies—alive, connected and collective: The virtual physical future of our bodies and our senses. *AI & SOCIETY*. HTTPS://DOI.ORG/10.1007/S00146-020-01137-1

Boddington, G. (n.d.). *body>data>space*. Body>data>space. Retrieved June 24, 2022, from HTTP://WWW.BODYDATASPACE.NET/

Bond, K. E. (1994). How 'wild things' tamed gender distinctions. *Journal of Physical Education, Recreation & Dance*, *65*(2), 28–33. HTTPS://DOI.ORG/10.1080/07303084.1994.10606851

Bond, K. E., & Stinson, S. W. (2000). "I Feel Like I'm Going to Take Off!": Young People's Experiences of the Superordinary in Dance. *Dance Research Journal*, *32*(2), 52–87. HTTPS://DOI.ORG/10.2307/1477981

Bourdieu, P. (1986). Chapter: The forms of capital. In *Handbook of Theory and Research for the Sociology of Education.* (pp. 241–258). Greenwood Press. HTTPS://WWW.SOCIALCAPITALGATEWAY.ORG/CONTENT/PAPER/BOURDIEU-P-1986-FORMS-CAPITAL-RICHARDSON-J-HANDBOOK-THEORY-AND-RESEARCH-SOCIOLOGY-EDUC

Braidotti, R. (2013). Posthuman Humanities. *European Educational Research Journal*, *12*(1), pp.1–19. HTTPS://DOI.ORG/10.2304/EERJ.2013.12.1.1

Braidotti, R. (2019). *Posthuman Knowledge*. Polity Press. HTTPS://WWW.VLEBOOKS.COM/PRODUCT/INDEX/1674304?PAGE=0

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Braun, V., & Clarke, V. (2022). *Thematic Analysis: A practical guide*. Sage Publications. HTTPS://UK.SAGEPUB.COM/EN-GB/EUR/THEMATIC-ANALYSIS/BOOK248481

Breiner, J.M., Harkness, S.S., Johnson, C.C. and Koehler, C.M. (2012), What Is STEM? A Discussion About Conceptions of STEM in Education and Partnerships. *School Science and Mathematics, 112*: 3-11. HTTPS://DOI.ORG/10.1111/J.1949-8594.2011.00109.X

Brennan, K., & Resnick, M. (2012). *New frameworks for studying and assessing the development of computational thinking*. 25.

Brewer, D. F. C., and Nash, M. J. (1989). The Chinese Wall security policy. *Proceedings. 1989 IEEE Symposium on Security and Privacy*, 206–214. HTTPS://DOI.ORG/10.1109/SECPRI.1989.36295

Brewster, D. (1817). *Kaleidoscopes—Brewster's Speficiations* (Patent No. 4136). HTTPS://WEB.ARCHIVE.ORG/WEB/20110721020838/HTTP://WWW.BREWSTERSOCIETY.COM/BREWSTER_PATENT.PDF

Brocki, J. M., & Wearden, A. J. (2006). A critical evaluation of the use of interpretative phenomenological analysis (IPA) in health psychology. *Psychology & Health*, *21*(1), 87–108. HTTPS://DOI.ORG/10.1080/14768320500230185

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The journal of the learning sciences*, *2*(2), 141-178.

Brown, C., & Wild, M. (Eds.). (2023). *Ethical Dilemmas in Education: Considering Challenges and Risks in Practice*. Open University Press.

Bruner, J. (1977). The process of education. Cambridge, Mass. ; London: Harvard University Press.

Bruner, J. S. (2006). *In search of pedagogy: Volume I [1957-1978] : the selected works of Jerome S. Bruner / Jerome S. Bruner.* Routledge.

Bruner, J. S. (2006b). *In search of pedagogy: Volume II [1979-2006] : the selected works of Jerome S. Bruner / Jerome S. Bruner.* Routledge.

Bryman, A. (2021). *Social Research Methods 6E*. Oxford University Press.

Buckingham Shum, S. (2022). *The UTS "EdTech Ethics" Deliberative Democracy Consultation: Rationale, Process and Outcomes.* Connected Intelligence Centre, University of Technology Sydney, AUS. HTTPS://CIC.UTS.EDU.AU/PROJECTS/EDTECH-ETHICS

Bullock, B. B., Nascimento, F. L., & Doore, S. A. (2021). Computing Ethics Narratives: Teaching Computing Ethics and the Impact of Predictive Algorithms. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, 1020–1026. https://doi.org/10.1145/3408877.3432468

Buttle, F., & Thomas, G. (1997, October). Questionnaire colour and mail survey response rate. *Journal of the Market Research Society*, *39*(4), pp. 625+. https://go.gale.com/ps/i.do?p=AONE&u=anon~fe60de79&id=GALE|A20224457&v=2.1&it=r&sid=googleScholar&asid=d3dcc898

Burgess, R. (1984). *In the Field: An Introduction to Field Research (Contemporary Social Research):* (1st ed.). Routledge.

Cadwalladr, C., & Graham-Harrison, E. (2018, March 17). Revealed: 50 million Facebook profiles harvested for Cambridge Analytica in major data breach | Cambridge Analytica. *The Guardian*. https://www.theguardian.com/news/2018/mar/17/cambridge-analytica-facebook-influence-us-election

Cairns, R. (2021). Exams tested by Covid-19: An opportunity to rethink standardized senior secondary examinations. *PROSPECTS*, *51*(1), 331–345. https://doi.org/10.1007/s11125-020-09515-9

Callahan, D. M. (2018). The Gay Divorce of Music and Dance: Choreomusicality and the Early Works of Cage-Cunningham. *Journal of the American Musicological Society*, *71*(2), 439–525.

Cambridge Cognition. (2015, November 17). Spatial Working Memory (SWM) [Research neuroscience]. *Cambridge Cognition*. https://www.cambridgecognition.com/cantab/cognitive-tests/executive-function/spatial-executive-function-swm

Cambridge University Press (CUP). (2017). Ballet in *Cambridge Advanced Learner's Dictionary & Thesaurus* Retrieved October 21, 2021. https://dictionary.cambridge.org/dictionary/english/

Camp, T. (1997). The Incredible Shrinking Pipeline. *Commun. ACM*, *40*(10), 103–110. https://doi.org/10.1145/262793.262813

Campbell, D. T., & Stanley, J. C. (2011). *Experimental and quasi-experimental designs for research*. Wadsworth.

Canning, J. (2019). The UK Teaching Excellence Framework (TEF) as an illustration of Baudrillard's hyperreality. *Discourse: Studies in the Cultural Politics of Education, 40*(3), 319–330. HTTPS://DOI.ORG/10.1080/01596306.2017.1315054

Capocchiani, V., Lorenzi, M. G., Michelini, M., Rossi, A. M., & Stefanel, A. (2011). Physics in dance and dance to represent physical processes. *Journal of Applied Mathematics*, *4*(4), 71–84.

Capurro, R. (2006). Towards an Ontological Foundation of Information Ethics. *Ethics and Information Technology*, *8*(4), 175–186. HTTPS://DOI.ORG/10.1007/S10676-006-9108-0

Capurro, R. (2009). Digital Ethics. *Global Forum on Civilization and Peace*, 207–216. HTTP://WWW.capurro.de/korea.html

Capurro, R. (2018). Why Information Ethics? *International Journal of Applied Research on Information Technology and Computing*, *9*(1), 50. HTTPS://DOI.ORG/10.5958/0975-8089.2018.00005.2

Caracelli, V. J. (2006). Enhancing the policy process through the use of ethnography and other study frameworks: A mixed-method strategy. *Research in the Schools*, *13*(1), 84-92.

Carlucci Aiello, L. (2016). The multifaceted impact of Ada Lovelace in the digital age. *Artificial Intelligence*, *235*, 58–62. HTTPS://DOI.ORG/10.1016/J.ARTINT.2016.02.003

Carter, R. (2018). Waves to Waveforms: Performing the Thresholds of Sensors and Sense-Making in the Anthropocene. *Arts*, *7*(4). HTTPS://WWW.MDPI.COM/2076-0752/7/4/70

Carvalho, G., de Matos, D. M., & Rocio, V. (2007). *Document Retrieval for Question Answering: A Quantitative Evaluation of Text Preprocessing*. 6.

Cellan-Jones, R. (2019, May 7). Computing in schools in "steep decline." *BBC News*. HTTPS://WWW.BBC.COM/NEWS/TECHNOLOGY-48188877

Chalmers, A. (1999). What is this called science. *Glasgow: Bell & Bain Ltd*.

Chalmers, A. (2013). *What Is This Thing Called Science? Books* (4th ed.). Open University Press.

Chan, J. C. P., Leung, H., Tang, J. K. T., & Komura, T. (2010). T Komura, A virtual reality dance training system using motion capture technology. *IEEE Trans Learn Technology*, 187–195.

Chappell, K., Craft, A., Rolfe, L., & Jobbins, V. (2009). Dance partners for creativity: Choreographing space for co-participative research into creativity and partnership in dance education. *Research in Dance Education*, *10*(3), 177–197. HTTPS://DOI.ORG/10.1080/14647890903324147

Chappell, K. (2018). From Wise Humanising Creativity to (Posthumanising) Creativity. In: Snepvangers, K., Thomson, P., Harris, A. (eds) Creativity Policy, Partnerships and Practice in Education. Creativity, Education, and the Arts. Palgrave Macmillan, Cham. HTTPS://DOi.org/10.1007/978-3-319-96725-7_13

Chappell, K. (2022). Researching Posthumanizing Creativity: Expanding, Shifting, and Disrupting. *Qualitative Inquiry*, *28*(5), 496–506. HTTPS://DOI.ORG/10.1177/10778004211065802

Charmaz, K. (2014). *Constructing Grounded Theory* (2nd ed.). Sage Publ. HTTP://UK.SAGEPUB.COM/EN-GB/EUR/CONSTRUCTING-GROUNDED-THEORY/BOOK235960

Charollais, P. (2017). *ECMA-404, JSON 2nd edition, December 2017*.

Chen, W. (2001). Description of an expert teacher's constructivist-oriented teaching: Engaging students' critical thinking in learning creative dance. *Research Quarterly for Exercise and Sport*, *72*(4), 366-375.

Cheng, Y., Yang, B., Wang, B., Wending, Y., & Tan, R. (2019). Occlusion-Aware Networks for 3D Human Pose Estimation in Video. *2019 IEEE/CVF International Conference on Computer Vision (ICCV)*, 723–732. HTTPS://DOI.ORG/10.1109/ICCV.2019.00081

Chip, & Heath, D. (2015). 3. Data and Innovation—Data-Informed Product Design [Book]. In P. Pavliscak (Ed.), *Data-Informed Product Design*. O'Reilly Media Inc. HTTPS://WWW.OREILLY.COM/LIBRARY/VIEW/DATA-INFORMED-PRODUCT-DESIGN/9781492048688/CH03.HTML

Chivukula, S. S., Li, Z., Pivonka, A. C., Chen, J., & Gray, C. M. (2022). *Surveying the Landscape of Ethics-Focused Design Methods* (No. arXiv:2102.08909). arXiv. HTTP://ARXIV.ORG/ABS/2102.08909

Christen, M., Ineichen, C., & Tanner, C. (2014). How "moral" are the principles of biomedical ethics? – a cross-domain evaluation of the common morality hypothesis. *BMC Medical Ethics, 15*(1), 47. HTTPS://DOI.ORG/10.1186/1472-6939-15-47

Christensen, K., & West, R. E. (2018). The Development of Design-Based Research. *Foundations of Learning and Instructional Design Technology*. HTTPS://EDTECHBOOKS.ORG/LIDTFOUNDATIONS/DEVELOPMENT_OF_DESIGN-BASED_RESEARCH

Choudnury, S., & Slaby, J. (Eds.). (2011). *Critical Neuroscience: A Handbook of the Social and Cultural Contexts of Neuroscience*. Wiley-Blackwell. HTTPS://WWW.WILEY.COM/EN-GB/CRITICAL+NEUROSCIENCE:+A+HANDBOOK+OF+THE+SOCIAL+AND+CULTURAL+CONTEXTS+OF+NEUROSCIENCE-P-9781444333282

Chun Tie, Y., Birks, M., & Francis, K. (2019). Grounded theory research: A design framework for novice researchers. *SAGE Open Medicine*, *7*, 2050312118822927. HTTPS://DOI.ORG/10.1177/2050312118822927

Clark-Ibáñez, M. (2004). Framing the Social World With Photo-Elicitation Interviews. *American Behavioral Scientist*, *47*(12), 1507–1527. HTTPS://DOI.ORG/10.1177/0002764204266236

Clarke, V., & Braun, V. (2013). Successful qualitative research: A practical guide for beginners. *Successful qualitative research*, 1-400.

Clay, A., Delord, E., Couture, N., & Domenger, G. (2010). Augmenting a Ballet Dance Show Using the Dancer's Emotion: Conducting Joint Research in Dance and Computer Science. In F. Huang & R.-C. Wang (Eds.), *Arts and Technology* (pp. 148–156). Springer. HTTPS://DOI.ORG/10.1007/978-3-642-11577-6_19

Clay, A., Domenger, G., Conan, J., Domenger, A., & Couture, N. (2014). Integrating augmented reality to enhance expression, interaction & collaboration in live performances: A ballet dance case study. *2014 IEEE International Symposium on Mixed and Augmented Reality—Media, Art, Social Science, Humanities and Design (ISMAR-MASH'D)*, 21–29. HTTPS://DOI.ORG/10.1109/ISMAR-AMH.2014.6935434

Clason, D. L., & Dormody, T. J. (1994). Analyzing Data Measured by Individual Likert-Type Items. *Journal of Agricultural Education, 35*(4), 31–35.

Cockburn, A. (2006). *Agile software development: the cooperative game*. Pearson Education.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge. https://www-routledge-com.ezp.lib.cam.ac.uk/Research-Methods-in-Education/Cohen-Manion-Morrison/p/book/9781138209886

Cohn, M. (2004). *User Stories Applied Book*. Mountain Goat Software. https://www.mountaingoatsoftware.com/books/user-stories-applied

Cohn, M. (2005). *Agile Estimating and Planning* (1st edition). Prentice Hall.

Coleman, V. (2021). Digital Divide in UK Education during COVID-19 Pandemic: Literature Review. Research Report. In *Cambridge Assessment*. University of Cambridge Local Examinations Syndicate (Cambridge Assessment). https://eric.ed.gov/?id=ED616296

Collier, K. (2011). *Agile Analytics: A Value-Driven Approach to Business Intelligence and Data Warehousing*. Addison-Wesley's Professional. https://learning.oreilly.com/library/view/agile-analytics-a/9780321669575/

Collins, A. (1992). Toward a Design Science of Education. In: Scanlon, E., O'Shea, T. (eds) New Directions in Educational Technology. NATO ASI Series, vol 96. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-77750-9_2

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. *Journal of the Learning Sciences*, *13*(1), 15–42. https://doi.org/10.1207/s15327809jls1301_2

Collins, F. S., Morgan, M., & Patrinos, A. (2003). The Human Genome Project: lessons from large-scale biology. *Science (New York, N.Y.)*, *300*(5617), 286–290. https://doi.org/10.1126/science.1084564

Collins, H. (2010). Tacit and Explicit Knowledge. In *Tacit and Explicit Knowledge*. University of Chicago Press. https://doi.org/10.7208/9780226113821

Colucci-Gray, D. L., Burnard, P., Cooke, C., Davies, R., Gray, D., & Trowsdale, J. (2017). Reviewing The Potential And Challenges Of Developing Steam Education Through Creative Pedagogies For 21st Learning: *BERA Report*.

Conway, P. (2006). Cecilia McDowall. *Tempo, 60*(237), 66-67. Cambridge University Press. https://www.jstor.org/stable/3878715

Cooke, J., & Woollard, J. (2006). *Visual literacy and painting with technology: Observations in the early year's classroom* (M. Hayes & D. Whitebread, Eds.; pp. 107–123). McGraw-Hill. HTTPS://EPRINTS.SOTON.AC.UK/55253/

Cooper, R., Zhao, L., & Wang, C. (2007). A model driven architecture and toolset for building immersive software engineering teaching tools. *6th European Conference On E-Learning*, 129–137.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, *13*(1), 3–21. HTTPS://DOI.ORG/10.1007/BF00988593

Cortese, A., & Rossi-Arnaud, C. (2010). Working memory for ballet moves and spatial locations in professional ballet dancers. *Applied Cognitive Psychology*, *24*, 266–286. HTTPS://DOI.ORG/10.1002/ACP.1593

Corsi-Cabrera, M., & Gutierrez, L. (1991). Spatial Ability in Classic Dancers and Their Perceptual Style. *Perceptual and Motor Skills*, *72*(2), 399–402. HTTPS://DOI.ORG/10.2466/PMS.1991.72.2.399

Craft, A. (2005). *Creativity in schools: Tensions and dilemmas*. Psychology Press.

Craft, A. (2008). *Tensions in creativity and education: enter wisdom and trusteeship?* (A. Craft, H. Gardner, & G. Claxton, Eds.). Corwin Press. HTTP://WWW.CORWIN.COM/BOOKSPRODDESC.NAV?PRODID=BOOK229398&#TABVIEW=TOC

Cremers, P. H., Wals, A. E., Wesselink, R., & Mulder, M. (2017). Utilization of design principles for hybrid learning configurations by interprofessional design teams. *Instructional Science*, *45*(2), 289-309.

Creswell, J. W. (2009). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (3rd ed.). Thousand Oaks, CA: Sage Publications.

Creswell, J. W. (2014). *A Concise Introduction to Mixed Methods Research*. SAGE Publications.

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and Conducting Mixed Methods Research* (3rd ed.). SAGE Publications Inc. HTTPS://US.SAGEPUB.COM/EN-US/NAM/DESIGNING-AND-CONDUCTING-MIXED-METHODS-RESEARCH/BOOK241842

Crnkovic-Friis, L., & Crnkovic-Friis, L. (2016, June 27 – July 1). Generative Choreography using Deep Learning. *The 7th International Conference on Computational Creativity*. ICCC2016, Paris. HTTPS://ARXIV.ORG/PDF/1605.06921

Cross, E. S., & Ticini, L. F. (2012). Neuroaesthetics and beyond: new horizons in applying the science of the brain to the art of dance. *Phenomenology and the cognitive sciences*, *11* 5-16.

Cruz-Garza, J. G., Hernandez, Z. R., Nepaul, S., Bradley, K. K., & Contreras-Vidal, J. L. (2014). Neural decoding of expressive human movement from scalp electroencephalography (EEG). *Frontiers in Human Neuroscience*, *8*. HTTPS://WWW.FRONTIERSIN.ORG/ARTICLES/10.3389/FNHUM.2014.00188

Csikszentmihalyi, M. (1988). Society, culture, and person: A systems view of creativity. In *The Nature of Creativity* (p. 325). Cambridge University Press. http://scholar.worldlib.site:8000/upload/202203/29/20220329110125156O.pdf

Csikszentmihalyi, M. (2014). *Applications of Flow in Human Development and Education: The Collected Works of Mihaly Csikszentmihalyi* (2014th edition). Springer.

Dacanay, C., Jessup L., Krystal S., Lee J., Lewis A., McClendon B., Shiffman D., & Weinberg M. (2021, May 10). A New Code of Conduct and License for ml5.js. *Medium*. HTTPS://MEDIUM.COM/ML5JS/A-NEW-CODE-OF-CONDUCT-AND-LICENSE-FOR-ML5-JS-6B0E4C109B76

Dallaway, E. (2016). *Closing the Gender Gap in Cybersecurity* (p. 11). CREST.

Dallaway, E. (2020). *CREST Gender Report*. HTTPS://WWW.CREST-APPROVED.ORG/WP-CONTENT/UPLOADS/2022/04/CREST-GENDER-REPORT_202004.PDF

Dallaway, E. (2022). CREST *Women in Cyber: Stories Uncut* (p. 15). CREST. HTTPS://WWW.CREST-APPROVED.ORG/WP-CONTENT/UPLOADS/2022/11/CREST-WOMEN-IN-CYBER-STORIES-UNCUT.PDF

Dale, J. A., Hyatt, J., & Hollerman, J. (2007). The Neuroscience of Dance and the Dance of Neuroscience: Defining a Path of Inquiry. *Journal of Aesthetic Education*, *41*(3), 89–110.

Dayma, B., Patil, S., Cuenca, P., Saifullah, K., Abraham, T., Lê, P., Melas, L., & Ghosh, R. (2021). *DALL-E Mini*. HTTPS://GITHUB.COM/BORISDAYMA/DALLE-MINI

De Bruijne, M., & Wijnant, A. (2014). Improving Response Rates and Questionnaire Design for Mobile Web Surveys. *Public Opinion Quarterly, 78*(4), 951–962. HTTPS://DOI.ORG/10.1093/POQ/NFU046

de Bruin, B. (2015). Ethics and the Global Financial Crisis: Why Incompetence Is Worse than Greed. Cambridge University Press. HTTPS://DOI.ORG/10.1017/CBO9781139237093

de Bruin, B., & Floridi, L. (2017). The Ethics of Cloud Computing. Science and Engineering Ethics, 23(1), 21–39. HTTPS://DOI.ORG/10.1007/S11948-016-9759-0

De Capitani di Vimercati, S., & Samarati, P. (2011). Clark and Wilson Model. In H. C. A. van Tilborg & S. Jajodia (Eds.), *Encyclopedia of Cryptography and Security* (pp. 208–209). Springer US. HTTPS://DOI.ORG/10.1007/978-1-4419-5906-5_814

De Lisle, J. (2018). The Benefits and Challenges of Mixing Methods and Methodologies: Lessons Learnt From Implementing Qualitatively Led Mixed Methods Research Designs in Trinidad and Tobago. *Caribbean Curriculum*, *8*, 7–120.

De Smedt, B., Taylor, J., Archibald, L., & Ansari, D. (2010). How is phonological processing related to individual differences in children's arithmetic skills?. *Developmental science*, *13*(3), 508-520.

De Smedt, B., Ansari, D., Grabner, R. H., Hannula-Sormunen, M., Schneider, M., & Verschaffel, L. (2011). Cognitive neuroscience meets mathematics education: It takes two to tango. *Educational research review*, *6*(3), 232-237.

Dean, V., & Nourbakhsh, I. (2022). Teaching Ethics by Teaching Ethics Pedagogy: A Proposal for Structural Ethics Intervention. Proceedings of the 5^{3r}d ACM *Technical Symposium on Computer Science Education 1*, 272–278. HTTPS://DOI.ORG/10.1145/3478431.3499319

Debaere, F., Wenderoth, N., Sunaert, S., Van Hecke, P., & Swinnen, S. P. (2004). Changes in brain activation during the acquisition of a new bimanual coordination task. *Neuropsychologia*, *42*(7), 855–867. HTTPS://DOI.ORG/10.1016/J.NEUROPSYCHOLOGIA.2003.12.010

Dede, C. (2004) If design-based research is the answer, what is the question? A commentary on Collins, Joseph, and Bielaczyc; diSessa and Cobb; and Fishman, Marx, Blumenthal, Krajcik, and Soloway in the JLS special issue on design-based research. *The Journal of the Learning Sciences, 13*(1), 105-114.

Dede, Chris. (2005). Why Design-Based Research Is Both Important and Difficult. 45(1), 5. HTTPS://WWW.JSTOR.ORG/STABLE/44429182

DeepMotion.com (2023) [Software] HTTPS://PORTAL.DEEPMOTION.COM/DASHBOARD

Deleuze, G., & Guattari, F. (1989). A Thousand Plateaus: Capitalism and Schizophrenia (B. Massumi, Trans.). HTTPS://W.JSTOR.ORG/STABLE/203963?ORIGIN=CROSSREF

Denzin, N. K., & Lincoln, Y. S. (1995). Transforming qualitative research methods: Is it a revolution? *Journal of Contemporary Ethnography*, *24*(3), 349-358.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2017). *The SAGE Handbook of Qualitative Research* (5th ed.). Sage Publ. HTTP://US.SAGEPUB.COM/EN-US/NAM/THE-SAGE-HANDBOOK-OF-QUALITATIVE-RESEARCH/BOOK242504

Dept for Education, Gov. UK. (2013). *National curriculum in England: computing programmes of study*. HTTPS://WWW.GOV.UK/GOVERNMENT/PUBLICATIONS/NATIONAL-CURRICULUM-IN-ENGLAND-COMPUTING-PROGRAMMES-OF-STUDY.

Dept for Education, Gov UK, (2014). National curriculum in England: Secondary curriculum. HTTPS://WWW.GOV.UK/GOVERNMENT/PUBLICATIONS/NATIONAL-CURRICULUM-IN-ENGLAND-SECONDARY-CURRICULUM.

Dept for Education. Gov.UK, (2015). *Further additional GCSE and A level subject content consultation.* HTTPS://ASSETS.PUBLISHING.SERVICE.GOV.UK/GOVERNMENT/UPLOADS/SYSTEM/UPLOADS/ATTACHMENT_DATA/FILE/473195/FURTHER_ADDITIONAL_GCSE_AND_A_LEVEL_SUBJECT_CONTENT_CONSULTATION.PDF

Dept for Education. Gov.UK. (2022). *iQTS Teachers standards update* (p. 16). HTTPS://ASSETS.PUBLISHING.SERVICE.GOV.UK/GOVERNMENT/UPLOADS/SYSTEM/UPLOADS/ATTACHMENT_DATA/FILE/1081356/IQTS_TEACHERS__STANDARDS_JUNE_2022_UPDATE.PDF

Dept for Media, Culture, and Sports. (2020). *Participation Survey October to December 2019: Main Report*. HTTPS://WWW.GOV.UK/GOVERNMENT/STATISTICS/PARTICIPATION-SURVEY-OCTOBER-TO-DECEMBER-2019-REPORT/PARTICIPATION-SURVEY-OCTOBER-TO-DECEMBER-2019-MAIN-REPORT

Dept for Media, Culture, and Sports. (2022). *Participation Survey October to December 2021: Main Report*. HTTPS://WWW.GOV.UK/GOVERNMENT/STATISTICS/PARTICIPATION-SURVEY-OCTOBER-TO-DECEMBER-2021-REPORT/PARTICIPATION-SURVEY-OCTOBER-TO-DECEMBER-2021-MAIN-REPORT

Derby, E., Larsen, D., & Schwaber, K. (2006). Agile Retrospectives: Making Good Teams Great. Pragmatic Bookshelf.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational researcher*, *32*(1), 5-8.

Dixon, B. (2019). Experiments in Experience: Towards an Alignment of Research through Design and John Dewey's Pragmatism. *Design Issues*, *35*(2), 5–16. HTTPS://DOI.ORG/10.1162/DESI_A_00531

Dixon, B., & French, T. (2020). Processing the method: Linking Deweyan logic and design-in-research. *Design Studies*, *70*, 100962. HTTPS://DOI.ORG/10.1016/J.DESTUD.2020.100962

Dubber, M., Pasquale, F., & Das, S. (Eds.). (2020). The Oxford Handbook of Ethics of AI–- Oxford Handbooks. Oxford University Press. HTTPS://ACADEMIC.OUP.COM/EDITED-VOLUME/34287

Dunlevy, T. (2017, February 23). Ballerina brings Disney/DreamWorks animator back to Montreal. *Montrealgazette*. HTTPS://MONTREALGAZETTE.COM/ENTERTAINMENT/MOVIES/BALLERINA-BRINGS-DISNEYDREAMWORKS-ANIMATOR-BACK-TO-MONTREAL

Easterday, M. W., Lewis, D. R., & Gerber, E. M. (2014). *Design-Based Research Process: Problems, Phases, and Applications*.

Ennes, H. E. (1980). *Boolean Algebra for Computer Logic*. Howard W Sams & Co. Indianapolis, USA. 0-672-21554-3

Ercikan, K., & Roth, W.-M. (Eds.). (2009). *Generalizing from educational research: Beyond qualitative and quantitative polarization*. Routledge.

Fabretti, F. (2014). *Software Theory: A Cultural and Philosophical Study*. Media Philosophy. HTTPS://ROWMAN.COM/ISBN/9781783481965/SOFTWARE-THEORY-A-CULTURAL-AND-PHILOSOPHICAL-STUDY

Farahany, N. A. (2012). Incriminating Thoughts. *STANFORD LAW REVIEW*, *64*(351), 58. HTTPS://SCHOLARSHIP.LAW.DUKE.EDU/CGI/VIEWCONTENT.CGI?ARTICLE=5321&CONTEXT=FACULTY_SCHOLARSHIP

Farahany, N. A., Greely, H. T., Hyman, S., Koch, C., Grady, C., Pașca, S. P., Sestan, N., Arlotta, P., Bernat, J. L., Ting, J., Lunshof, J. E., Iyer, E. P. R., Hyun, I., Capestany, B. H., Church, G.

M., Huang, H., & Song, H. (2018). The ethics of experimenting with human brain tissue. *Nature*, *556* (7702), 429–432. HTTPS://DOI.ORG/10.1038/D41586-018-04813-X

Farahany, N. & Ramos, K. M. (2020) Neuroethics: Fostering Collaborations to Enable Neuroscientific Discovery, *AJOB Neuroscience*, *11*(3), pp. 148-154, DOI: 10.1080/21507740.2020.1778117

Farahany, N. A. (2023). *The battle for your brain: defending the right to think freely in the age of neurotechnology*. St. Marti''s Press.

Faria, B. (2017).“"Visualizing Sorting Algorithm”" Honors Projects Overview. 127. HTTPS://DIGITALCOMMONS.RIC.EDU/HONORS_PROJECTS/127/

Ferrington, G. (2010). ‘Take a listening walk and learn to listen. *Published ONLINE. URL HTTP://INTERACt.uoregon.edu/MediaLit/wfae/library/articles/ferrington_listening_walk. pdf.*

Feurzeig, W., Papert, S., Bloom, M., Grant, R., & Solomon, C. (1970). Programming-languages as a conceptual framework for teaching mathematics. *ACM SIGCUE Outlook*, *4*(2), 13-17.

Fincher, S., Dziallas, S., & Knox, D. (2019). Space, Place and Practice in Computing Education. *Proceedings of the 1st UK & Ireland Computing Education Research Conference on–- UKICER*. HTTPS://DOI.ORG/10.1145/3351287.3351297

Filipová, P. (2019). Space: The Final Frontier of Gender and Globalization. *SKASE Journal of Literary and Cultural Studies, 1*(2), 10.

Fisher, D., & Frey, N. (2014). Using teacher learning walks to improve instruction. *Principal Leadership*, *14*(5), 58-61.

Fitzallen, N. (2016). STEM Education: What Does Mathematics Have To Offer? Mathematics *Education Research Group of Australasia*.

Fitzgerald, P.M., (2023) Turning pointe: the lived experience of embodied occupational identity in professional ballet dancers. HTTPS://EPRINTS.BBK.AC.UK/ID/EPRINT/50680/1/PF%20FINAL%20THESIS.PDF

Flemisch, F., Bielecki, K., Hernández, D. L., Meyer, R., Baier, R., Herzberger, N. D., & Wasser, J. (2020). *Let’s Get in Touch Again: Tangible AI and Tangible XR for a More Tangible, Balanced Human Systems Integration*. In T. Ahram, W. Karwowski, A. Vergnano, F. Leali,

& R. Taiar (Eds.), Intelligent Human Systems Integration 2020 (pp. 1007–1013). Springer International Publishing. HTTPS://DOI.ORG/10.1007/978-3-030-39512-4_153

Flewelling, P. (2018). The Agile Developer's Handbook. Packt Publishing. HTTPS://WWW.PACKTPUB.COM/PRODUCT/THE-AGILE-DEVELOPERS-HANDBOOK/9781787280205

Flick, U. (2019). The Concepts of Qualitative Data: Challenges in Neoliberal Times for Qualitative Inquiry. *Qualitative Inquiry*, *25*(8), 713–720. HTTPS://DOi.org/10.1177/1077800418809132

Floridi, L. (2011a). A Defence of Constructionism: Philosophy as Conceptual Engineering. *Metaphilosophy, 42*(3), 282–304. HTTPS://DOI.ORG/10.1111/J.1467-9973.2011.01693.X

Floridi, L. (2011b). The Philosophy of Information. Oxford University Press.

Floridi, L. (2013). The Ethics of Information. Oxford University Press. HTTPS://ACADEMIC.OUP.COM/BOOK/35378

Floridi, L. (Ed.). (2016). The Routledge Handbook of Philosophy of Information (1st ed.). Routledge. HTTP://WWW.ROUTLEDGE.COM/THE-ROUTLEDGE-HANDBOOK-OF-PHILOSOPHY-OF-INFORMATION/FLORIDI/P/BOOK/9780367370466

Floridi, L., & Taddeo, M. (2016b). What is data ethics?. *Philosophy Transactions of the Royal Society A: Mathematical, Physical, Engineering Sciences, 374*(2083). HTTPS://ROYALSOCIETYPUBLISHING.ORG/DOI/FULL/10.1098/RSTA.2016.0360

Floridi, L. (2018). Soft Ethics and the Governance of the Digital. *Philosophy & Technology, 31*(1), 1–8. HTTPS://DOI.ORG/10.1007/S13347-018-0303-9

Floridi, L. (2023). AI as Agency Without Intelligence: On ChatGPT, Large Language Models, and Other Generative Models. *Philosophy & Technology*, *36*(1), 15. HTTPS://DOI.ORG/10.1007/S13347-023-00621-Y

Flyvbjerg, B. (2001). Making Social Science Matter: Why Social Inquiry Fails and How it Can Succeed Again: Cambridge University Press.

Fook, J. (2002). Theorizing from practice: Towards an inclusive approach for social work research. *Qualitative social work*, *1*(1), 79-95.

Foster, D., Long, R., & Danechi, S. (2022). *Teacher recruitment and retention in England*. HTTPS://COMMONSLIBRARY.PARLIAMENT.UK/RESEARCH-BRIEFINGS/CBP-7222/

Franzke, A. (2021). An exploratory qualitative analysis of AI ethics guidelines. *Journal of Information, Communication and Ethics in Society*, *ahead-of-print*. HTTPS://DOI.ORG/10.1108/JICES-12-2020-0125

Friedman, B. (1996). Value-sensitive design. *Interactions*, *3*(6), 16–23. HTTPS://DOI.ORG/10.1145/242485.242493

FFT (Fisher Family Foundation) datalab. (2022). *National Trends in A-level, and GCSE entries and grades* [Data Trends]. HTTPS://RESULTS.FFTEDUCATIONDATALAB.ORG.UK/GCSE/COMPUTING.PHP?V=20210812

Fuechsle, M., Miwa, J. A., Mahapatra, S., Warschkow, O., Hollenberg, L. C. L., & Simmons, M. Y. (2012). *Realisation of a single-atom transistor in silicon*. *145*(443, 444), 66–74.

Furber, S. (2012). *Shut down or restart? | Royal Society* (No. DES2448; p. 122). HTTP://ROYALSOCIETY.ORG/TOPICS-POLICY/PROJECTS/COMPUTING-IN-SCHOOLS/REPORT/

Füzesi, A (Choreographer) (2011, May 13). *Bubble-sort with Hungarian ('Csángó') folk dance*. Sapientia University, Tirgu Mures (Marosvásárhely), Romania. HTTPS://WWW.YOUTUBE.COM/WATCH?V=SEMGJAJ7I74

Gagné, and Gagné, Robert M. *Principles of Instructional Design*. 5th ed. Southbank, Vic. ; London: Thomson/Wadsworth, 2005. Print.

Garafola, L. (1985). The Travesty Dancer in Nineteenth-Century Ballet. *Dance Research Journal*, *17*(2), 35. HTTPS://DOI.ORG/10.2307/1478078

Garaschuk, K. (2022). Learning Benefits of Collaborative Exams. *The Journal for Research and Practice in College Teaching*, *7*(1), 42–55. HTTPS://JOURNALS.UC.EDU/INDEX.PHP/JRPCT/ARTICLE/VIEW/4699

García-Cabrera, L. (2017). SOS COMPUTER SCIENCE WOMEN ARE NEEDED BY 2020. *Iceri2017 Proceedings*, 859–867. HTTPS://DOI.ORG/10.21125/ICERI.2017.0297

GDPR. General Data Protection Regulation, European Commission (2016) (testimony of European Commission). HTTPS://EUR-LEX.EUROPA.EU/LEGAL-CONTENT/EN/TXT/HTML/?URI=CELEX:32016R0679&FROM=EN#D1E40-1-1

GDPR. General Data Protection Regulation, European Commission (2021) (Commission implementing decision (EU) 2021/07 on Civil society initiative for a ban on biometric mass

surveillance practices). HTTPS://EUR-LEX.EUROPA.EU/LEAGAL-CONTENT/EN/TXT/HTM/?URI=OJ:2021:013:FULL

George, J., & Petter, S. (2016). *The Poor Get Poorer and the Rich Get Fiber: Why Free/Low-Cost Internet Might Not Bridge the Digital Divide*.

Giddings, L. S., & Grant, B. M. (2006). Mixed methods research for the novice researcher. *Contemporary Nurse, 23*(1), 3–11. HTTPS://DOI.ORG/10.5172/CONU.2006.23.1.3

Gillespie, T. (2018). *Custodians of the Internet: Platforms, Content Moderation, and the Hidden Decisions That Shape Social Media*. Yale University Press.

Giurchescu, A., & Torp, L. (1991). Theory and Methods in Dance Research: A European Approach to the Holistic Study of Dance. *Yearbook for Traditional Music, 23*, 1-10. HTTPS://DOI.ORG/10.2307/768392

Glaveanu, V. P. (2013). Rewriting the language of creativity: The five A's framework. *Review of General Psychology*, *17*(1), 69–81. HTTPS://DOI.ORG/10.1037/A0029528

Glister, P. (1997). *Digital literacy | Guide books*. Wiley. HTTPS://DL-ACM-ORG.EZP.LIB.CAM.AC.UK/DOI/ABS/10.5555/260946

Goff, J. (2017). Design & Data: how to humanize data. Data Canvas, UX Collective HTTPS://UXDESIGN.CC/DESIGN-AND-DATA-HOW-TO-HUMANIZE-DATA-32A03079311F

Golu, F. (2021). Tech Fatigue—A New Pandemic. *Studia Doctoralia*, *12*(2), Article 2. HTTPS://DOI.ORG/10.47040/SDPSYCH.V12I2.129

Gothelf, J. (2013). *Lean UX: Applying Lean Principles to Improve User Experience*. O'Reilly Media, Inc.

Gotterbarn, D. W. (2018). *ACM Code of Ethics and Professional Conduct*. ACM. HTTPS://WWW.ACM.ORG/BINARIES/CONTENT/ASSETS/ABOUT/ACM-CODE-OF-ETHICS-AND-PROFESSIONAL-CONDUCT.PDF

Gove, M. (2012). *"Harmful" ICT curriculum set to be dropped to make way for rigorous computer science [Press Release]*. Dept for Education, Gov.UK. HTTPS://WWW.GOV.UK/GOVERNMENT/NEWS/HARMFUL-ICT-CURRICULUM-SET-TO-BE-DROPPED-TO-MAKE-WAY-FOR-RIGOROUS-COMPUTER-SCIENCE

Gov.UK (2020) Data Ethics Framework. Central Digital and Data Office. HTTPS://WWW.GOV.UK/GOVERNMENT/PUBLICATIONS/DATA-ETHICS-FRAMEWORK/DATA-ETHICS-FRAMEWORK-2020

Gray, J. A., & DiLoreto, M. (2016). The Effects of Student Engagement, Student Satisfaction, and Perceived Learning in Online Learning Environments. *International Journal of Educational Leadership Preparation*, *11*(1), 20.

Gray, D. E. (2021). *Doing Research in the Real World*. SAGE.

Graves, J. M., Abshire, D. A., Amiri, S., & Mackelprang, J. L. (2021). Disparities in Technology and Broadband Internet Access Across Rurality: Implications for Health and Education. *Family & Community Health*, *Publish Ahead of Print*. HTTPS://DOI.ORG/10.1097/FCH.0000000000000306

Green, D. D., & Roberts, G. E. (2012). Impact of postmodernism on public sector leadership practices: Federal government human capital development implications. *Public Personnel Management*, *41*(1), 79-96.

Green, J. (2002). Somatic knowledge: The body as content and methodology in dance education. *Journal of dance education*, *2*(4), 114-118.

Green, J. (2015). Somatic sensitivity and reflexivity as validity tools in qualitative research. *Research in Dance Education*, *16*(1), 67-79.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255–274. HTTPS://DOI.ORG/10.3102/01623737011003255

Griffith, A. (1998). Insider / Outsider: Epistemological Privilege and Mothering Work. *Human Studies*, *21*(4), 361–376. HTTPS://DOI.ORG/10.1023/A:1005421211078

Griffiths, M. (1998). *Educational Research For Social Justice: Getting Off the Fence*. McGraw-Hill Education (UK).

Grosz, B. J., Grant, D. G., Vredenburgh, K., Behrends, J., Hu, L., Simmons, A., & Waldo, J. (2019). Embedded EthiCS: Integrating ethics across CS education. *Communications of the ACM*, *62*(8), 54–61. HTTPS://DOI.ORG/10.1145/3330794

Grum, J. (2016). Surface Hardening: Laser. In G. Totten (Ed.), Encyclopaedia of Iron, Steel, and Their Alloys (pp. 3420–3501). CRC Press.

Gutica, M. (2021). Fostering High School Girls' Interest and Attainment in Computer Science. *Proceedings of the 2^{6t}h ACM Conference on Innovation and Technology in Computer Science Education 1*, 471–477. HTTPS://DOI.ORG/10.1145/3430665.3456353

Guzdial, M., & Adams, J. C. (2021). Disputing Dijkstra, and birthdays in base 2. *Communications of the ACM*, *64*(3), 12–13. HTTPS://DOI.ORG/10.1145/3446806

Guzdial, M. (2019). Computing for Other Disciplines. The Cambridge Handbook of Computing Education Research, 584–605. HTTPS://DOI.ORG/10.1017/9781108654555.020

Guzdial, M., & Boulay, B. du. (2019). The History of Computing Education Research. *The Cambridge Handbook of Computing Education Research*, 11–39. HTTPS://DOI.ORG/10.1017/9781108654555.002

Guzdial, M. (2010). Chapter 7. Why Is It So Hard to Learn to Program? In A. Oram & G. Wilson (Eds.), *Making Software*. O'Reilly Media Inc. HTTPS://WWW.OREILLY.COM/LIBRARY/VIEW/MAKING-SOFTWARE/9780596808310/CH07.HTML

Hagendoorn, I. (2003). The Dancing Brain. *Cerebrum*, *5*(2), 19–34.

Hagendoorn, I.G. (2004). Some speculative hypotheses about the nature and perception of dance and choreography. *Journal of Consciousness Studies 11* (3/4), 79-110.

Hagendoorn, I.G. (2012). Inscribing the body, exscribing space. *Phenomenology and the Cognitive Sciences, 11 (1*), 69-78.

Hagendoorn, I.G. (2019). An Agile Mind in an Agile Body. In: Midgelow, V.L. [ed.], The Oxford Handbook of Improvisation in Dance. Oxford University Press, 749-61.

Haill, L. (2014) *Flickering Phrontesterion* [Digital EEG exhibition]. Retrieved 20 April 2021, from HTTPS://LUCIANAHAILL.WORDPRESS.COM/DIGITAL-ARTWORKS/

Haill, L. (2019) *Mind the Gap* [Digital EEG exhibition]. Retrieved 21 March 2022, from HTTPS://LUCIANAHAILL.WORDPRESS.COM/2019/11/04/MIND-THE-GAP/

Han, J., Jo, M., Hyun, E., & So, H. J. (2015). Examining young children's perception toward augmented reality-infused dramatic play. *Educational Technology Research and Development*, *63*, 455-474.

Hammersley, P. M. & Atkinson, M. (2007). *Educational Research and Evidence-Based Practice*. SAGE.

Haraway, D. (2006). A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late 20th Century. In J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas (Eds.), The International Handbook of Virtual Learning Environments (pp. 117–158). Springer Netherlands. HTTPS://LINK.SPRINGER.COM/CHAPTER/10.1007/978-1-4020-3803-7_4

Haraway, D. (2016). Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press. HTTPS://DOI.ORG/10.2307/J.CTV11CW25Q

Haraway, D. (2018). *Modest Witness @ Second Millennium. FemaleMan_Meets_OncoMouse: Feminism and Technoscience*. Routledge. HTTPS://WWW.ROUTLEDGE.COM/MODESTWITNESSSECONDMILLENNIUM-FEMALEMANMEETSONCOMOUSE-FEMINISM-AND/HARAWAY-GOODEVE/P/BOOK/9781138303416

Harel, I. E., & Papert, S. E. (Eds) (1991). *Constructionism*. Ablex Publishing.

Hassan, N. R. (2011). Is information systems a discipline? Foucauldian and Toulminian insights. *European Journal of Information Systems*, *20*(4), 456–476. HTTPS://DOI.ORG/10.1057/EJIS.2011.2

Hayk, A., & Martins, J. (2020). *Avatar generator playground—Boring Avatars* [Javascript]. HTTPS://BORINGAVATARS.COM/

Helsby, D. (2015). *The Art of First Person Animation for Destiny*. GDC. HTTPS://WWW.GDCVAULT.COM/PLAY/1022298/THE-ART-OF-FIRST-PERSON

Hennick, C. (2021, June 29). All Together Now. *All Together Now*. HTTP://BLOG.BOSTONDYNAMICS.COM/ALL-TOGETHER-NOW

Hesse-Biber, S. N. (2010). *Mixed methods research: Merging theory with practice*. Guilford Press.

Hesse-Biber, S. (2014, July 8). *The 'Thing-ness' Problem of Mixed Methods Research by Professor Sharlene Hesse-Biber—YouTube* [Lecture Recording]. The 'Thing-ness' Problem of Mixed Methods Research, St Catherine's College, Oxford University. HTTPS://WWW.YOUTUBE.COM/WATCH?V=8CWGGG4V7ZM

Hesse-Biber, S. (2015). Mixed Methods Research: The "Thing-ness" Problem. *Qualitative Health Research*, *25*(6), 775–788. HTTPS://DOI.ORG/10.1177/1049732315580558

Hesse-Biber, S. N., & Johnson, R. B. (Eds.). (2015b). *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*. Oxford University Press.

Hesse-Biber, S. N., Rodriguez, D., & Frost, N. A. (2015c). *A Qualitatively Driven Approach to Multimethod and Mixed Methods Research* (S. N. Hesse-Biber & R. B. Johnson, Eds.). Oxford University Press. HTTPS://DOI.ORG/10.1093/OXFORDHB/9780199933624.013.3

Hidi, S. (2016). Revisiting the role of rewards in motivation and learning: Implications of neuroscientific research. *Educational Psychology Review, 28*(1), 61-93

Hjalmarson, M., & Parsons, A. (2021). Conjectures, Cycles and Contexts: A Systematic Review of Design-based Research in Engineering Education. *Studies in Engineering Education*. *1*(2), 142-155.

Hoadley, C. (2004). Methodological alignment in design-based research. *Educational Psychologist, 39*(4), 203-212. HTTPS://DOi.org/10.1207/s15326985ep3904_2

Hohenwarter, M., Hohenwarter, J., Kreis, Y., & Lavicza, Z. (2008). *Teaching and Learning Calculus with Free Dynamic Mathematics Software GeoGebra*. HTTPS://ORBILU.UNI.LU/HANDLE/10993/47219

Hollstein, B. (2014). Mixed Methods Social Networks Research. An Introduction. In S. Dominguez & B. Hollstein (Eds.), *Mixed Methods Social Networks Research. Design and Applications.* Cambridge University Press.

Hyman, A. (1982). *Charles Babbage, Pioneer of the Computer*. Oxford University Press. HTTPS://BLACKWELLS.CO.UK/BOOKSHOP/PRODUCT/CHARLES-BABBAGE-PIONEER-OF-THE-COMPUTER-BY-ANTHONY-HYMAN/9780691083032

Huang, Y. M., & Lin, P. H. (2017). Evaluating students' learning achievement and flow experience with tablet PCs based on AR and tangible technology in u-learning. *Library Hi Tech*, *35*(4), 602-614.

Hutchinson, A., & Guest, A. H. (1977). *Labanotation: Or Kinetography Laban: the System of Analyzing and Recording Movement* (3rd ed.). Taylor & Francis.

ICO. Information Commissioner's Office. (2020). *Age appropriate design: A code of practice for online services*. ICO. HTTPS://ICO.ORG.UK/FOR-ORGANISATIONS/GUIDE-TO-DATA-PROTECTION/ICO-CODES-OF-PRACTICE/AGE-APPROPRIATE-DESIGN-A-CODE-OF-PRACTICE-FOR-ONLINE-SERVICES/

Icons8 LLC. (2018). *[Icons8.com]*. *HTTPS://ICONS8.COM*

IEEE SA—- *IEEE 2089-2021*. (2021). Standard for an Age-Appropriate Digital Services Framework. IEEE Standards Association. Retrieved June 20, 2022, from HTTP://STANDARDS.IEEE.ORG/IEEE/2089/7633/

IEEE Brain – Neuroethics Framework (draft 2023). IEEE Addressing the Ethical, Legal, Social, and Cultural Implications of Neurotechnology. HTTPS://BRAIN.IEEE.ORG/PUBLICATIONS/IEEE-NEUROETHICS-FRAMEWORK/

ICO Information Commissioner's Office. (2021). *General Data Protection Regulation (GDPR)*. ICO. HTTPS://ICO.ORG.UK/FOR-ORGANISATIONS/GUIDE-TO-DATA-PROTECTION/GUIDE-TO-THE-GENERAL-DATA-PROTECTION-REGULATION-GDPR/CONTROLLERS-AND-PROCESSORS/WHAT-ARE-CONTROLLERS-AND-PROCESSORS/

Illes, J., Moser, M. A., McCormick, J. B., Racine, E., Blakeslee, S., Caplan, A., ... & Weiss, S. (2010). Neurotalk: improving the communication of neuroscience research. *Nature Reviews Neuroscience*, *11*(1), 61-69. HTTPS://WWW.NCBI.NLM.NIH.GOV/PMC/ARTICLES/PMC2818800/

Ingold, T. (2010). *Bringing Things to Life: Creative Entanglements in a World of Materials*. 16. HTTPS://EPRINTS.NCRM.AC.UK/1306/

Ingold, T. (2011). Being Alive: Essays on Movement, Knowledge and Description. Routledge.

ISO/IEC 27001:2022(en). (2022) Information security, cybersecurity and privacy protection — Information security management systems. HTTPS://WWW.ISO.ORG/OBP/UI/#ISO:STD:ISO-IEC:27001:ED-3:V1:EN

Jankovic, M., & Bogaerts, S. (2021). Predicting success in the performing arts: Ballet and music. *Psychology of Music*, *49*(4), 945–957. HTTPS://DOI.ORG/10.1177/0305735620911983

Järhult, J. D. (2015). One Health: a doctor's perspective. *Veterinary Record, 176*(14), 351–353. HTTPS://DOI.ORG/10.1136/VR.H839

Jenkins, T. (2002, August). On the difficulty of learning to program. In *Proceedings of the 3rd Annual Conference of the LTSN Centre for Information and Computer Sciences* (Vol. 4, No. 2002, pp. 53-58).

Jeyasingh, S. (2000). The Body in Space: Structures in Dance. In W. Pullan & H. K. D. H. Bhadeshia (Eds.), *Structure: In science and art* (pp. 48–72). Cambridge University Press.

Johansson, L. G., & Johansson, L. G. (2016). Theories about the Development of Science. *Philosophy of Science for Scientists*, 103-121.

Johnson, D. (2019). MusE-XR: musical experiences in extended reality to enhance learning and performance [Thesis]. HTTPS://DSPACE.LIBRARY.UVIC.CA/HANDLE/1828/10988

Jonas, W. (2014). The strengths/limits of Systems Thinking denote the strengths/limits of Practice-Based Design Research. *FORMakademisk*, *7*(4).

Jones, J. C. (1970). Design Methods: Seeds of human futures. *John Wiley and Sons*.

Judova, M.,(Director). (2014, August 9). *Body(input); //work in progress I.* HTTPS://VIMEO.COM/103027310

Kafai, Y., & Resnick, M. (1996). *Constructionism in practice Designing, thinking, and learning in a digital world.* Lawrence Erlbaum Associates, Inc. HTTPS://DOI.ORG/10.4324/9780203053492

Kali, Y. and Hoadley, C. (2023) Design-based research methods in CSCL: Calibrating our epistemologies and ontologies. In U. Cress, C. Rosé, A. Wise, and J. Oshima (Eds.), International Handbook of Computer-Supported Collaborative Learning. Springer. *Pre-print*

Kandinsky, W., Dearstyne, H., & Rebay, H. (1947). *Point and line to plane: Contribution to the analysis of the pictorial elements*. New York : Solomon R. Guggenheim Foundation. HTTP://ARCHIVE.ORG/DETAILS/POINTLINETOPLANE00KAND

Kartoglu, U., Vesper, J., Teräs, H., & Reeves, T. (2017). Experiential and authentic learning approaches in vaccine management. *Vaccine*, *35*(17), 2243-2251.

Kashyap, V. (2022, June 1). What Is a Cross-Functional Team, and How to Build One? *Kanbanize Blog*. HTTPS://KANBANIZE.COM/BLOG/CROSS-FUNCTIONAL-TEAMS/

Kaufmann, L. (2008). Dyscalculia: neuroscience and education. *Educational research*, *50*(2), 163-175.

Kaufman, J. C., (2016). *Creativity 101: Vol. Second edition*. Springer Publishing Company.

Kaufman, J. C., & Glăveanu, V. P. (2019). A review of creativity theories: What

questions are we trying to answer? In J.C. Kaufman & R. J. Sternberg (Eds.), *Cambridge handbook of creativity (2nd Ed)* (pp. 27-43). New York: Cambridge University Press.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(3), 2–10. HTTPS://DOI.ORG/10.1007/BF02905780

Kelly, A. E. (2004). Design research in education: Yes, but is it methodological? *Journal of the Learning Sciences, 13*(1), 115-128.

Kelly, L. B. (2018). Preservice Teachers' Developing Conceptions of Teaching English Learners. *TESOL Quarterly*, *52*(1), 110–136. HTTPS://DOI.ORG/10.1002/TESQ.375

Kemp, P., Wong, B., & Berry, M. (2016). *The Roehampton Annual Computing Education Report: 2015 data from England.* HTTPS://PURE.ROEHAMPTON.AC.UK/WS/FILES/4999867/THE_ROEHAMPTON_ANNUAL_COMPUTING_EDUCATION_REPORT_2015.PDF

Kemp, P., Berry, M., & Wong, W. (2018). *The Roehampton Annual Computing Education Report: Data from 2017*. HTTPS://WWW.BCS.ORG/MORE/BCS-ACADEMY-OF-COMPUTING/THE-ROEHAMPTON-ANNUAL-COMPUTING-EDUCATION-REPORT/

Kemp, P., & Berry, M. (2019). *The Roehampton Annual Computing Education Report Data from 2018.* HTTPS://PURE.ROEHAMPTON.AC.UK/PORTAL/EN/PUBLICATIONS/THE-ROEHAMPTON-ANNUAL-COMPUTING-EDUCATION-REPORT-PRE-RELEASE-SNAP

Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology*, *41*(1), 56-68.

Kidd, J. (2019). Digital media ethics and museum communication. *The Routledge handbook of museums, media, and communication*, 193-204.

Kilicarslan, A., Grossman, R. G., & Contreras-Vidal, J. L. (2016). A robust adaptive denoising framework for real-time artifact removal in scalp EEG measurements. *Journal of neural engineering*, *13*(2), 026013.

Kincheloe, J. L. (2001). Describing the Bricolage: Conceptualizing a New Rigor in Qualitative Research. *Qualitative Inquiry*, *7*(6), 679–692. HTTPS://DOI.ORG/10.1177/107780040100700601

Kincheloe, J. L., McLaren, P., Steinberg, S., & Monzó, Lilia. D. (2018). Chapter 10: Critical Pedagogy, and Qualitative Research: Moving to the Bricolage. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (5th ed., pp. 235–260). SAGE Publications.

Kitzinger, J. (1995). Qualitative research: Introducing focus groups. *BMJ (Clinical Research Ed.)*, *311*(7000), 299–302. HTTPS://DOI.ORG/10.1136/BMJ.311.7000.299

Kleinman, Z. (2018, March 21). Cambridge Analytica: The story so far—BBC News. *Cambridge Analytica: The Story so Far - BBC News*. HTTPS://WWW.BBC.CO.UK/NEWS/TECHNOLOGY-43465968

Knaster, R., & Leffingwell, D. (2020). SAFe 5.0 Distilled: Achieving Business Agility with the Scaled Agile Framework. Addison-Wesley Professional. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/SAFE-50-DISTILLED/9780136820406/

Knust, A. (1979). *Dictionary of Kinetography Laban (Labanotation)* (Vol. 2). Macdonald and Evans.

Konak, A., & Bartolacci, M. R. (2016). Using a Virtual Computing Laboratory to Foster Collaborative Learning for Information Security and Information Technology Education. *The Journal of Cybersecurity Education Research and Practice (JCERP) 27*(1)

Kövecses, Z. (2005). *Metaphor in culture: Universality and variation*. Cambridge University Press. HTTPS://DOI.ORG/10.1017/CBO9780511614408

Kövecses, Z. (2020). *Extended Conceptual Metaphor Theory*. Cambridge University Press. DOI:10.1017/9781108859127

Kozai, A. C., Twitchett, E., Morgan, S., & Wyon, M. A. (2020). Workload Intensity and Rest Periods in Professional Ballet: Connotations for Injury. *International Journal of Sports Medicine*, *41*(06), 373–379. HTTPS://DOI.ORG/10.1055/A-1083-6539

Kratochwill, T. R., & Levin, J. R. (Eds.). (2014). *Single-case intervention research: Methodological and statistical advances* (pp. xiii, 366). American Psychological Association. https://doi.org/10.1037/14376-000

Krippendorf, K. (2006). *The Semantic Turn: A New Foundation for Design*. Taylor & Francis. http://www.routledge.com/The-Semantic-Turn-A-New-Foundation-for-Design/Krippendorff/p/book/9780415322201

Kwasnicka, D., Dombrowski, S. U., White, M., & Sniehotta, F. F. (2015). Data-prompted interviews: Using individual ecological data to stimulate narratives and explore meanings. *Health Psychology*, *34*(12), 1191. https://doi.org/10.1037/hea0000234

Lakoff, G., & Johnson, M. (1980). The metaphorical structure of the human conceptual system. *Cognitive science*, *4*(2), 195-208.

Lakoff, G., & Johnson, M. (1980b). Metaphors we live by. Chicago: University of Chicago Press.

Lakoff, G. (1993). The contemporary theory of metaphor. In Metaphor and Thought (pp. 202-251). Cambridge University Press.

LePrince-Ringuet, D. (2018, December 17). Google's latest experiment teaches AI to dance like a human. *Wired*. https://www.wired.co.uk/article/google-ai-wayne-mcgregor-dance-choreography

Latour, B. (2008). What is the style of matters of concern. *Two lectures in empirical philosophy. Department of Philosophy of the University of Amsterdam, Amsterdam: Van Gorcum*.

Law, A. M., & Kelton, W. D. (1991). *Simulation modeling and analysis* (2nd ed). McGraw-Hill. https://faculty.ksu.edu.sa/sites/default/files/index.pdf

Leffingwell, D. (2007). *Scaling software agility: best practices for large enterprises*. Pearson Education.

Leffingwell, D. (2010). *Agile Software Requirements: Lean Requirements Practices for Teams, Programs, and the Enterprise [Book]*. Addison-Wesley Professional. https://www.oreilly.com/library/view/agile-software-requirements/9780321685438/

Leffingwell, D. (2011). *Scaling Software Agility: Best Practices for Large Enterprises [Book]*. Addison-Wesley Professional. https://www.oreilly.com/library/view/scaling-software-agility/0321458192/

Leffingwell, D. (2018). *SAFe 4.5 reference guide: scaled agile framework for lean enterprises*. Addison-Wesley Professional.

Leonard, A. E., Daily, S. B., Jörg, S., & Babu, S. V. (2020). Coding moves: Design and research of teaching computational thinking through dance choreography and virtual interactions. *Journal of Research on Technology in Education*, 1–19. HTTPS://DOI.ORG/10.1080/15391523.2020.1760754

Lévi-Strauss, C. (1962). *Claude Levi Strauss' Concept of Bricolage – Literary Theory and Criticism*. Weidenfeld and Nicolson. HTTPS://LITERARINESS.ORG/2016/03/21/CLAUDE-LEVI-STRAUSS-CONCEPT-OF-BRICOLAGE/

Lewis, E. (2012). Impact of education for sustainability at a montessori primary school: [Murdoch University]. http://researchrepository.murdoch.edu.au/12034/

Li, X., & Chu, S. K. (2018). Using design-based research methodology to develop a pedagogy for teaching and learning of Chinese writing with wiki among Chinese upper primary school students. *Computers & Education*, *126*, 359-375.

Liang, S., & Fu, Y. (2018). *Otter AI*. AISense. OTTER.AI [Computer software] HTTPS://OTTER.AI/BLOG/AISENSE-ANNOUNCES-OTTER-BRINGS-POWER-OF-AMBIENT-VOICE-INTELLIGENCE-TO-EVERYDAY-CONVERSATIONS

Lindell, A. K., & Kidd, E. (2011). Why Right-Brain Teaching is Half-Witted: A Critique of the Misapplication of Neuroscience to Education. *Mind, Brain, and Education*, *5*(3), 121–127. HTTPS://DOI.ORG/10.1111/J.1751-228X.2011.01120.X

Linstead, S., & Mullarkey, J. (2003). Time, Creativity and Culture: Introducing Bergson. *Culture and Organization, 9*(1), 3–13. https://doi.org/10.1080/14759550302799

Lindstrom, L., & Jeffries, R. (2004). Extreme programming and agile software development methodologies. *Information Systems Management*, *21*, 41–52.

Liu, M.-L., & Blanc, L. (1996). On the Retention of Female Computer Science Students. *Proceedings of the Twenty-Seventh SIGCSE Technical Symposium on Computer Science Education*, 32–36. HTTPS://DOI.ORG/10.1145/236452.236486

Livingstone, S. (2018, November 8). Children are being 'datafied from birth'—BBC News. *BBC News*. HTTPS://WWW.BBC.CO.UK/NEWS/EDUCATION-46112665

Loke, L., & Núñez-Pacheco, C. (2018). Developing somatic sensibilities for practices of discernment in interaction design. *The Senses and Society*, *13*(2), 219–231. HTTPS://DOI.ORG/10.1080/17458927.2018.1468690

Loorbach, N. R., Peters, O., Karreman, J., & Steehouder, M. F. (2015). Validation of the Instructional Materials Motivation Survey (IMMS) in a self-directed instructional setting aimed at working with technology. *British Journal of Educational Technology*, *46*(1), 204–218. HTTPS://DOI.ORG/10.1111/BJET.12138

Lord, T. R., and Garrison, J. (1998). Comparing spatial abilities of collegiate athletes in different sports. *Percept. Motor Skills* 86, 1016–1018. doi: 10.2466/pms.1998.86.3.1016

Maaß, K., Geiger, V., Ariza, M.R., & Goos, M. (2019). The Role of Mathematics in interdisciplinary STEM education. *ZDM, 51*(6), 869-884. HTTPS://DOI.ORG/10.1007/S11858-019-01100-5

MacDonald, C., & Rozaklia, L. (2017). Assessing the implementation of authentic, client-facing student projects in user experience (UX) education: Insights from multiple stakeholders—MacDonald—2017—Proceedings of the Association for Information Science and Technology—Wiley Online Library. *80th Annual Meeting of the Association for Information Science & Technology*, *54*(1), 268–278.

MacDowell, P. (2023). Teachers designing immersive learning experiences for environmental and sustainability education. In *Immersive education: Designing for learning* (pp. 171-186). Cham: Springer International Publishing.

Magritte, R. (1935). René Magritte. La Clef des songes (The key of Dreams). Brussels, 1935 | MoMA. https://www.moma.org/audio/playlist/180/2390

Manning, E. (2013). *Always More Than One: Individuation's Dance :* Duke University Press. HTTPS://WWW.DUKEUPRESS.EDU/ALWAYS-MORE-THAN-ONE/

Margolis, M. (2019, March 1). The GV research sprint: A 4-day process for answering important startup questions. *Medium*. HTTPS://LIBRARY.GV.COM/THE-GV-RESEARCH-SPRINT-A-4-DAY-PROCESS-FOR-ANSWERING-IMPORTANT-STARTUP-QUESTIONS-97279B532B25

Margulieux, L., Guzdial, M., & Catrambone, R. (2012). Subgoal-labeled instructional material improves performance and transfer in learning to develop mobile applications. *ninth annual*

international conference on international computing education research, 71–78. HTTPS://DOI.ORG/10.1145/2361276.2361291

Markham, A. N. (2019). Critical Pedagogy as a Response to Datafication. *Qualitative Inquiry*, *25*(8), 754–760. HTTPS://DOI.ORG/10.1177/1077800418809470

Martens, S. E., Meeuwissen, S. N., Dolmans, D. H., Bovill, C., & Könings, K. D. (2019). Student participation in the design of learning and teaching: Disentangling the terminology and approaches. *Medical teacher*, *41*(10), 1203-1205.

Martin, F., & Bolliger, D. U. (2018). *Engagement Matters: Student Perceptions on the Importance of Engagement Strategies in the Online Learning Environment*. *22*(1), 18.

Martinelli, R., & Milosevic, D. (2016). *Project Management ToolBox | Wiley Online Books* (2nd ed.). HTTPS://ONLINELIBRARY.WILEY.COM/DOI/BOOK/10.1002/9781119174820

Mascheroni, G., Livingstone, S., Stoilova, M., Nandagir, R., Milosevic, T., Zdrodowska, A., Staksrud, E., Siibak, A., Sukk, M., & Giuseppe Zaffaroni, L. (2020). *The datafication of childhood: Examining children's and parent's data practices, children's right to privacy and parent's dilemmas*.

Maturana, H.R., Varela, F.J. (1980). Embodiments of Autopoiesis. In: Autopoiesis and Cognition. Boston Studies in the Philosophy and History of Science, vol 42. Springer, Dordrecht. HTTPS://DOI.ORG/10.1007/978-94-009-8947-4_11

Matthews, J. C. (1998). Somatic Knowing and Education. *The Educational Forum*, *62*(3), 236–242. HTTPS://DOI.ORG/10.1080/00131729808984349

Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. *Journal of educational psychology*, *91*(2), 358-368.

Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of educational psychology*, *91*(4), 638.

Mayer, R. E., and Moreno. R (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist 38*(1) pp. 43-52.

Mayer, R. E. (2005). Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles.

In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 183–200). Cambridge University Press. HTTPS://DOI.ORG/10.1017/CBO9780511816819.013

Mayer, R. E. (2020). *Multimedia Learning* (3rd ed.). Cambridge University Press.

Mayer, R. E. (2022). Instructional media and instructional methods in digital language learning: Are we asking the right questions? *Bilingualism: Language and Cognition*, *25*(3), 396–397. HTTPS://DOI.ORG/10.1017/S1366728921000559

McDonough, E.F., III (2000), Investigation of Factors Contributing to the Success of Cross-Functional Teams. Journal of Product Innovation Management, 17: 221-235. HTTPS://DOI.ORG/10.1111/1540-5885.1730221

McFarland, D. J., & Wolpaw, J. R. (2011). Brain-Computer Interfaces for Communication and Control. *Communications of the ACM*, *54*(5), 60–66. HTTPS://DOI.ORG/10.1145/1941487.1941506

McGinn, K. (2015). Silos in education are the main barrier to collaboration. *Veterinary Record, 176*(16), 419–419. https://doi.org/10.1136/vr.h1928

McGregor, I. (2002). *The relationship between simulation and emulation*. *2*, 1683–1688 vol.2. HTTPS://DOI.ORG/10.1109/WSC.2002.1166451

McNaughton, M., Rao, L., & Mansingh, G. (2017). An agile approach for academic analytics: A case study. *Journal of Enterprise Information Management*, *30*(5), 701–722. HTTPS://DOI.ORG/10.1108/JEIM-06-2016-0121

Mergel, I., Ganapati, S., & Whitford, A. B. (2021). Agile: A new way of governing. *Public Administration Review*, *81*(1), 161-165.

Merleau-Ponty, M. (1945). *Maurice Merleau-Ponty: Phenomenology of Perception* (C. Smith, Trans. (2002). Routledge.

Michael, M. G., Fusco, S. J., & Michael, K. (2008). A research note on ethics in the emerging age of überveillance. *Computer Communications*, *31*(6), 1192-1199. HTTPS://DL.ACM.ORG/DOI/ABS/10.1016/J.COMCOM.2008.01.023

Michael, K., Pitt, J., Abbas, R., Perakslis, C., & Michael, M. (2023). Cyborgs and Human–Machine Communication Configurations. In A. Guzman, R. McEwen, & S. Jones, *The Sage Handbook*

of Human–Machine Communication (pp. 32–44). SAGE Publications Ltd. https://doi.org/10.4135/9781529782783.n6

Microsoft. (2021). *Evolving Zero Trust: How real-world deployments and attacks are shaping the future of Zero Trust strategies* (p. 9) [White Paper]. Microsoft. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWJJdT

Microsoft. (2022). *Microsoft Responsible AI Standard, v2* (p. 27). https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4ZPmV

Midjourney Lab. (2022). *Midjourney AI Art Generator from text prompt* (open beta) [Software]. https://www.midjourney.com/home/#about

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, *77*(12), 1321-1329.

Milgram, D. (2011). How to recruit women and girls to the science, technology, engineering, and math (STEM) classroom. *Technology and Engineering Teacher, 71*(3), 4-11.

Mishkin, A. (2019). Applying Self-Determination Theory towards Motivating Young Women in Computer Science. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 1025–1031. https://doi.org/10.1145/3287324.3287389

Mitchell, W. J. (2003). *Me++: The Cyborg Self and the Networked City*. MIT Press.

Monahan, T., & Wall, T. (2007). Somatic Surveillance: Corporeal Control through Information Networks. *Surveillance & Society*, *4*(3). https://doi.org/10.24908/ss.v4i3.3446

Moore, J., & Price, C. (2009). Development of an educational immersive environment for primary school literacy education. In *Proceedings Of The 3rd European Conference On Games Based Learning* (pp. 271–278).

Moore, M. (2015). *PhysicsonPointe: Merritt Moore*. Dr. Merritt Moore. Retrieved 24 March 2023, from http://merrittmoore.com/about

Morse, S. J., & Roskies, A. L. (2013). *A Primer on Criminal Law and Neuroscience: A contribution of the Law and Neuroscience Project, supported by the MacArthur Foundation*. Oxford University Press.

Mozilla Festival. (2023). https://www.mozillafestival.org/en/

Nakano, R., Hilton, J., Balaji, S., Wu, J., Ouyang, L., Kim, C., Hesse, C., Jain, S., Kosaraju, V., Saunders, W., Jiang, X., Cobbe, K., Eloundou, T., Krueger, G., Button, K., Knight, M., Chess, B., & Schulman, J. (2022). *WebGPT: Browser-assisted question-answering with human feedback.* arXiv. HTTP://ARXIV.ORG/ABS/2112.09332

Nelson, E. (2001). *The Complete Idiot's Guide to the Roman Empire: Engrossing Stories of Roman Conquest, Palace Intrigue, and the Politics of Empire*. Penguin.

Newby, P. (2014). *Research Methods for Education, second edition*. Routledge. HTTPS://DOI.ORG/10.4324/9781315758763

Nextech. (2021, September 24). Dancing Into the Future With Augmented Reality Human Holograms [Extech.com]. *Dancing Into the Future With Augmented Reality Human Holograms*. HTTPS://WWW.NEXTECHAR.COM/BLOG/DANCING-INTO-THE-FUTURE-WITH-AUGMENTED-REALITY-HUMAN-HOLOGRAMS

NHS.UK, *Electroencephalogram (EEG)*. (2017, October 18). HTTPS://WWW.NHS.UK/CONDITIONS/ELECTROENCEPHALOGRAM/

Norris, T. (2018). Consuming Schools: Commercialism and the End of Politics. University of Toronto Press. HTTPS://DOI.ORG/10.3138/9781442690257

Noverre, J.-G. (1783). *Lettres sur la danse et sur les ballets*. Chez Aimé Delaroche, Imprimeur-Libraire du Gouvernement & de la Ville.

OCR (2022) *GCSE Computer Science (9-1) (J277) Specification For teaching from September 2020 onwards For exams in 2022 onwards.* OCR Oxford Cambridge and RSA. HTTPS://WWW.OCR.ORG.UK/IMAGES/558027-SPECIFICATION-GCSE-COMPUTER-SCIENCE-J277.PDF

ODI data ethics canvas 2020, adapted from Otserwalder, 2008

OECD (2016). Innovating Education and Educating for Innovation: The Power of Digital Technologies and Skills, OECD Publishing. HTTP://DX.DOI.ORG/10.1787/9789264265097-EN

OECD (2018). *Future of Education and Skills 2030: Conceptual Learning Framework* (Conceptual Learning Framework No. JT03438116). OECD. HTTPS://WWW.OECD.ORG/EDUCATION/2030/EDUCATION-AND-AI-PREPARING-FOR-THE-FUTURE-AI-ATTITUDES-AND-VALUES.PDF

OECD. (2023). *Teaching for the Future: Global Engagement, Sustainability and Digital Skills, International Summit on the Teaching Profession*. OECD Publishing. HTTPS://DOI.ORG/10.1787/D6B3D234-EN

Ofsted. (2022). *Research review series: Computing*. Ofsted. HTTPS://WWW.GOV.UK/GOVERNMENT/PUBLICATIONS/RESEARCH-REVIEW-SERIES-COMPUTING/RESEARCH-REVIEW-SERIES-COMPUTING

Önen, Ö., & Tibet, B. (2020). Ethical Decision-Making in Schools. *Oxford Research Encyclopedia of Education*. HTTPS://DOI.ORG/10.1093/ACREFORE/9780190264093.013.635

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers* (Vol. 1). John Wiley & Sons.

Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A., Papadakos, T., & Smith, A. (2014). *Value Proposition Design: How to Create Products and Services Customers Want*. John Wiley & Sons, Incorporated. HTTP://EBOOKCENTRAL.PROQUEST.COM/LIB/CAM/DETAIL.ACTION?DOCID=1887760

Osterwalder, A., Pigneur, Y., Smith, A., & Etiemble, F. (2020). *The invincible company: how to constantly reinvent your organization with inspiration from the world's best business models* (Vol. 4). John Wiley & Sons.

Oved, D. (2018, May 7). *Real-time Human Pose Estimation in the Browser with TensorFlow.js*. HTTPS://BLOG.TENSORFLOW.ORG/2018/05/REAL-TIME-HUMAN-POSE-ESTIMATION-IN.HTML

Ozdamli, F., & Ozdal, H. (2018). Developing an Instructional Design for the Design of Infographics and the Evaluation of Infographic Usage in Teaching Based on Teacher and Student Opinions. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(4). HTTPS://DOI.ORG/10.29333/EJMSTE/81868

Palk, A., Illes, J., Thompson, P. M., & Stein, D. J. (2020). Ethical issues in global neuroimaging genetics collaborations. *NeuroImage*, *221*, 117208.

Panetto, H., Debruyne, C., Proper, H. A., Ardagna, C. A., Roman, D., & Meersman, R. (Eds.). (2018). *On the Move to Meaningful Internet Systems. OTM 2018 Conferences: Confederated International Conferences: CoopIS, C&TC, and ODBASE 2018, Valletta, Malta, October 22-26, 2018, Proceedings, Part I* (Vol. 11229). Springer International Publishing. HTTPS://DOI.ORG/10.1007/978-3-030-02610-3

Papert, S., Solomon, C., Soloway, E., & Spohrer, J. C. (1971). Twenty things to do with a computer. *Studying the novice programmer*, 3-28.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas* (1st ed.). Basic Books.

Parrish, M. (2016). Toward transformation: Digital tools for online dance pedagogy. *Arts education policy review*, *117*(3), 168-182.

Pavlik, K., & Nordin-Bates, S. (2016). Imagery in Dance: A Literature Review. *Journal of Dance Medicine & Science*, *20*(2), 51–63. HTTPS://DOI.ORG/10.12678/1089-313X.20.2.51

Patton, J. (2014). *User Story Mapping*. O'Reilly Media Inc. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/USER-STORY-MAPPING/9781491904893/

Pavliscak, P. (2015). *Data and Innovation*. O'Reilly. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/DATA-INFORMED-PRODUCT DESIGN/9781492048688/CH03.HTML

Perron, B. (2009). Horror Video Games: Essays on the Fusion of Fear and Play. McFarland.

Peteranetz, M. S., Flanigan, A. E., Shell, D. F., & Soh, L.-K. (2018). Helping Engineering Students Learn in Introductory Computer Science (CS1) Using Computational Creativity Exercises (CCEs). *IEEE Transactions on Education*, *61*(3), 195–203. HTTPS://DOI.ORG/10.1109/TE.2018.2804350

Phillips, D. & Dolle, J. (2006). From Plato to Brown and beyond: Theory, practice and the promise of design experiments. In L. Verschaffel, F. Dochy, M. Boekaerts & S. Vosniadou (Eds.) Instructional psychology: Past, present and future trends. Sixteen essays in honour of Erik de Corte (pp. 277-292). Oxford, UK: Elsevier Science Ltd.

Pichler, R. (2010). *Agile Product Management with Scrum: Creating Products that Customers Love*. Addison-Wesley Professional. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/AGILE-PRODUCT-MANAGEMENT/9780321684165/

Pichler, R. (2016). *Strategize: Product Strategy and Product Roadmap Practices for the Digital Age—Agile Centre - Certified Scrum, Agile Leadership, Scaled Agile Training & Consultancy*. Pichler Consulting. HTTPS://WWW.AGILECENTRE.COM/STRATEGIZE-PRODUCT-STRATEGY-AND-PRODUCT-ROADMAP-PRACTICES-FOR-THE-DIGITAL-AGE/

Pichler, R. (2022). The Product Vision Board updated (2011). *Roman Pichler*. HTTPS://WWW.ROMANPICHLER.COM/BLOG/THE-PRODUCT-VISION-BOARD/

Pointon, C. (2015). BioShock's Meta-Narrative - BioShock and Philosophy. What bioshock teaches gamers about gaming. In BioShock and Philosophy: Irrational Game, Rational Book., John Wiley & Sons, Inc HTTPS://DOI.ORG/10.1002/9781118915899.CH1

Polanyi, M. (1961). Knowing and Being. *Mind*, *70*(280), 458–470. HTTP://WWW.JSTOR.ORG/STABLE/2251603

Polanyi, M. (1966). The Logic of Tacit Inference. *Philosophy*, *41*(155), 1–18. HTTP://WWW.JSTOR.ORG/STABLE/3749034

Popper, K. (1962). *Conjecture and Refutations: The Growth of Scientific Knowledge*. Basic Books. HTTP://WWW.ROSENFELS.ORG/POPPER.PDF

Popper, K. (1995). *The Myth of the Framework: In Defence of Science and Rationality*. Routledge. HTTPS://WWW.ROUTLEDGE.COM/THE-MYTH-OF-THE-FRAMEWORK-IN-DEFENCE-OF-SCIENCE-AND-RATIONALITY/NOTTURNO-POPPER/P/BOOK/9780415135559

Posner, P. L. (2009). The Pracademic: An Agenda for Re-Engaging Practitioners and Academics. *Public Budgeting & Finance, 29*(1), 12–26. HTTPS://DOI.ORG/10.1111/J.1540-5850.2009.00921.X

Pugh-McCutchen, B. (2006). *Teaching Dance as Art in Education*. Human Kinetics.

Punch, K. F., & Oancea, A. (2014). *Introduction to Research Methods in Education* (2nd ed.). Sage Publications. HTTP://UK.SAGEPUB.COM/EN-GB/EUR/INTRODUCTION-TO-RESEARCH-METHODS-IN-EDUCATION/BOOK239756

Qammaz, A., & Argyros, A. A. (2019), *MocapNET: Ensemble of SNN Encoders for 3D Human Pose Estimation in RGB Images*, British Machine VIsion Conference (BMVC 2019), Cardiff, UK, September 2019.

Quezada, R. L., Talbot, C., & Quezada-Parker, K. B. (2020). From Bricks and Mortar to Remote Teaching: A Teacher Education Program‘s Response to COVID-19. *Journal of Education for Teaching*, *46*(4), 472–483. HTTPS://DOI.ORG/10.1080/02607476.2020.1801330

Ramos-Vega, M. C., Palma-Morales, V. M., Pérez-Marín, D., & M. Moguerza, J. (2021). Stimulating children's engagement with an educational serious videogame using Lean UX co-design. *Entertainment Computing*, *38*, 100405. HTTPS://DOI.ORG/10.1016/J.ENTCOM.2021.100405

Ramsetty, A., & Adams, C. (2020). Impact of the digital divide in the age of COVID-19. *Journal of the American Medical Informatics Association : JAMIA*, *27*(7), 1147–1148. HTTPS://DOI.ORG/10.1093/JAMIA/OCAA078

Research Data Team, (2015, March). *Data Management Guide* [Text]. University of Cambridge HTTPS://WWW.DATA.CAM.AC.UK/DATA-MANAGEMENT-GUIDE

Research Data Team, (2015, March). *Looking after your data | Research Data Management*. Looking after Your Data. University of Cambridge HTTPS://WWW.DATA.CAM.AC.UK/DATA-MANAGEMENT-GUIDE/LOOKING-AFTER-YOUR-DATA

Resnick, M. (2014, August). Give P'sa chance: Projects, peers, passion, play. In Constructionism and creativity: Proceedings of the Third International Constructionism Conference. Austrian Computer Society, Vienna (pp. 13-20)

Resnick, M. (2017). *Lifelong Kindergarten: Cultivating Creativity Through Projects, Passion, Peers, and Play* (1st ed.). MIT Press.

Resnick, M., & Rusk, N. (2020). Coding at a crossroads. *Communications of the ACM*, *63*(11), 120–127. HTTPS://DOI.ORG/10.1145/3375546

Rességuier, A., & Rodrigues, R. (2020). AI ethics should not remain toothless! A call to bring back the teeth of ethics. *Big Data & Society, 7*(2). HTTPS://DOI.ORG/HTTP://DX.DOI.ORG.EZP.LIB.CAM.AC.UK/10.1177/2053951720942541

Reeve, J., Zaugg, I., & Zheng, T. (2022). Mapping data ethics curricula. *Journal of Information, Communication and Ethics in Society*, *20*(3), 388–399. HTTPS://DOI.ORG/10.1108/JICES-12-2021-0124

Reynolds, T.T. (2018, December 28). The inside story of Bandersnatch, the weirdest Black Mirror tale yet. Wired UK. HTTPS://WWW.WIRED.CO.UK/ARTICLE/BANDERSNATCH-BLACK-MIRROR-EPISODE-EXPLAINED

rhizome | Description, Functions, & Examples. (2018). In Britannica (Ed.), Encyclopedia Britannica. https://www.britannica.com/science/rhizome

Rhodes, M. (1961). An Analysis of Creativity. *The Phi Delta Kappan*, *42*(7), 305–310.

Rice, C., & Mündel, I. (2018). Story-Making as Methodology: Disrupting Dominant Stories through Multimedia Storytelling. *Canadian Review of Sociology/Revue Canadienne de Sociologie*, *55*(2), 211–231. HTTPS://DOI.ORG/10.1111/CARS.12190

Rich, L., Perry, H., & Guzdial, M. (2004). A CS1 course designed to address interests of women. *ACM SIGCSE Bulletin*, *36*, 190–194. HTTPS://DL.ACM.ORG/DOI/ABS/10.1145/1028174.971370

Richardson, L. (1997). Skirting a Pleated Text: De-Disciplining an Academic Life. *Qualitative Inquiry*, *3*(3). HTTPS://DOI.ORG/10.1177/107780049700300303

Robertson, A. (2018, November 13). Exams 'useless' for computer science, say experts. *Schools Week*. HTTPS://SCHOOLSWEEK.CO.UK/EXAMS-USELESS-FOR-COMPUTER-SCIENCE-SAY-EXPERTS/

Robinson, V. (1998). Methodology and the Research-Practice Gap. *Educational Researcher*, *27*, 17–26. HTTPS://DOI.ORG/10.3102/0013189X027001017

Robinson, S. (2008). Conceptual Modelling for Simulation Part I: Definition and Requirements. *The Journal of the Operational Research Society*, *59*(3), 278–290. https://www.jstor.org/stable/30132749

Roderick, R. (2010). Baudrillard: Fatal Strategies (1993). http://rickroderick.org/308-baudrillard-fatal-strategies-1993/

Rodgers, P. A., & Yee, J. (Eds.). (2014). *The Routledge Companion to Design Research*. Routledge. HTTPS://DOI.ORG/10.4324/9781315758466

Rodríguez-Ardura, I., & Meseguer-Artola, A. (2019). Imagine, feel "there," and flow! Immersive experiences on m-Facebook, and their affective and behavioural effects. Information Technology & People, *32*(4), 921–947. https://doi.org/http://dx.doi.org.ezp.lib.cam.ac.uk/10.1108/ITP-10-2017-0358

Rogers, C., & Thomas, M. S. C. (2022). *Educational Neuroscience: The Basics* (1st ed.). Routledge. HTTP://WWW.ROUTLEDGE.COM/EDUCATIONAL-NEUROSCIENCE-THE-BASICS/ROGERS-THOMAS/P/BOOK/9781032028552

Rogers, M. (1998). *The Classic Ballet: Basic Technique and Terminology.* Library Journal.

Rokoko.com (2022) Rokoko Video Studio. AI driven motion capture to animation [computer software]. Denmark. HTTPS://WWW.ROKOKO.COM/PRODUCTS/VIDEO

Rose, D. (2015). *Leading Agile Teams*. Project Management Institute. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/LEADING-AGILE-TEAMS/9781628251043/

Rose, D. (2016). *Data Science: Create Teams That Ask the Right Questions and Deliver Real Value*. Apress.

Rose, G. (2001). *Visual methodologies: An introduction to the interpretation of visual materials*. Sage.

Royal Academy of Dance. (2021). *Royal Academy of Dance: Specificiation 2021*. HTTPS://MEDIA.ROYALACADEMYOFDANCE.ORG/MEDIA/2021/08/05110706/2021-SPECIFICATIONS-20210803-1.PDF

Royal Society (Great Britain). (2017). *After the reboot: Computing education in UK schools.*

Ryder, M. (2022). *The-Ryder-Review-Independent-legal-review-of-the-governance-of-biometric-data-in-England-and-Wales-Ada-Lovelace-Institute-June-2022.pdf*. Ada Lovelace Institute. HTTPS://WWW.ADALOVELACEINSTITUTE.ORG/WP-CONTENT/UPLOADS/2022/06/THE-RYDER-REVIEW-INDEPENDENT-LEGAL-REVIEW-OF-THE-GOVERNANCE-OF-BIOMETRIC-DATA-IN-ENGLAND-AND-WALES-ADA-LOVELACE-INSTITUTE-JUNE-2022.PDF

Ruhren, K. C. (2017, August 6). Are Dancers' Brains Wired Differently? *Dance Magazine*. HTTPS://WWW.DANCEMAGAZINE.COM/ARE-DANCERS-BRAINS-WIRED-DIFFERENTLY/

Sajous-Turner, A., Anderson, N. E., Widdows, M., Nyalakanti, P., Harenski, K., Harenski, C., ... & Kiehl, K. A. (2020). Aberrant brain gray matter in murderers. *Brain imaging and behavior*, *14*, 2050-2061. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6942640/pdf/nihms-1533753.pdf

Salganik, M. (2017). *Bit by Bit: social research in the digital age*. Princeton University Press. HTTPS://WWW.BITBYBITBOOK.COM/EN/1ST-ED/ETHICS/DIGITAL-IS-DIFF/

Salles, A., Evers, K., & Farisco, M. (2019). The Need for a Conceptual Expansion of Neuroethics. *AJOB Neuroscience*, *10*(3), 126–128. HTTPS://DOI.ORG/10.1080/21507740.2019.1632972

Sambeth, A., Durning, S., Huotilainen, M., & de Bruin, A. (2022). Educational neuroscience: Current status and future opportunities. In *Researching medical education* (pp. 187–195). John Wiley & Sons, Ltd. HTTPS://DOI.ORG/10.1002/9781119839446.CH17

Sansom, A. N. (2011). Chapter Five: Movement and Dance in the Early Years. *Counterpoints: Crossing the Divide*, *407*, 61–92.

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences, 23*(1), 18-36.

Scaled Agile Framework (2021, February 10) SAFe 5 for Lean Enterprise HTTPS://V5.SCALEDAGILEFRAMEWORK.COM/

Scale Agile Framework (2023, March 15) SAFe 6 https://scaledagileframework.com/

Schaller, R. R. (1997). Moore's law: past, present and future. *IEEE Spectrum*, *34*(6), 52–59. HTTPS://DOI.ORG/10.1109/6.591665

Schiller, W., & Meiners, J. (2003). Dance—Moving beyond steps to ideas. In S. Wright (Ed.), *Children, Meaning-Making and the Arts* (2nd ed., pp. 91–116). Pearson Education.

Schmidt, M., Egger, F., Kieliger, M., Rubeli, B., & Schüler, J. (2016). Gymnasts and Orienteers Display Better Mental Rotation Performance Than Nonathletes. *Journal of Individual Differences*, *37*(1), 1–7. HTTPS://DOI.ORG/10.1027/1614-0001/A000180

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. Jossey-Bass.

Schrijvers, M., Janssen, T., & Rijlaarsdam, G. (2017). 'WRR-Policy Brief 6 Big Data and Security Policies: Serving Security, Protecting [English Version]. *Levende Talen Tijdschrift*, *17*(1), 3-13. HTTPS://ENGLISH.WRR.NL/PUBLICATIONS/POLICY-BRIEFS/2017/01/31/BIG-DATA-AND-SECURITY-POLICIES-SERVING-SECURITY-PROTECTING-FREEDOM

Sentance, S., Barendsen, E., & Schulte, C. (2018). Computer Science Education : Perspectives on Teaching and Learning in School. London: Bloomsbury Academic

Sentance, S. (2018b, October 19). *Recent developments in computer science education research* [Seminar]. HTTPS://WWW.COMPUTINGATSCHOOL.ORG.UK/MEDIA/1KYM4F2T/RECENTDEVELOPMENTSINCOMPUTERSCIENCEEDUCATIONRESEARCH.PDF

Sententia, W. (2004). Neuroethical considerations: cognitive liberty and converging technologies for improving human cognition. *Annals of the New York Academy of Sciences*, *1013*(1), 221-228.

Serio, Á. D., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an Augmented Reality System on Students' Motivation for a Visual Art Course. *Computers & Education*, *68*(3), 586–596. HTTPS://DOI.ORG/10.1016/J.COMPEDU.2012.03.002

Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, *27*(3), 379–423. HTTPS://DOI.ORG/10.1002/J.1538-7305.1948.TB01338.X

Shapiro, B. R., Meng, A., O'Donnell, C., Lou, C., Zhao, E., Dankwa, B., & Hostetler, A. (2020). Re-Shape: A Method to Teach Data Ethics for Data Science Education. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–13. HTTPS://DOI.ORG/10.1145/3313831.3376251

Sharmanska, V., Quadrianto, N., & Lampert, C. H. (2014). *Learning to Transfer Privileged Information* (arXiv:1410.0389). arXiv. HTTP://ARXIV.ORG/ABS/1410.0389

Sharmanska, V., & Quadrianto, N. (2017). In the Era of Deep Convolutional Features: Are Attributes Still Useful Privileged Data? In R. S. Feris, C. Lampert, & D. Parikh (Eds.), *Visual Attributes* (pp. 31–48). Springer International Publishing. HTTPS://DOI.ORG/10.1007/978-3-319-50077-5_3

Shattuck, J., & Anderson, T. (2013). Using a design-based research study to identify principles for training instructors to teach online. *International Review of Research in Open and Distributed Learning*, *14*(5), 186-210.

Shaw, A. (2022). *BHVplayer*. HTTPS://GITHUB.COM/GLASTONBRIDGE/BVHPLAYER [Computer Software]

Shayannia, S. A. (2023). Presenting an agile supply chain mathematical model for COVID-19 (Corona) drugs using metaheuristic algorithms (case study: Pharmaceutical industry). *Environmental Science and Pollution Research*, *30*(3), 6559–6572. HTTPS://DOI.ORG/10.1007/S11356-022-22608-6

Shields, R. (2003). *The Virtual* (1st ed.). Routledge. HTTPS://WWW.ROUTLEDGE.COM/THE-VIRTUAL/SHIELDS/P/BOOK/9780415281812

Shum, S. B. (2022). *The UTS "EdTech Ethics" Deliberative Democracy Consultation: Rationale, Process and Outcomes* (p. 33). University of Technology Sydney. HTTPS://CIC.UTS.EDU.AU/WP-CONTENT/UPLOADS/2022/02/UTS_EDTECHETHICS_DELIBDEMOCRACY_JAN2022.PDF

Sidman, M. (1960). *Tactics of scientific research: Evaluating experimental data in psychology* (pp. x, 428). Basic Books.

Silva, A. J., Bickle, J., & Landreth, A. (2013). *Engineering the Next Revolution in Neuroscience: The New Science of Experiment Planning*. Oxford University Press.

Simon, H. A. (1996). *The sciences of the artificial* (3rd ed.). MIT Press.

Simon, H. A. (2019). *The Sciences of the Artificial, reissue of the third edition with a new introduction by John Laird*. MIT press.

Skelton, M. and Manuel, P. (2019). *Team Topologies: Organizing Business and Technology Teams for Fast Flow*. IT Revolution Press.

SkyMagic: Mt Fuji Drone Show. (2016). HTTPS://SKYMAGIC.SHOW/PROJECT/MT-FUJI/

Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretative phenomenological analysis: Theory, method and research / Jonathan A. Smith, Paul Flowers and Michael Larkin.* London : SAGE Publications Ltd.

Smith, J.A., Flowers, P., & Larkin, M. (2022). Interpretative Phenomenological Analysis – Theory, Method, and Research. 2nd Edition. Sage Publications. HTTPS://UK.SAGEPUB.COM/EN-GB/EUR/INTERPRETATIVE-PHENOMENOLOGICAL-ANALYSIS/BOOK250130

Smith, J., & Nizza, I. (2022). *Essentials of Interpretative Phenomenological Analysis (Essentials of Qualitative Methods)*. American Psychological Association. HTTPS://WWW.AMAZON.CO.UK/ESSENTIALS-INTERPRETATIVE-PHENOMENOLOGICAL-ANALYSIS-QUALITATIVE/DP/1433835657

Smith-Nunes, G., Cook, P., Neale, C., & Golz, P. (2016). Data network simulator with classical ballet. *Proceedings of the Conference on Electronic Visualisation and the Arts*, 70–75. HTTPS://DOI.ORG/10.14236/EWIC/EVA2016.13

Smith-Nunes, G., Shaw, A., & Neale, C. (2018). PainByte | Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction. *TEI '18:*

Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction, 493–497. HTTPS://DOI.ORG/10.1145/3173225.3173296

Smith-Nunes, G. (2021). *Singularity webVR showacase* [FrameVR]. Singularity. HTTPS://FRAMEVR.IO/ILRN2021-SHOWCASESINGULARITY

Smith-Nunes, G., (2023). AI-imagery. Proceedings of the Nineth International Immersive Learning Research Network Conference. *iLRN2023 Proceeding of Ninth International Immersive Learning Research Network, (pre-print).*

Solomon, C. (1986). *Computer Environments for Children | The MIT Press*. The MIT Press. HTTP://MITPRESS.MIT.EDU/BOOKS/COMPUTER-ENVIRONMENTS-CHILDREN

Solomon, C. J. (1976). Leading a Child to a Computer Culture. *ACM SIGCSE Bulletin*, *8*(1), 79–83. HTTPS://DOI.ORG/10.1145/952989.803452

Solomon, C. J., & Papert, S. (1976). A case study of a young child doing Turtle Graphics in LOGO. In *Proceedings of the June 7-10, 1976, national computer conference and exposition* (pp. 1049-1056).

Solomon, F., Champion, D., Steele, M. & Wright, T. (2022) Embodies physics: Utilizing dance resources for learning and engagement in STEM. *Journal of Learning Science. 31*(1), pp73-106.

Sorden, S. D. (2012). The cognitive theory of multimedia learning. *Handbook of educational theories, 1* (22).

Spieler, B., Grandl, M., & Krnjic, V. (2020). The hAPPy-Lab: A gender-conscious way to learn coding basics in an open makerspace setting. *CEUR Workshop Proceedings*, *2755*, 64–75. HTTPS://GRAZ.PURE.ELSEVIER.COM/EN/PUBLICATIONS/THE-HAPPY-LAB-A-GENDER-CONSCIOUS-WAY-TO-LEARN-CODING-BASICS-IN-AN

Spot Choreography SDK (Version 2.3.5). (2021). Boston Dynamic [Computer Software]. HTTPS://DEV.BOSTONDYNAMICS.COM/DOCS/CONCEPTS/CHOREOGRAPHY/README

Spotify Design Team. (2020). *Introducing Spotify's New Design Principles*. HTTPS://SPOTIFY.DESIGN/ARTICLE/INTRODUCING-SPOTIFYS-NEW-DESIGN-PRINCIPLES

Starr, J. W. (1970). Student Opinion On Methods Of Assessment. *Educational Review*, *22*(3), 243–253. HTTPS://DOI.ORG/10.1080/0013191700220303

Stuart, M., & Kirstein, L. (1952). *The Classic Ballet: Basic Technique and Terminology*. University Press of Florida.

Strauss, A., & Corbin, J. M. (1997). *Grounded theory in practice*. Sage.

Sullins, J. (2000). Transcending the meat: immersive technologies and computer mediated bodies. *Journal of Experimental & Theoretical Artificial Intelligence, 12*(1), 13–22. HTTPS://DOI.ORG/10.1080/095281300146281

Summer, E., and Weiss, E. (Directors). (2016) *Ballerina* [Film]. L'Atelier Animation.

Sutar, B., Narlikar, J.V (Eds)., T*yagi,* A *(illustrator) Science: textbook for class VIII.* (2022). National Council Of Educational Research And Training, (NCERT).

Sutton, J. (2005) Moving and Thinking Together in Dance. In R. Grove, G. Sullivan, & S. McKechnie (Eds.), *Thinking in Four Dimensions: Creativity and cognition in contemporary dance* (pp. 51–55). Melbourne University Press.

Sweller, J. (2005). Implications of Cognitive Load Theory for Multimedia Learning. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (1st ed., pp. 19–30). Cambridge University Press. HTTPS://DOI.ORG/10.1017/CBO9780511816819.003

Tang, H., Dai, M., Du, X., Hung, J.-L., & Li, H. (2023). An EEG study on college students' attention levels in a blended computer science class. *Innovations in Education and Teaching International*, 1–13. HTTPS://DOI.ORG/10.1080/14703297.2023.2166562

Tarnavsky, A. E., Smolyansky, E., Harpaz, I. K., & Perets, S. (2020). *Connected Papers*. [Computer Software] HTTPS://WWW.CONNECTEDPAPERS.COM/ABOUT

Temple, B. A., Bentley, K., Pugalee, D. K., Blundell, N., & Miranda Pereyra, C. (2020). Using Dance & Movement to Enhance Spatial Awareness Learning. *Athens Journal of Education*, *7*(2), 153–168. HTTPS://DOI.ORG/10.30958/AJE.7-2-2

Teperek, M. (2015a, February 18). *Research Data Policies* [Text]. University of Cambridge HTTPS://WWW.DATA.CAM.AC.UK/RESEARCH-DATA-POLICIES

Teperek, M. (2015b, February 21). *Data Management Guide* [Text]. Cambridge Data, University of Cambridge. HTTPS://WWW.DATA.CAM.AC.UK/DATA-MANAGEMENT-GUIDE

TES Jobs. (2019, October). *Appointment of a Purple Spotted Unicorn (or exceptional Computer Science Teacher* [TES Jobs]. HTTPS://WWW.TES.COM/JOBS/VACANCY/APPOINTMENT-OF-A-PURPLE-SPOTTED-UNICORN-OR-EXCEPTIONAL-COMPUTER-SCIENCE-TEACHER-BELHAVEN-DUNBAR-EAST-LOTHIAN-1252908

Thomas, N., Miller, A. J., Ayaz, H., & Brown, J. D. (2023). Haptic shared control improves neural efficiency during myoelectric prosthesis use. *Scientific Reports*, *13*(1), 484. HTTPS://RDCU.BE/C95VD

Thompson, N. (2008). Existentialist ethics: From Nietzsche to Sartre and beyond. *Ethics and Social Welfare*, *2*(1), 10-23.

Thouless, R. H. (1939). The Effects of Errors of Measurement on Correlation Coefficients. *British Journal of Psychology. General Section*, *29*(4), 383–403. HTTPS://DOI.ORG/10.1111/J.2044-8295.1939.TB00927.X

Tortora, S. (2006). *The dancing dialogue: Using the communicative power of movement with young children*. Paul H. Brookes Pub.

Trajkova, M., & Cafaro, F. (2018). Takes Tutu to Ballet: Designing Visual and Verbal Feedback for Augmented Mirrors. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *2*, 1–30. HTTPS://DOI.ORG/10.1145/3191770

Tweney, R. D. (2005). Cognitive Science and the 'Dancing Brain'. In Grove, R., Stevens, C., & McKechnie, S. (Eds.) *Thinking in Four Dimensions: Creativity and Cognition in Contemporary Dance,* (pp. 149–153). Melbourne University Press.

Turkle, S., & Papert, S. (1990). Epistemological Pluralism: Styles and Voices within the Computer Culture. *Signs*, *16*(1), 128–157. HTTP://LINKS.JSTOR.ORG/SICI?SICI=0097-9740%28199023%2916%3A1%3C128%3AEPSAVW%3E2.0.CO%3B2-D

UKRI (2022) *Research Ethics Guidance* HTTPS://WWW.UKRI.ORG/COUNCILS/ESRC/GUIDANCE-FOR-APPLICANTS/RESEARCH-ETHICS-GUIDANCE/

Van Den Akker, J. (1999) Principles and methods of development research. In: Van Den Akker, J., Nieveen, N., Branch, R.M., Gustafson, K.L. and Plomp, T., Eds., Design Methodology and Developmental Research in Education and Training, Kluwer Academic Publishers, The Netherlands, 1-14.

van Kessel, C., & Kline, K. (2019). “If you can’t tell, does it matter?” Westworld, the murder of the real, and 21st century schooling. *Journal of Curriculum and Pedagogy, 16*(2), 196–216. HTTPS://DOI.ORG/10.1080/15505170.2018.1542358

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. HTTPS://DOI.ORG/10.1016/J.CHB.2017.03.010

Vastola, R., Coppola, S., & Sibilio, M. (2016). Motion Analysis Technologies for Biomechanical Gait and Postural Analysis in Ballet. *Journal of Sports Science*, *4*. HTTPS://DOI.ORG/10.17265/2332-7839/2016.04.008

Vaughn, R. (2015, November 4). Decision to scrap ICT a “kick in the teeth,” say experts. *Tes Magazine*. HTTPS://WWW.TES.COM/MAGAZINE/ARCHIVE/DECISION-SCRAP-ICT-KICK-TEETH-SAY-EXPERTS

Vedres, B. (2022). Collaborative Creativity as a Field within Computational Social Science. *SSRN Electronic Journal*, 18. HTTPS://DOI.ORG/10.2139/SSRN.4063722

Velásquez-Henao, J. D. (2021). Analysis of bibliographic datasets using Python — TechMiner - A Package for Bibliographical Analysis using Python 0.0.0 documentation (Version 0.0.0) [Computer Software]. HTTPS://JDVELASQ.GITHUB.IO/TECHMINER/

Waite, J. (2017). *Pedagogy in teaching Computer Science in schools: A Literature Review*. London: Royal Society.

Watson, A. (2005). Dance and mathematics: Engaging senses in learning. *Australian Senior Mathematics Journal*, *19*(1), 16–23.

Wang, C., & Wang, S. J. (2017). Relevé: An at-home ballet self-learning interactive system. *KnE Engineering*, 242–248. HTTPS://DOI.ORG/10.18502/KEG.V2I2.622

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, *53*(4), 5–23. HTTPS://DOI.ORG/10.1007/BF02504682

Wang, L. L., Stanovsky, G., Weihs, L., & Etzioni, O. (2019). Gender trends in computer science authorship. *arXiv:1906.07883 [Cs]*. HTTP://ARXIV.ORG/ABS/1906.07883

Wanzel, K. R., & Fish, J. S. (2003). Residency training in plastic surgery: A survey of educational goals. *Plastic and Reconstructive Surgery*, *112*(3), 723–729; discussion 730. HTTPS://DOI.ORG/10.1097/01.PRS.0000069705.52702.80

Weidler-Lewis, J., DuBow, W., Kaminsky, A., & Weston, T. (2019). Supporting women's persistence in computing and technology: A case for compulsory critical coding? *Information and Learning Sciences*. *120*(5/6), 366-382. DOI:10.1108/ILS-08-2018-0083

West, K. (2018, July 29). Reinventing Research: Agile in the Academic Laboratory | Agile Alliance. *Agile Alliance* |. Agile2018 Conference, San Diego. HTTPS://WWW.AGILEALLIANCE.ORG/RESOURCES/EXPERIENCE-REPORTS/REINVENTING-RESEARCH-AGILE-IN-THE-ACADEMIC-LABORATORY/

Weston, T. J., Dubow, W. M., & Kaminsky, A. (2019). Predicting women's persistence in computer science-and technology-related majors from high school to college. *ACM Transactions on Computing Education (TOCE)*, *20*(1), 1-16.

Whitley Jr, B. E. (1997). Gender differences in computer-related attitudes and behavior: A meta-analysis. *Computers in human behavior*, *13*(1), 1-22.

Whitman, W. 2004 (1855) Song of Myself. Project Gutenberg EBook-No. 12718. HTTPS://WWW.GUTENBERG.ORG/EBOOKS/12718

Whiting, N. (2018, April 17). How the term XR was coined. A Chat with Nick Whiting of Epic Games. HTTPS://YOUTU.BE/OCPJK_1C28U

Wing, J. (2006). Computational Thinking. *Communication of the ACM*, *49*(3). HTTPS://WWW.CS.CMU.EDU/AFS/CS/WEB/PEOPLE/15110-S13/WING06-CT.PDF

Wingate, L. (2017). *Evaluation Data Matrix Template – EvaluATE*. HTTPS://EVALUATE.ORG/TEMPLATE/TOOL-DATAMATRIX/

Winter, R. (1996). Some Principles and Procedures for the Conduct of Action Research. In *New Directions in Action Research* (1st ed.). Routledge.

Wood, S. (2016, July 16). Design Doesn't Scale. *Design Doesn't Scale*. HTTPS://MEDIUM.COM/@HELLOSTANLEY/DESIGN-DOESNT-SCALE-4D81E12CBC3E

Wolcott, M. D., Lobczowski, N. G., Lyons, K., & McLaughlin, J. E. (2019). Design-based research: Connecting theory and practice in pharmacy educational intervention research. *Currents in Pharmacy Teaching and Learning*, *11*(3), 309-318.

Wu, J., & Chen, V. D.-T. (2018). Refining conjecture mapping for design-based research. In J. C. Yang, M. Chang, L.-H. Wong, & M. M. T. Rodrigo (Eds.), Proceedings of the 26th International Conference on Computers in Education (ICCE) 2018 (pp. 767-771). Manila, Philippines: Asia-Pacific Society for Computers in Education (APSCE). HTTPS://APSCE.NET/ICCE/ICCE2018/WP-CONTENT/UPLOADS/2018/12/C7-10.PDF.

Wu, Y., Wang, S., Bezemer, C.-P., & Inoue, K. (2019). How do developers utilize source code from stack overflow? *Empirical Software Engineering*, *24*(2), 637–673. HTTPS://DOI.ORG/10.1007/S10664-018-9634-5

Xu, D., Wolz, U., Kumar, D., & Greenburg, I. (2018). Updating Introductory Computer Science with Creative Computation. *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, 167–172. HTTPS://DOI.ORG/10.1145/3159450.3159539

Yardley, A., Atkinson, P., Delamont, S., Cernat, A., Sakshaug, J. W., & Williams, R. A. (2019). *Bricolage as method*. HTTPS://METHODS.SAGEPUB.COM/FOUNDATIONS/BRICOLAGE-AS-METHOD

York, E., & Conley, S. N. (2020). Creative Anticipatory Ethical Reasoning with Scenario Analysis and Design Fiction. Science and Engineering Ethics, 26(6), 2985–3016. HTTPS://DOI.ORG/10.1007/S11948-020-00253-X

Zhang, W., Liu, Z., Zhou, L., Leung, H., & Chan, A. B. (2017). Martial Arts, Dancing and Sports dataset: A challenging stereo and multi-view dataset for 3D human pose estimation. *Image and Vision Computing*, *61*, 22–39. HTTPS://DOI.ORG/10.1016/J.IMAVIS.2017.02.002

Appendices

1A Research Dissemination

Article/Conference Paper	Year	Author Position	Peer Reviewed
Farthing. R, Akuetteh, T., Katja, Osljak,K., Smith-Nunes, G, Comacho, K., and Zhao, J. (2023) The 'future' of privacy: Youth-centric notions of privacy and surveillance around the world. 2023 12th Annual Summit RightCon Costa Rica June 5-9	2023	4th	Double blind
Smith-Nunes (2023, May) Doctoral Colloquium-AI-imagery - An immersive computational analysis. 2023 9th International Conference of the Immersive Learning Research Network (iLRN) 2023-5-19 | Conference paper and AR gallery LINK	2023	Sole	Double Blind
Farthing. R, Akuetteh, T., Katja, Osljak,K., Smith-Nunes, G, Comacho, K., and Zhao, J. (2023) '*It sets boundaries making your life personal and more comfortable*': Understanding young people's privacy needs and concerns IEEE Technology and Society Magazine 2023-03-12 | Journal article DOI: 10.1109/MTS.2023.3244554	2023	4th	Double Blind
Farthing, R., Smith-Nunes, G. & Camacho, K. 2023 *Young people's rights in the digital age* HTTPS://TRUSTECH4KIDS.GITHUB.IO/FILES/ABREPORTFINAL202303.PDF	2023	2nd	
Smith-Nunes, Shaw (2022) Doctoral Colloquium-ME++ Data-ethics of biometrics through Ballet and AR 2022 8th International Conference of the Immersive Learning Research Network (iLRN)	2022	1st	Double Blind
Farthing, R., Michael, K., Abbas, R., & Smith-Nunes, G. (2021). Age-Appropriate Digital Services for Young People: Major Reforms | IEEE Journals & Magazine | IEEE Xplore. *IEEE Consume Electronics*, *10*(4). HTTPS://DOI.ORG/10.1109/MCE.2021.3053772.	2021	4th	Double Blind
Smith-Nunes, Shaw, Neale (2021) Doctoral Colloquium-ME++ Data-ethics of biometrics through Ballet and AR 2022 8th International Conference of the Immersive Learning Research Network (iLRN)	2021	1st	Double Blind
Smith-Nunes, (2019) Computing meets classical ballet. Hello World Magazine, 9, p18-19. RPi Publishing Ltd, UK Https://helloworld.raspberrypi.org/issues/9	2019	sole	
Related pre-PhD			
Smith-Nunes, G., Shaw, A., & Neale, C. (2018). PainByte | Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction. *TEI '18: Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*, 493–497. HTTPS://DOI.ORG/10.1145/3173225.3173296	2018	1st	Double Blind
Smith-Nunes, Shaw, Neale, (2017)[pain]byte VR Storytelling & Classical Ballet EVA London 2017 2017 | Conference paper DOI: 10.14236/EWIC/EVA2017.82 *Part of* ISBN: 9781780173993	2017	1st	Double Blind

From this thesis, I intend to initially publish the following papers:

(i) A case study lens on AgileDBR: bridging the domain-siloed methodological approaches to academic research **(ii)** Biometrics and humanising data for immersive learning for computing education **(iii)** Creative computing practices, DataDrivenDance, a possibility for widening participation.

3A Haraway

Haraway's Sympoiesis (Haraway, 2016), in its simplest form, is 'making-with' as an 'entire being' beyond the one, the individual forms within my research both in practice and the study itself. Here, 'entire being' does not refer to one individual but to a complex of individuals in space and time. The term sympoiesis, suggested by M. Beth Dempster (1998, p. 61), is defines as 'collectively-producing systems that do not have self-defined spatial or temporal boundaries'. Information and control are distributed among components. Haraway uses complex terms that take time to digest and comprehend. Haraway proposes an understanding of biological evolutionary theory based on Darwinism and the idea that life can be considered as computer code alongside cause and effect relationships. The 'polytemporal, polyspatial' (p. 60) entanglements of the interconnected network constitutes part of my research. The making–with–the assemblages of people, places, code, technology, communication, and ideas generates emergent, dynamic, iterative rematterings. It is these ideas that are brought to life through the ontological kaleidoscope. A rematterings in each iteration of ideas, practice, and form through in inter-intra actions of the team problem definition goes beyond simple connections, creating novel explanations and stories. It is this storytelling that is important in this research. Experience stories of data and CS concepts are brought to life through the arts and immersive modalities. Novel explanations through movement, immersive, and data enable access to different audiences.

Reference

Haraway, D. (2016). *Staying with the Trouble: Making Kin in the Chthulucene*. Duke University Press. HTTPS://DOI.ORG/10.2307/J.CTV11CW25Q

4A Mixed Methods

Over the past 20 years, there has been an exponential growth in the number of research articles with MMR as their methodology (Hollstein, 2014). A change to a more rigid approach to MMR seems to be happening (Hesse-Biber et al., 2015c), which may hinder the innovation and knowledge generation garnered through MMR. 'Mixed-up methods' is a phrase that comes from a talk by Hesse-Biber in 2015 discussing MMR. While published papers claim to use mixed methods, what is written does not come across as mixed methods but multiple methods or something else entirely (Hesse-Biber et al., 2015c). This results in ambiguity and is a deviation from what is defined as mixed methods. The challenge for novice research is that MMR suffers from 'conflicting guidance' (Maudsley, 2011) as to what the research standards are in terms of theory, assumption and going beyond the paradigmatic lens of either qualitative or quantitative. It is 'thinking qualitatively AND quantitatively' (Maudlsey, 2011); it is an integrated design approach (Greene et al., 1989) that does not create concrete barriers by this mixing or 'epistemological ecumenism' (Onwuegbuzie, 2000). It creates an epistemological unity. A good example linked to education from nursing is Ironside's study (2003), where the mixed methods approach was measured and balanced in informing and expanding the understanding of the 'mismatching' between the quantitative and qualitative findings.

The word 'approach' instead of paradigm is preferred by Morgan (2007) due to the multiple understandings of paradigm offering a 'pragmatic approach'. He goes further into describing the tensions of theory and data generation in real-world research. Beyond the inductive and deductive to abductive reasoning, there is a bidirectional flow between induction and deduction, first 'converting observations into theories and then assessing those theories through action' (Morgan 2007). This bidirectional flow brings to mind Whitman's words, '*You shall listen to all sides and filter them from yourself'*. The nature of reality is looked upon as being multi-faceted and reflective of different power positionalities in society (Mertens, 2012). A dialectical position allows for multiple points of view. The authors quote Green and Hall (2010) to clarify this point. It is the multiple points of view within the kaleidoscopic lens that are central to this research study.

Hesse-Biber often advocates the use of mixed methods to understand the phenomenon in society (Mertens and Hesse-Biber, 2010). The emphasis is on 'credible evaluation practice', provided to the reader/researcher with practical strategies. The authors stress the importance

of applying philosophical and social theory perspectives in the evaluation process of these strategies. It is not just a matter of combining quantitative and qualitative methods: 'evaluation is also tightly linked to specific epistemological, methodologies in theoretical perspectives and assumptions' (Hesse-Biber, 2010). MMR's central focus is the research problem rather than the method. It is achieved through a combination of quantitative and qualitative methods, providing a more comprehensive understanding of the research puzzle. Hammersley and Atkinson (2007) suggest that such research is not as black and white as quantitative or qualitative research but is a variant of each. It is to carry out research applying a range (quantitative and/or qualitative) of strategies appropriate to the research practice and problem being studied (Hammersley, Hammersley & Atkinson, 2007) in relation to design-based research (DBR).

References

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255–274. HTTPS://DOI.ORG/10.3102/01623737011003255

Hammersley, P. M. (2007). Educational Research and Evidence-Based Practice. SAGE.

Hammersley, M. (2013). The Myth of Research-Based Policy and Practice. SAGE.

Hesse-Biber, S. N. (2010). Mixed methods research: Merging theory with practice. Guilford Press.

Hesse-Biber, S. N., & Johnson, R. B. (Eds.). (2015). *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*. Oxford University Press.

Hesse-Biber, S. N., Rodriguez, D., & Frost, N. A. (2015). *A Qualitatively Driven Approach to Multimethod and Mixed Methods Research* (S. N. Hesse-Biber & R. B. Johnson, Eds.). Oxford University Press. HTTPS://DOI.ORG/10.1093/OXFORDHB/9780199933624.013.3

Ironside, P. M. (2003). New pedagogies for teaching thinking: The lived experiences of students and teachers enacting narrative pedagogy. *Journal of nursing education*, *42*(11), 509-516.

Maudsley, G. (2011). Mixing it but not mixed-up: Mixed methods research in medical education (a critical narrative review). *Medical Teacher*, *33*(2), e92–e104. HTTPS://DOI.ORG/10.3109/0142159X.2011.542523

Mertens, D. M. (2010). Transformative Mixed Methods Research. *Qualitative Inquiry*, *16*(6), 469–474. HTTPS://DOI.ORG/10.1177/1077800410364612

Mertens, D. M., Ebrary, I., & Hesse-Biber, S. N. (2013). *Mixed methods and credibility of evidence in evaluation*. Jossey-Bass.
HTTP://CAPITADISCOVERY.CO.UK/ROEHAMPTON/ITEMS/783642
HTTP://SITE.EBRARY.COM/LIB/ROEHAMPTON/DOC?ID=10722544

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained. *Journal of Mixed Methods Research*. HTTPS://DOI.ORG/10.1177/2345678906292462

Onwuegbuzie, A. J., & Johnson, R. B. (2021). *The Routledge Reviewer's Guide to Mixed Methods Analysis*. Routledge.

4B Conjecture Mapping According to Sandoval –and alternative to TEST and LEARN cards.

The following expanded discussion cover Sandoval's (2014) Conjecture mapping and examples of this could have been implemented in this study.

Sandoval (2014) developed conjecture maps to support the DBR process by linking the conjectures (hypothesis) to the invention design, implementation and outcomes of a given study. A conjecture map consists of conjectures about a study, namely embodiment – intervention itself, materials, participants and tools; mediating processes – observations, artefacts, data generation; and, lastly, outcomes – the theoretical and practical discussions and conclusions of a given study. Sandoval describes this as taking the theoretically salient features of the proposed learning environment design and then mapping how these features work together to produce the desired outcomes. This dual driver of the research is important to DBR, but is it not one of simultaneity, but one of concurrency (Phillip & Dolle, 2006). What is meant by concurrency? Concurrent in computing terms means a programme can be split up into units (tasks) that can be run in any order and have a determinate outcome. In a research sense, it is an asynchronous process, with elements starting at the same time but completing earlier or later. It is also concurrent, as different parts of the research are design, developed, deployed and evaluated on an iterative cycle. Once the concurrent nature is understood, the dual drivers do not seem insurmountable or in conflict, as noted by Phillip and Dolle (2006). Instead, it should be viewed as an asynchronous concurrent (AC) process. Asynchronous concurrency is one of the key benefits of using DBR or Agile.

Sandoval (2004) started with a generalised version of conjecture maps as a tool to aid in linking the theoretical features to the how, who and what of the research study, as well as the outcome elements. The map is broken down into elements of the research study: conjectures, embodiment, mediating processes and outcomes, with two additional surrounding elements of design conjectures (how a given 'task' produces the desired outcome) and the theoretical conjectures (why the task produced the given learning outcome). The map suggests a linearity to the research process rather than the cyclic iterative of many DBR studies.

Each of the sections relates to the desired research outcomes in the form of high-level conjectures. This leads to the tools, materials, participants, tasks and discursive practices needed to bring the study to life, or to instantiate or embody it, as Sandoval describes it. Once the embodiment of the conjectures has been designed and developed, this leads to the design

conjectures, which feed into the mediating processes. Design conjectures are the process of the engagement of participants in the designed tasks. Then the mediating processes should be observable and ultimately measurable (or testable). This measurability (Rossi, 2007) looks at whether or not the desired mediating process occurs, and whether it can be linked to the designed 'tasks' of the 'intervention'. The theoretical conjectures follow from the design principles and measurements to the desired outcomes; the theoretical conjectures relate to how the design principles produce the learning, the why it works or not of any given conjecture. Outcomes need to be written in a way that conveys specificity: What do I expect to see or happen? How can this be observed /measured through the mediating processes? Any conjecture is designed to visually represent only the 'nascent' features to guide the design and not become overly complex or swamped (Sandoval, 2013). These processes generate the guiding design principles, which are more general in natural, and, therefore, the principles themselves are untestable in an empirical sense. Design principles are the general guidelines of the design: they are high-level. On Sandoval's conjecture map, there is no visible place for design principles.

One of the crucial things about conjecture maps or conjunction mapping is the breakdown of ideas into their most simplistic and researchable form through data. The conjecture is explored through the embodiment and mediating process and, eventually, the outcomes. However, to benefit from and use this, we need to think about the data's more essential elements. How will the data for the conjecture be used to warrant any claims made through the conjecture? Through a series of questions, we can interrogate the conjecture: (i) What learning gains are made in the intervention? (ii) How did we raise awareness of data-ethics? (iii) What educational resources are supported in (i) and (ii) during the educational, dance and technological workshops? What is the sort of qualifier, the difference between what can we get from this? What claim am I making-with the conjecture, the principle of proof that something is possible to achieve? (iv). That raises awareness of data-ethics or raise awareness of data-ethics for computing students is all students. Because of the digitally mediated world that we live in that uses biometrics throughout most of our lives. We are datafied from birth.

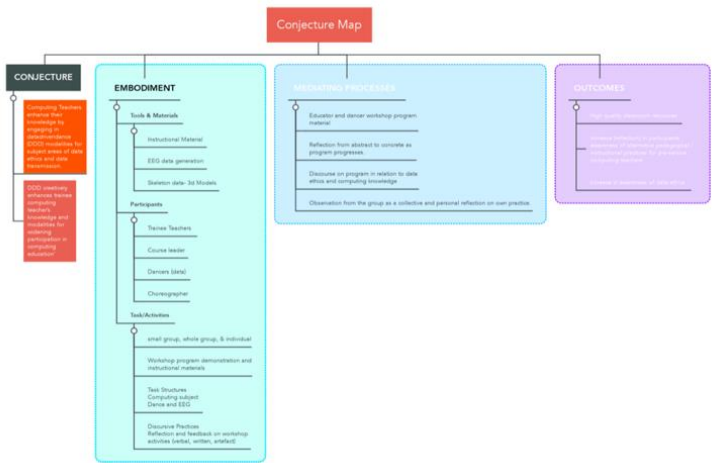
Incremental changes in conjectures leading to design principles occur through small changes during the incremental sprint. So, on this kind of continuum, what did the data show? How did it back? And then what was the minimal claim made for each increment? This then has to be shared with an eventual full increment complete clean and a design principle that works beyond this study. Small changes in the iteration lead to a kind of broader supporting

knowledge. An experience of this sort for the computing education community, the neuroethics community and the dance community in immersive technology develops both massive learning and immersive learning design specialists. In order that particular community.

Conjectures are generalisable in how the findings are interpreted by others. Again, they are not necessarily generalisable within an education context but to one of scaleability, which includes the notations of generalisation and replicability. Bell, Hoadley and Linn (2004) in Chapter Four state that the design principles are an intermediate step in developing scientific findings, which must be generalised and replicable. Within this study, the word scaleable is taken from Agile. It includes both notions of generalisable and replicable (Pichler, 2010). Scaleable differs in that it is contextualised with local experience due to the 'classroom context', and each classroom is individualised (Pichler, 2016). It is challenging to replicate those, even with the same individuals, because they need to interpret design principles that are not readily falsifiable, as in scientific laws. Principles are inductive from previous examples of success and are continuously subjected to continual refinement over time. As a result of conjunction mapping, design principles are not yielded; rather, they are concretised over time through the whole design process. Every time an increment is developed in the study, the data tell us to change, modify and sometimes remove the principles.

An initial mapping of the scoping sprint of my study is done using Sandoval's technique. The conjecture map below does not include the design or theoretical conjectures, just an initial conjecture that assumes an Agile iterative, reflexive, revision process.

Fig 4B.1 Initial conjecture map



Conjectures about teaching-learning strategies can help students achieve the goal of raising awareness of data and ethics. How can we support PGCE teachers in achieving this goal? How well does one know X or Y of the curriculum? How was the strategy designed and implemented with regard to the effects and results of implementing this strategy? What will the improved look be? These are the questions that I ask in each of the iterations. A critique of DBR is that it is not considered scientific, mainly because of its implementation, and that design-based researchers update their conjectures and adjust or design them while experimenting. Agile supports this approach through the iterative, sprint-based approach with (reflexive) retrospectives; therefore, the rebuild of epics and features (main elements, goals) into stories leads on to the development of the next sprint, all to add value to the research/study.

Redefining conjecture maps have a few updates or refinements, as seen in the literature. Wu and Chen's (2018) paper covers two important aspects that troubled me when reviewing Sandoval's original conjecture map: the need to link design principles to embodiment and the mediating element not just as a process but as a process to gather evidence. Wu and Chen also changed their outcomes to latent outcomes to incorporate or 'capture the implicit or often un-observable' (Wu & Chen, 2018). Although the structure of the conjecture map has not changed, Wu and Chen present it in a way to highlight the process and purpose of each element in more concrete terms. It is simply a case of applying the lexicon to improve clarity.

Conjectures, according to Sandoval (2014), are the initial steps that educational researchers must consider when seeking to understand the how and why a particular learning event occurs because of specifically designed learning, a theoretical conceptualisation. There is a duality within educational DBR of furthering the understanding of the learning processes, coupled with improvements to educational practices. It is a duality where, Sandoval argues, conjectures (the theoretical conceptualisation of the study) are the starting point for educational DBR researchers. Bakker (2018) refers to conjectures as hypotheses, an 'emergent theory' that then needs an 'empirical test' (p. 48). This is also evident in industry, specifically following an Agile mindset and approach, with the use of a Features & Benefits Hypothesis (FAB matrix), (*SAFe 5.0 Framework*, 2021.); an EPIC hypothesis statement (SAFe 5.1) (SAFe 5 2021); a Lean UX (user experience) (Gothelf, 2013); a Value Proposition Design (Osterwalder et al., 2014); and a Google Ventures (GV) research sprint (Margolis, 2019).

How does the conjecture map lead to the development of the design principles, these guiding underlying approaches to the research, to enable the research questions/conjectures to be explored and, if possible, eventually answered? This does not fully align with my study or my approach to teaching, learning, nor AgileDBR research. Conjecture Maps, for me, lack actionable transparency. This means the conjecture map does not allow me as a researcher to be able to know the processing and practices that led to these conjecture evolutions and be able to repeat it.

References

Bakker, A. (2018). Design research in education: a practical guide for early career researchers. Routledge.

Cohn, M. (2004). *User Stories Applied Book*. Mountain Goat Software. HTTPS://WWW.MOUNTAINGOATSOFTWARE.COM/BOOKS/USER-STORIES-APPLIED

Gothelf, J. (2013). Lean UX: Applying Lean Principles to Improve User Experience. O'Reilly Media, Inc.

Margolis, M. (2019, March 1). The GV research sprint: a 4-day process for answering important startup questions. *Medium*. HTTPS://LIBRARY.GV.COM/THE-GV-RESEARCH-SPRINT-A-4-DAY-PROCESS-FOR-ANSWERING-IMPORTANT-STARTUP-QUESTIONS-97279B532B25

Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A., Papadakos, T., & Smith, A. (2014). *Value Proposition Design: How to Create Products and Services Customers Want*. John Wiley & Sons, Incorporated. HTTP://EBOOKCENTRAL.PROQUEST.COM/LIB/CAM/DETAIL.ACTION?DOCID=1887760

Phillip, D. C., & Dolle, J. R. (2006). Why Design-Based Research Is Both Important and Difficult. 5.

Sandoval, W. (2014). Conjecture Mapping: An Approach to Systematic Educational Design Research. *The Journal of the Learning Sciences*, *23*(1), 18–36. HTTPS://DOI.ORG/10.1080/10508406.2013.778204

Sandoval, W. A., & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. *Educational Psychologist*, *39*(4), 199–201. HTTPS://DOI.ORG/10.1207/S15326985EP3904_1

Whitman, W. (2004). *Song of Myself Selections (1855 version)*. Project Gutenberg. HTTPS://WWW.GUTENBERG.ORG/EBOOKS/12718

Wu, J., & Chen, D. T. (2018). Refining conjecture mapping for design-based research.

4C Dot Voting

I did not use dot voting as one of the methods for this study but I have used this effective technique many times. There are many resources available for Dot Voting but I am sharing the Scaled Agiled Framework (SAFe) approach in line with the rest of the thesis.

Dot voting is a technique used in Agile approach to help groups make decisions. It's a straightforward and efficient method for prioritising solutions or ideas based on the preferences of a team or group of stakeholders. Dot voting involves giving team members a set of coloured dots (typically stickers) and asking them to arrange them next to the options they like. Each individual has a limited quantity of dots to use, which forces them to choose which options are most essential to them.

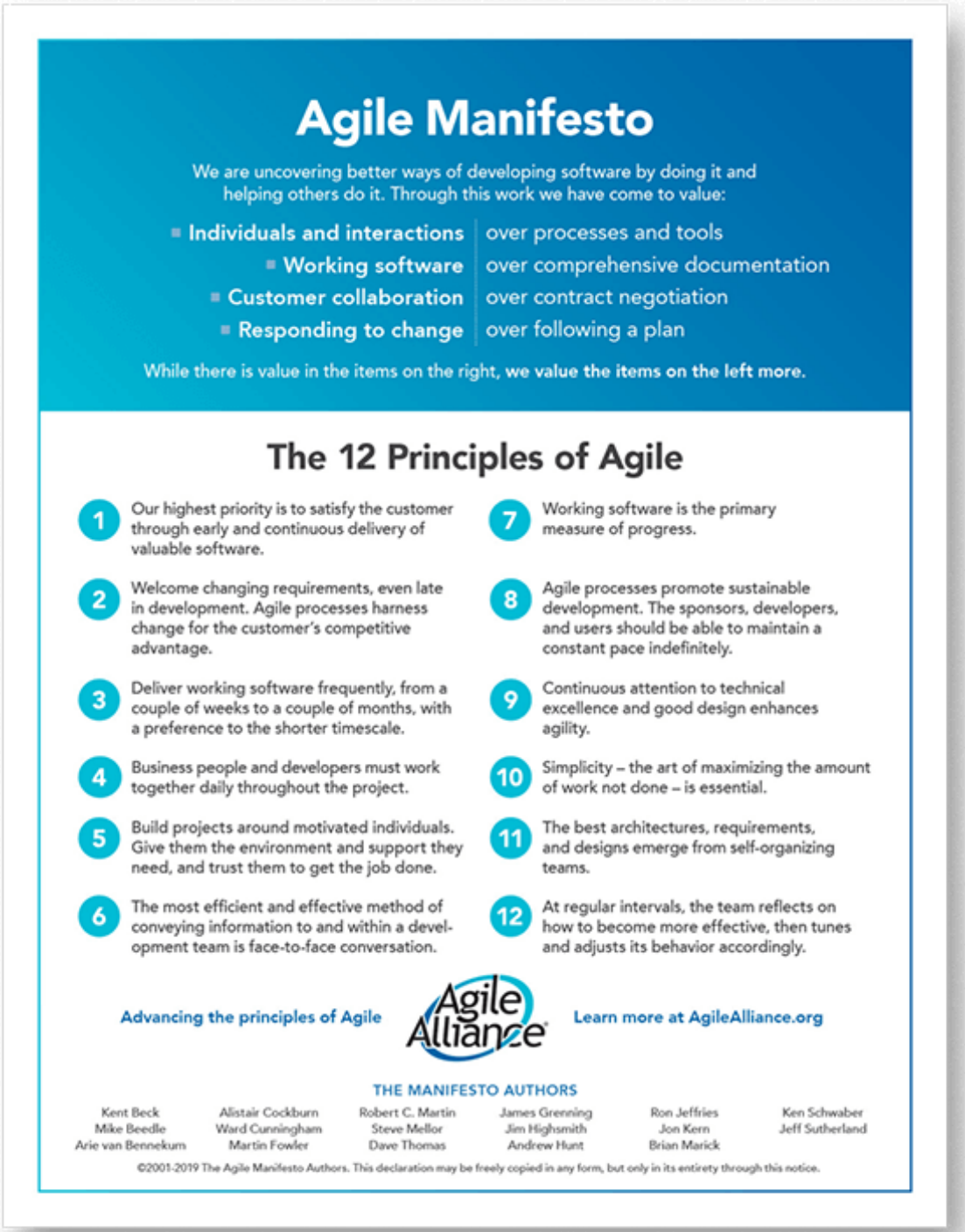
Figure 4C.1 Dot voting online and offline example

The dots are then counted, and the selections with the most dots are regarded to be the most popular or have the highest priority. This enables the group to swiftly discover areas of agreement and proceed with a shared understanding. Dot voting is often used during sprint planning, retrospective meetings, and other collaborative activities in Agile. It's a simple and transparent technique that encourages participation and empowers teams to make decisions together.

Reference:

SAFe® Collaborate Dot Voting FAQs (2021)
HTTPS://SUPPORT.SCALEDAGILE.COM/S/ARTICLE/COLLABORATE-DOT-VOTING-FAQS?LANGUAGE=EN_US

4D Agile Manifesto



Agile Manifesto

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

▪ **Individuals and interactions**	over processes and tools
▪ **Working software**	over comprehensive documentation
▪ **Customer collaboration**	over contract negotiation
▪ **Responding to change**	over following a plan

While there is value in the items on the right, **we value the items on the left more.**

The 12 Principles of Agile

1. Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
2. Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
3. Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4. Business people and developers must work together daily throughout the project.
5. Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
7. Working software is the primary measure of progress.
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
9. Continuous attention to technical excellence and good design enhances agility.
10. Simplicity – the art of maximizing the amount of work not done – is essential.
11. The best architectures, requirements, and designs emerge from self-organizing teams.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

Advancing the principles of Agile — Agile Alliance — Learn more at AgileAlliance.org

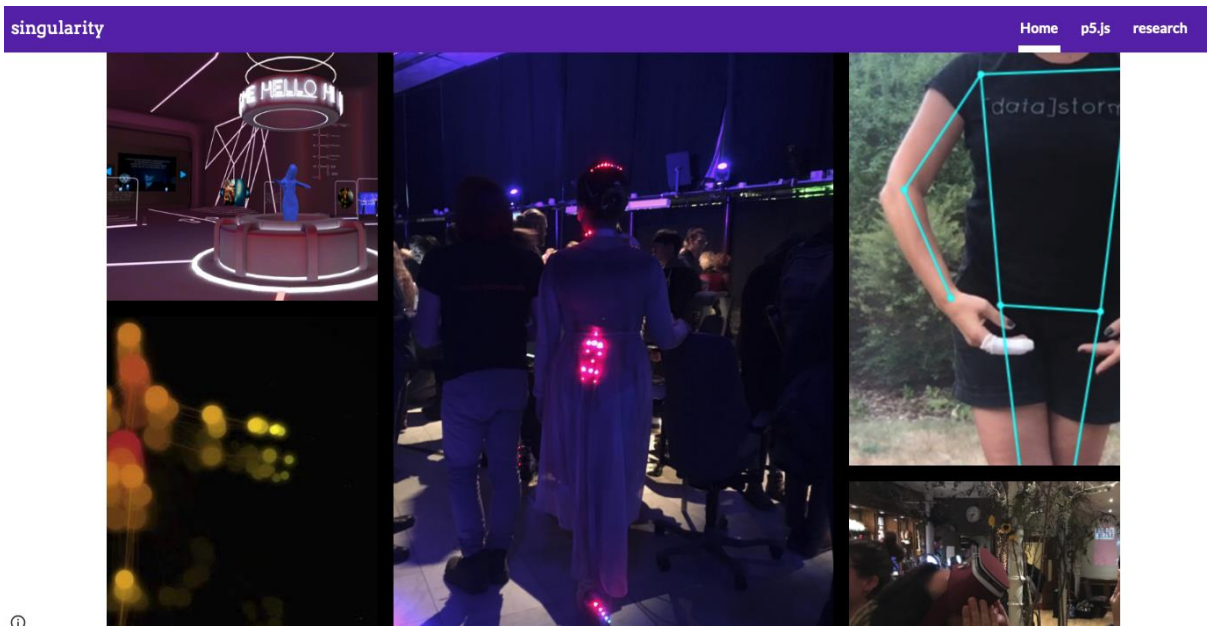
THE MANIFESTO AUTHORS

Kent Beck, Mike Beedle, Arie van Bennekum, Alistair Cockburn, Ward Cunningham, Martin Fowler, Robert C. Martin, Steve Mellor, Dave Thomas, James Grenning, Jim Highsmith, Andrew Hunt, Ron Jeffries, Jon Kern, Brian Marick, Ken Schwaber, Jeff Sutherland

©2001-2019 The Agile Manifesto Authors. This declaration may be freely copied in any form, but only in its entirety through this notice.

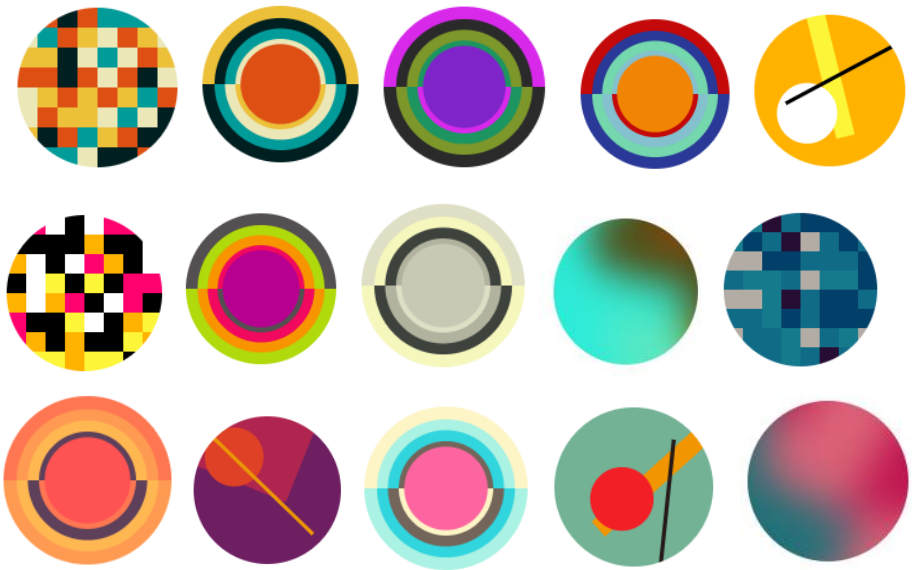
5A Minisite:

HTTPS://SITES.GOOGLE.COM/CAM.AC.UK/SINGULARITY/HOME



5B Boring Avatars (boringavatars.com)

Trainee Computing Teachers

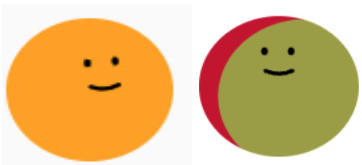


PGCE Leads

Technologist

Choreographer

Dancers



5C Consent Form

University of Cambridge
Faculty of Education

184 Hills Rd, Cambridge CB2 8PQ
Tel: +44(0) 01223 767600
Graduate@educ.cam.ac.uk www.educ.cam.ac.uk

UNIVERSITY OF CAMBRIDGE
Faculty of Education

Consent Form

Project Title: Raising awareness of data ethics in PGCE computing education using ballet and brainwave data as narrative tools - An AgileDBR approach.

I, the undersigned, have read and understood the participant information sheet about the study and have had the opportunity to ask questions and get satisfactory answers about the study. I understand that I have the right to withdraw from the study without any consequences at any point of the research. I also understand who will have access to information provided and what will happen to the data at the end of the study. I am aware that this study has been reviewed by and received ethics clearance through the University of Cambridge Faculty of Education Research Ethics Committee. If need be, I can find out more about this research study by contacting the researcher [email removed] or her supervisors at the faculty of education

Fully informed of my rights, I agree to participate in the study, carried out by Genevieve Smith-Nunes a full-time PhD student at the Faculty of Education, University of Cambridge.

Name: _____

Signature: _____

Date: _____

---------- For Researcher's Use Only----------

Name of researcher: Genevieve Smith-Nunes

Signature: _____

Date: _____

Consent for Biometrics: EEG and Video

For completion by participant Please tick one box only:

- I consent for video to be used for XR development and teaching but not for publication.
- I agree with the statement below:

I understand that the pictures have educational value. I consent to them being shown to relevant professional staff, used in educational publications, journals or textbooks. As a result, I realise that the general public may see them due to research dissemination. Efforts will be made to conceal my identity but full confidentiality is not guaranteed. However, once released I realise that recovery of the video may not be possible. I understand that no fee is payable by Genevieve Smith-Nunes or University of Cambridge, or any other person, in respect of the video, now or in the future. I confirm that the purposes for which the video could be used have been explained to me and that I have understood. Refusal to consent will not affect my participation in this study. I confirm that I give my informed consent for EEG and video recording.

Signature: ……

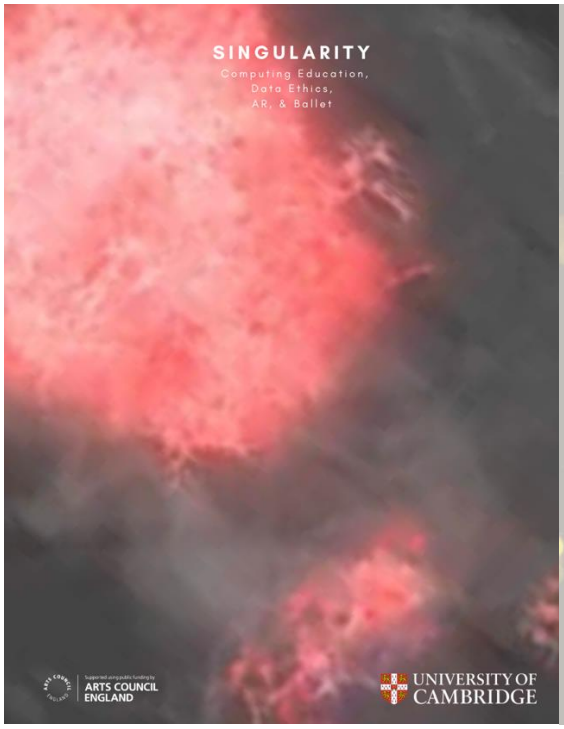
Date: ……...

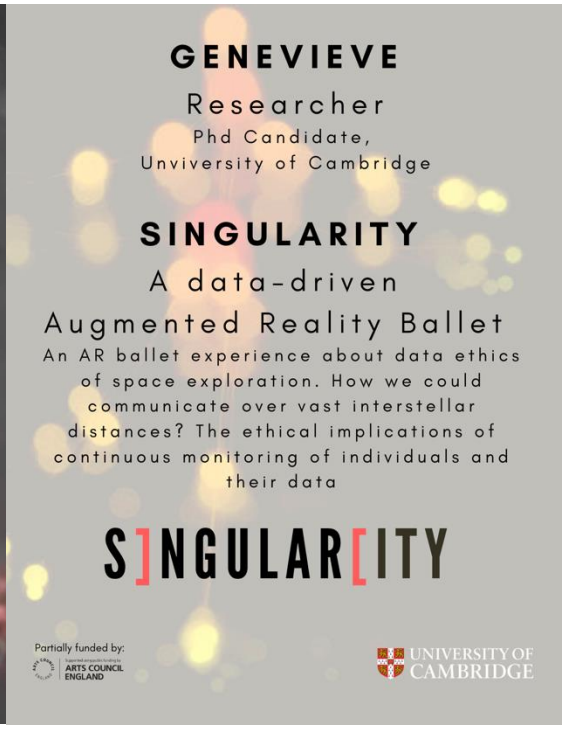
Modified from NHS patient consent for EEG studies.

https://www.cuh.nhs.uk/patient-information/scalp-telemetryvideo-eeg/

5D Participant Booklet

Link: https://www.canva.com/design/DAFbAkubhyA/9-APlADBhqnzFFJxY-vlsA/view?utm_content=DAFbAkubhyA&utm_campaign=designshare&utm_medium=link&utm_source=viewer





UNIVERSITY OF CAMBRIDGE

S]NGULAR[TY

RESEARCH

The Study: **Raising awareness of data ethics in PGCE computing education using ballet and brainwave data as narrative tools - An AgileDBR approach**

[Keywords: data ethics, education, creative computing, ballet, Agile]

Researcher: Genevieve Smith-Nunes
Supervisors: Prof Pam Burnard & Prof Rupert Wegerif

The purpose of the study is to explore through DBR and Agile how novel approaches to raise awareness of data ethics for computing education using biometric data as artefacts and classical ballet. Understand the participants' current approach to teaching computing, subject knowledge & programming competency, and engendered thinking of the field of computing, if any. The curriculum focus area is data transmission, signal processing, and data ethics from the pre-university examination board resources.

A series of workshops, studio practice, surveys, and interviews to collectively and collaboratively explore how to raise awareness of data ethics for computing PGCE students using biometrics and classical ballet.

RESEARCH CONT[NUED

UNIVERSITY OF CAMBRIDGE

Why have I been invited?
You have been invited to participate in this project because you are either:

- A trainee teacher (PGCE Computing)
- A Dancer who has had ballet training

What do I have to do?
This is voluntary participation in online workshops using your own computer/equipment via video conferencing tools such as MS Teams. Complete short online surveys and focus group interviews. All of which are voluntary. A training session for those using the EEG headset will be couriered to the participant. During this training process (circa 20 min), a demonstration of how to place the headset and adjust sensors to ensure a good connection. Followed by a demonstration of recording the data.

Consent
This is voluntary participation, and you can withdraw from the study at anytime. Your information will be used only for the purpose of this study. All data will be identified only by a code, anonymised, encoded, and known only to the researcher (Genevieve Smith-Nunes and her supervisors). Personal details are stored in a secure computer with access only by the immediate research team. The consent form is supplied with this information booklet, page 5.

RESEARCH CONT[NUED

UNIVERSITY OF CAMBRIDGE

Data Use & Storage

All data will be stored on a password-protected drive located at the University of Cambridge servers. The results of the research will be submitted as part of my thesis for a Doctorate in Education, and may appear in publications in academic materials such as books or journals. The findings from this research may also be adapted, published and shared amongst educational settings where children encounter technology.

You can ask the researcher to stop using your data or recordings for up to two weeks after the data collection period has concluded, using the contact details below, in which case it will not be used in future but may continue to appear in publications already in circulation.

Data Protection

GDPR. The General Data Protection Regulation (GDPR) operates in parallel to various other pieces of data protection legislation and updates, and expands people's rights to see, correct and, normally, delete personal data that is held by an organisation. Where data is required to be transported encryption and password protected software will be utilised, using University systems such as OneDrive.

RESEARCH CONT[NUED

UNIVERSITY OF CAMBRIDGE

With special regard to biometric data (EEG)

Electroencephalography (EEG) is a completely non-invasive functional imaging technique. Neural activity in human brains is associated with tiny electric currents that are recorded outside the human head by means of a number of electrodes touching to the scalp. EEG will be used to record, localize and characterize the highly dynamic neural activity of the brain. The recording of EEG, which reflects changes in electrical fields caused by the brain's activity, can be measured with electrodes that touch the scalp surface. The procedure of electrode placement is painless (though it might occasionally give rise to a slight feeling of discomfort due to the snug fit required by the wireless headset).

The headset is cleaned before and after each use. To improve signal detection application of the solution provided with the headset, applied to the headset sensors to. The data is recorded using Emotiv proprietary software then encrypted and stored. After the recording session the electrolyte solution may need to be removed from the hair, which is easily done by a hair wash. A typical recording session involves about 5 minutes for electrode application, followed by the recording session of 45 min to maximally 1 hour duration of shorter 5-10 minutes blocks. The participant will be carrying out a ballet class as part of the recording sessions.

RESEARCH CONT[NUED

UNIVERSITY OF CAMBRIDGE

Personal Data

The nature of personal data I will be collecting are responses to surveys, workshop interaction both voice and text, interviews and focus group tasks. The personal data collected will be contained only in the response sheets and will be stored securely and known only to the researcher. They will be anonymised. Please note, anonymous data cannot be withdrawn as the participant cannot be identified.

Are the possible disadvantages or risks in taking part?

A minor disadvantage due to the slight discomfort of wearing the EEG headset as it fits quite tight to the head.

Contact for further information

Should you have any further questions relating to the study, please contact me via email.

Contact Details

Genevieve Smith-Nunes:

The consent form is on the page. This is the information booklet. What follows in an explanation of some terminology and the technologies used in this study.

CONSENT FORM

UNIVERSITY OF CAMBRIDGE

University of Cambridge
Faculty of Education
184 Hills Rd, Cambridge CB2 8PQ
Tel: +44(0) 01223 767600
Graduate@educ.cam.ac.uk www.educ.cam.ac.uk

Project Title: Singularity - Raising awareness of data ethics in PGCE computing education using ballet and brainwave data as narrative tools - An AgileDBR approach

I, the undersigned, have read and understood the participant information sheet about the study and have had the opportunity to ask questions and get satisfactory answers about the study. I understand that I have the right to withdraw from the study without any consequences, at any point, on the research. I also understand who will have access to the information provided and what will happen to the data at the end of the study. I am aware that this study has been reviewed by and received ethics clearance through the University of Cambridge Faculty of Education Research Ethics Committee. If need be, I can find out more about this research study by contacting the researcher at ges52@cam.ac.uk or her supervisor at the faculty of education at rjwXX@cam.ac.uk

Fully informed of my rights, I agree to participate in the study, carried out by Genevieve Smith-Nunes, a full-time PhD student at the Faculty of Education, University of Cambridge.

Name: _____
Signature: _____
Date: _____

S]NGULAR[ITY

BIOMETRICS

- Skeleton Tracking
- Brainwave EEG data via Emotiv
- Unity 3D for AR build
- 3D assets created using Blender, Maya
- Music created using Brainwaves, Stellar Sounds & SonicPi
- Immersive Development by Glastonbridge Software

The term: biometrics
"The automated recognition of individuals based on their biological & behavioural characteristics".
ISO standards definition

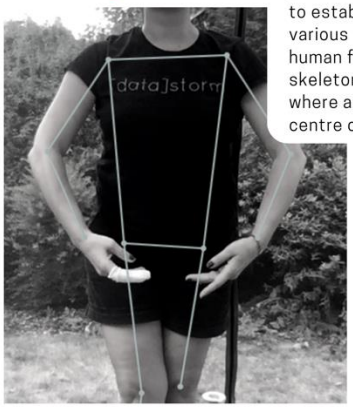
ARTS COUNCIL ENGLAND
UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

WHAT DO WE MEAN BY SKELETON TRACK]NG?

Skeleton & Biometric Data

Skeleton tracking is the processing of depth image data to establish the positions of various skeleton joints on a human form. For example, skeleton tracking determines where a user's head, hands, and centre of mass are.



ARTS COUNCIL ENGLAND
UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

POST POSE EST]MAT[ON?

Post (human) Pose Estimation (PPE) refers to computer vision techniques that detect human figures in images and video so that one could determine, for example, where someone's elbow shows up in an image.

This technology is not recognizing who is in an image — there is no personal identifiable information associated with pose detection. The algorithm is simply estimating where key body joints are. (Tensorflow, 2018)

ARTS COUNCIL ENGLAND
UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

WHAT DO WE MEAN BY BRA]NWAVES?

Brainwaves & Biometric Data

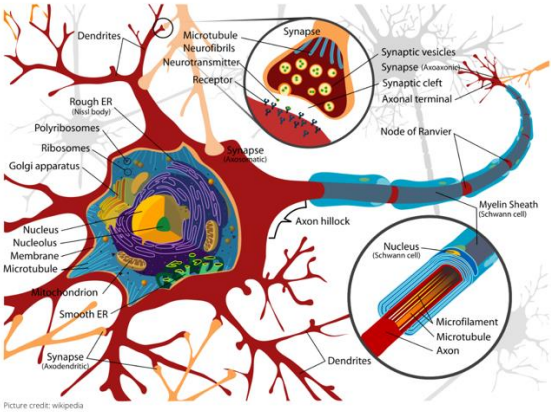
Brainwaves - the neural activity of a human brain is associated with tiny electric currents. This activity, electrical current, can be measured using electrodes that touch the scalp. The device used to record the EEG data is the wireless Emotiv InSight. This is a 5 channel EEG headset.

I would like to thank Emotiv for the support in this project

ARTS COUNCIL ENGLAND
UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

NEURONS



Picture credit: wikipedia

ARTS COUNCIL ENGLAND

UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

S]NGULAR[TY

AUGMENTED REAL]TY

AR - augmented reality. The following technology stake is being used to create the AR ballet

- Skeleton Tracking via MocapNET2 and our translation software captured through the use of 2D video.
- Brainwave data via Emotiv
- Unity 3D for AR build
- 3D assets created using Blender, Maya
- Brainwaves data sonification
- Immersive Development by Glastonbridge Software
- Partially Funded by Arts Council England

ARTS COUNCIL ENGLAND

UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

S]NGULAR[TY

3D MODELLING

AR development requires constructing 3D models of the dancers or actors that will appear in the AR experience. When 3D models are created for animation, they require careful construction because the polygon layout can create issues in unusual deformations. The models also require the construction of a skeleton and the painting of weights, which define the texture and polygon deformation of the model under movement.

- Unity 3D for AR build
- 3D assets created using Blender, Maya
- creating a simple proof of concept
- R&D cost funded by Arts Council England
- Bluposedancer.gtlf

ARTS COUNCIL ENGLAND

UNIVERSITY OF CAMBRIDGE

S]NGULAR[ITY

S]NGULAR[TY

DATA SONIFICATION

Making music with data using programming languages such as Python and P5.js. Data sonification is the presentation of data as sound using sonification. It is the auditory equivalent of the more established practice of data visualisation. The data is generated by dancer movements from the motion capture. Additionally, the brainwaves which are output to CSV files and read by the computer programs to generate musics depending on algorithmic designs.

ARTS COUNCIL ENGLAND

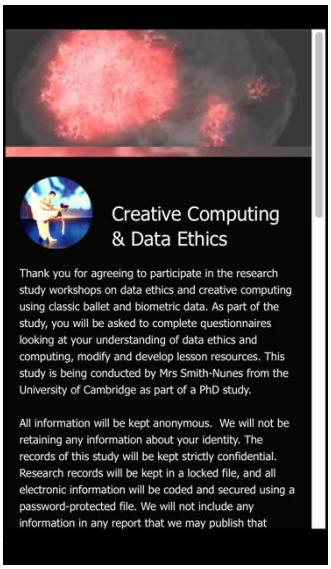
UNIVERSITY OF CAMBRIDGE

5E Questionnaire

HTTPS://FORMS.OFFICE.COM/R/5TCSBENFFJ

- Microsoft Forms

The questionnaire was designed in conjunction with one of the PGCE leads and share for review with 8 other K12 IT/Computing teachers. The use of emojis had already been tested as part of the Pilot study. See appendix 6A for pilot study

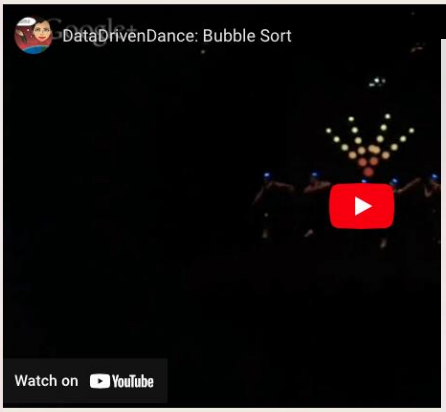


Creative Computing & Data Ethics ...

Data Driven Dance - creative computing

1

What do you think about this video clip? Have you seen this clip before?



Enter your answer

2

How do you think this ballet video relates to the computing curriculum?

Enter your answer

3

What is your current competency in the following areas:

	poor	fair	good	Very good	Exceptional
Data ethics	○	○	○	○	○
data transmission	○	○	○	○	○
programming pedagogies	○	○	○	○	○
Innovation in approaches to classroom delivery	○	○	○	○	○
Delivering lessons which address issues surrounding engendered subjects	○	○	○	○	○
Cross curricular lesson design	○	○	○	○	○

Back Next

Creative Computing & Data Ethics ...

Computing & Pedagogy

4

How could you use the ballet video in your computing classroom?

Enter your answer

5

How does classical ballet align with computing?

Enter your answer

6

What cross-curricular approaches could be used with ballet as a programming pedagogy?

Enter your answer

7

What challenges are there with this approach? Using ballet and biometrics in a computing classroom

Enter your answer

8

How is data ethics important in the computing classroom?

Enter your answer

9

Have you seen or taught any data ethics activities or lessons during your PGCE

Enter your answer

10

What activities have you seen, used or created during your PGCE for teaching data transmission/signal processing?

Enter your answer

Back Next

11

End of session confidence in content, pedagogical, and technical knowledge relating to DDD and data ethics

	poor	fair	good	very good	exceptional
I can plan data ethics activities for students	○	○	○	○	○
I can plan, using dance (ballet as a classroom tool) for computing concepts on: data transmission / signal processing, data ethics	○	○	○	○	○
I can integrate the technology, theory, and arts practice to enhance my teaching practice (content and approaches	○	○	○	○	○
I can enable students through dance and digital tools (Motion capture, data sonification, AR development) as ways of presenting their knowledge (data ethics) in different forms	○	○	○	○	○

5F Interview Schedules

PGCE Lead

Opening (To establish rapport)

1. Opening

A. (Establish Rapport) [smile, look at camera lens not participant on screen] My name is _____ and who I am

B. (Purpose) I would like to ask you some questions about data-ethics, the use of dance, in relation to computing ITT

C. (Motivation) I hope to use this information to help develop materials to cover data-ethics and creative approaches to computing ITT.

D. (Timeline) The interview should take about 40-50 minutes. Are you available to respond to some questions at this time? And are you OK for this to be recorded (verbal consent)

*optional and further questions if required

Transition:

A general introductory question, asking how they are doing.

Transition:

2. General Computing ITT

- How do the teaching standards play a role in the design of the ITT programme?
    - Are there any areas you can't cover, due to this?*
- What current challenges do you face in designing and delivering the curriculum content for your ITT computing program?

3. Data-ethics

- How is data-ethics, as a topic, incorporated in the ITT programme, if at all?
    - Do you see data-ethics as important for your students?
        - How and why is it important or not *
    - What barriers are there in delivering data-ethics?
- How did the biometric data use (P5.js skeleton tracking and brainwave visualisation) connect with your understanding of data-ethics?

4. Creativity in computing

- How does creativity and or creative pedagogies feature on your ITT programme?
    - What does it look like*
- Does dance feature on your ITT programme?*
    - How?

5. DataDrivenDance

- In what way did watching the ballet clip generate links to the computing curriculum?

- How do you think DataDrivenDance illuminates the issues surrounding data-ethics?

6 Closing

- (Summarise) *general overview of the interview in a sentence or two*
- (Maintain Rapport) 'I appreciate the time you took for this interview.
  Is there anything else you think would be helpful for me to know about data-ethics and dance that might be useful?'
- (Action to be taken) 'I should have all the information I need.
  Would it be alright to contact you if I have any more questions? Thank you all for your time and participation'.

DANCERS:

Questions during/following biometric capture and development of prototype:

1) Is there a difference in sense of self (identity) between the human and the virtual?

2) How does sharing your personal biometric data make you feel?

   a) Are there any differences between Movement and Brain data?*

3) How can biometric and immersive development tools be used in the computing classroom and dance studios to raise awareness of data-ethics?

5G Data Analysis Planning Tables

The data analysis planning tables and headings are taken from Data Analysis Planning Matrix (tables 2-4) taken from NSF research support project (WMU, 2017), a series of tables relating to each research question with who, what, when, and how elements under the following headings: indicator, data source & methods, increment/cohort, timing, analysis, and implication. The tables highlight the overall plan for each RQ, the term indication is used a conjecture in DBR. I kept the terminology from the original form for consistency with the WMU original design. This study uses an agile, iterative approach therefore each increment (iteration) will build upon the last.

Table 1: *RQ1* data analysis plan including sub questions.

Evaluation Question:

RQ1 How to raise awareness of Data Ethics?

Indicator Sub Question	**Data Source & Methods**	**Increment Cohort**	**Timing**	**Analysis**	**Interpretation**	**KEY**
In what ways is data ethics important for the computing classrooms? How participants define data ethics?	questionnaire Semi structure group interview		increment 1 sprint 1 increment 1 sprint 1, 2	An integrated data analysis approach that used both qualitative & quantitative statements together generated from participants via anonymous questionnaire. Quantitative analysis of survey data to determine difference (if there is any), correlation between participants and at each sprint stage. Looking at the data in multiple ways, or perspectives.	Identify which, if any, factors have been influenced by the intervention. Note down changes in definitions over time.	1-2-1 INTERVIEW GROUP INTERVIEW CODING ARTICLE MS LEARN COURSE BALLET VIDEO QUESTIONNAIRE EEG VISUALISATION VIDEO PPE MODEL / FRAMEVR
In what ways does the intervention demonstrate raised awareness of data through DDD with this cohort?	Semi structure group interview Observation via video		Education: increment 2 & 3 Dancer Increment 1, 3	Group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference Videos used for recall and input for generating 3d models (at this stage of the design)	Interpretative Phenomenological analysis (Smith, et al., 2022) to explore subjective viewpoints (Flick, 2009) examining the ways that people make meaning out of their experiences.	
How the participants engaged with the EEG data to explore ethics	Data interaction	Discussion of EEG data using visualisation and EEG articles	Education: increment 3 Dancer Increment 3	Participant response (chat, voice) using the biometric dataset from the dancers coupled with dancer stories	Identify common factors, if any, influenced by the intervention.	Dance Technologist Education
How to dancers view their body as a data artefact?	biometric skeleton tracking data – creating the 3d avatars		Post with visual prompt of the EEG data and 3d models	Dancers responses to data capture during and after sessions. Transcripts from rehearsals and Retrospectives	How has the dancer's understanding of data ethics changed over time? Including the use of their own body as data artefacts?	
How do the avatars (3d models) influence your view of: 1.Computing? 2.data ethics?	Semi structure group interview Artefacts/Video		Increment 3	*Edu* VR voice a variant of photo voice as part of the group interview 1-2-1 IPA interview additionally addressing the intervention & materials *Dancers* VR voice a variant of photo voice as part of the group interview	Area for development: HCI avatar analysis (most studies are quants based)	

Table 2: RQ2 data analysis plan including sub questions.

Evaluation Question:

RQ2 What new insights and unexplored approaches are there in combining classical ballet and biometrics data to broaden participation in computing education?

Indicator Sub Question	Data Source & Methods	Increment Cohort	Timing	Analysis	Interpretation	KEY
What did watching the ballet performance adds to your (teachers) understanding of teaching computing?			Edu session 1	An integrated data analysis approach that used both qualitative & quantitative statements together generated from student participants via anonymous questionnaire. Voice (transcript) and text data analysed using NPL during fieldwork. Post fieldwork phase reanalysed using IPA for in-depth analysis. Test Learn Cards	Crafting Mixed-Option Evaluation Designs by Caracelli & Green (1997) Interpretative Phenomenological analysis (Smith, et al., 2009, 2022; Smith & Nizza, 2022) designing mixed methods research by Creswell, Fetters, Ivankova (2004).	1-2-1 INTERVIEW GROUP INTERVIEW CODING ARTICLE MS LEARN COURSE BALLET VIDEO QUESTIONNAIRE EEG VISUALISATION VIDEO PPE MODEL / FRAMEVR
How can ballet be used in the computing classroom as a pedagogical tool			Increment 1, 3	Focus group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference Artefact from participants use in their own classroom Videos used for recall and input for generating 3d models (at this stage of the design) Test Learn Cards	How the participants used this is their own teaching practice. What	
How does this approach to ballet, choreography, and technology compare with the dancers/ choreographer's previous experience?			Each sprint: Observation after re-watching the recording	Observation via video (researcher) Test Learn Cards	Semi- structure interviews – thematical analysis- what they are saying. How this changes over time	
In what ways has DDD had on the participants experience and confidence levels when working with technology for dance.			Increment 1,2, & 3	Thematic Focus group: the variety of different perspectives and experiences that participants reveal during their interactive discussion. Focus of consensus or difference. IPA interview analysis: 1-2-1: How do the choreographer and Program lead view the intervention in relation to the role as "educator" Test Learn Cards	Comparison of confidence levels over each iteration. Dancer participants potential independent use of the technology in the future.	Dance Technologist Education

Table 3: RQ3 data analysis plan including sub questions.

Evaluation Question:

RQ3 Is (and how) AgileDBR as an effective methodological approach for educational academic research?

Indicator	Data Source & Methods	INCREMENT	Timing	Analysis	Interpretation
In what ways does AgileDBR support answering this, specifically the iterative implementation and analysis	Sprint planning boards Retrospectives	All on going for each cohort	Jan, 2021 Jan- June 2021 June- Aug 2021	Documentation analysis from sprint planning board, RoR, and researchers journal to gain insights into how it works primarily by comparing the first iteration with re-versioned iterations.	Develop a narrative of the Agile DBR methodology. Develop an 'interpretation' of these insights in the discussion section bringing out the narrative analysis highlighting what has been learnt.
Which theories scaffold this transdisciplinary project in the development of AgileDBR	Sprint planning boards Retrospectives Theory map	A start and end of sprints	Jan 2021 Mar- June 2021 May-Aug 2021	Theory mapping to each element – how the theory helped improve the iterative design, implementation, and evaluation of the methodology	The potential of AgileDBR as methodology for novice DBR researchers
AgileDBR aids the knowledge generation process of research?	Researcher's journal. Observations	End of each increment	Jan 2021 Mar- June 2021 May-Aug 2021	Researchers journal Sprint planning boards & Retrospectives highlight changes and developments between increments.	Highlight potential and iterate any improvements of AgileDBR as methodology for novice DBR researchers

Reference:

WMU Western Michigan University (2017) Data Collection Planning Matrix - EvaluATE. Retrieved 8 January 2021, from HTTPS://WWW.EVALU-ATE.ORG/LIBRARY/DATA/PLANNING-MATRIX/

5H Questionnaire Statistical Tests

This is the planning document I used to help with analysing the questionnaire data from initially the pilot and the main study. All questions were optional.

Variable name	characteristic
gender	Nominal scale with 7. Participant free form entry re-coded. This will take longer but allows the participant to self-define.
Degree disciple?	Nominal scale with 4 options (CS, other maths/science, arts, other)
Age	Continuous variable

Variable name within Q	Scale/ Range	Categories for analysis
What is your current competency the concept of data-ethics	Ordinal 1- 5	From 1 'poor' to 5 exceptional (a full understanding or ability)
What is your current competency of the concept of data transmission	Ordinal 1- 5	From 1 'poor' to 5 exceptional (a full understanding or ability)
What is your current competency of programming pedagogies	Ordinal 1- 5	From 1 'poor' to 5 exceptional (a full understanding or ability)
What is your current competency of delivering lessons which address issues surrounding engendered subjects.	Ordinal 1- 5 (this has already been covered by the research site. PGCE lead suggested this question be included)	From 1 'poor' to 5 exceptional (a full understanding or ability)

Questions (questionnaire 1)	Test
What do you think about this video clip? Have you seen this clip before?	Video elicitation thematic analysis - coding leading to constant comparison of subsequent workshop data generation (Charmaz constructivist grounded theory approach)
How do you think this ballet video relates to the computing curriculum?	Video elicitation thematic analysis - coding leading to constant comparison of subsequent workshop data generation (IPA, Smith, Larkin, Flowers, 2021)
What is your current competency of the following areas: data-ethics Data transmission Programming pedagogies Lesson delivery, engendered subjects	**Chi Squared** tests for all four independent variables and three dependent variables. **Mann Whitney U-Test**, Differences by gender with respect to dependent variables OR don't if not relevant. **Kruskal Wallis Test**, Differences by gender with respect to dependent variables

How could you use the ballet video in your computing classroom?	**thematic** analysis - coding leading to constant comparison of subsequent workshop data generation (IPA, Smith, Larkin, Flowers, 2021)
How does classical ballet align with computing?	**thematic** analysis - coding leading to constant comparison of subsequent workshop data generation (IPA, Smith, Larkin, Flowers, 2021)
What cross-curricular approaches could be used with ballet as a programming pedagogy?	**thematic** analysis - coding leading to constant comparison of subsequent workshop data generation (IPA, Smith, Larkin, Flowers, 2021)
Participant Details: age, gender	Parametric tests (If participants provided data) Gender with respect to Q3 **Kruskal Wallis Test**, comparison of gender codes to: data-ethics Data transmission Programming pedagogies Lesson delivery, engendered subjects
What discipline is your degree in, prior to starting your PGCE? Computer Science / Computing other Maths / Science Arts other	Degree discipline with respect to Q3 **Mann Whitney U-Tes**t, comparison of computer science and NOT computer science. **Mann Whitney U-Test,** comparison of other maths/science and NOT Other maths/science. **Mann Whitney U-Test**, comparison of Arts and NOT arts **Mann Whitney U-Test**, comparison of All other disciplines and NO other disciplines.
Any extra comments or thoughts you would like to add	**thematic analysis** - coding leading to constant comparison of subsequent workshop data generation (Charmaz constructivist grounded theory approach)

5I Natural Language Processing (NLP)

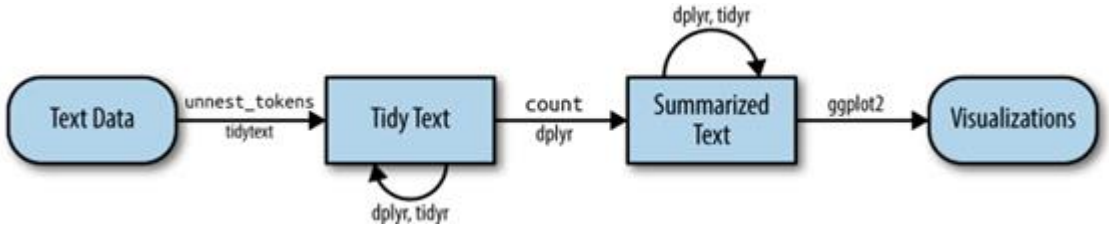
This study employed NLP with various stemming technique, via a python programming library NLTK natural language toolkit (nltk.org). The selection of python over R was purposeful, as this enabled me to carry out my research along with be enabling to share these techniques to trainee computing teachers. By providing access to different use-cases for python programming for the trainee computing was a considering factor in the choice of language and packages. What follows is a deeper overview of the NLP used in this study.

The NLP package NLTK incorporates WordNet as part of the software package. WordNet is a 'large lexical database of English. Nouns, verbs, adjectives, and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept' (Fellbaum, 1998). This programming technique is how many lexicon analysis software applications work behind the user-interface. The keywords are compared to mitigate bias/subjectivity from the researcher conducting the interview.

Keyword density or frequency analysis uses lemmatisation and stemming techniques to generate the keywords. The keywords are then compared to the themes generated by the researcher during the interview process. Lemmatisation takes into consideration the morphological analysis of the words. It is necessary to have detailed dictionaries that the algorithm can look through to link the form back to its 'lemma'. For example, using the following words, 'studies, studying, studies', would produce the following: the present tense singular verb form of study/studying would produce the gerund verb form of the study (Fellbaum, 1998). Stemming uses an algorithm that removes conjunctive words from the data and then reduces all the text to their root form (for example, thinking is reduced to think).

Treating text as data frames of individual words allows us to manipulate, summarise and visualise the characteristics of text easily and integrate NLP into the effective workflows we have already been using (Silge and Robinson, 2017).

Figure 5F.1. A flowchart of a typical text analysis using tidy data principles.



Data structures for analysis and storage, specifically within text mining, are important for understanding that different data structures adhere to different principles and toolsets that are used for analysis. The ‘tidy data’ structure, as used in figure x above, is a table with one token per row. A token is a meaningful unit of text, such as a word, which is part of the research data for analysis, and ‘tokenisation’ is the process of splitting text into tokens. Structuring text data in this way means that it conforms to tidy data principles and can be manipulated with a set of consistent tools for this data structure.

Alternatives are available: ‘String’ is stored as strings (i.e., character vectors); Corpus: raw strings annotated with additional metadata and details; and Document matrix: a sparse matrix describing a collection of documents with one row for each document and one column for each term (frequency analysis or specific count). Process: Text is put into a data frame (table, spreadsheet, or another format). This allows sentences to be put on each row and text mining works are the word level from a data structure perspective. From this, we break down the text into its component parts, and this is turned into a tidy data structure token: A token is a meaningful unit of text, most often a word, that we are interested in using for further analysis, and tokenisation is the process of splitting text into tokens.

Through explaining how the python package worked and providing sample code and data gave the trainee computing teachers new ways to explore python in their computing classroom while being mindful of the ethical implications of analysing data. The next two pages show the code files shared with participants.

NLP code that reads in a text file

NLP python code using NLTK package.
Token Test:

```
import nltk

from pprint import pprint
stopwords = nltk.corpus.stopwords.words('english')

#reads external file
f = open(' [add text file name here]', 'r')
text = f.read()

#tokenize text
words: list[str] = nltk.word_tokenize(text)

#remove stopwords and punctuation
words = [w for w in words if w.lower() not in stopwords and w.isalpha()]

# caluclates frequency distribution
fd = nltk.FreqDist(words)

#prints 4 most common words
print(fd.most_common(6))

#prints 4 most common words in a table
print(fd.tabulate(6))

# concordance is a collection of word locations along with their context
concol = nltk.Text(words)
concol.concordance('know', lines=3)

# collocations are series of words that frequently appear together in a given text
finder = nltk.collocations.BigramCollocationFinder.from_words(concol)
finder.ngram_fd.tabulate(3)

# collocations are series of words that frequently appear together in a given text
finder = nltk.collocations.TrigramCollocationFinder.from_words(concol)
finder.ngram_fd.tabulate(3)

# collocations are series of words that frequently appear together in a given text
finder = nltk.collocations.QuadgramCollocationFinder.from_words(concol)
finder.ngram_fd.tabulate(3)

#most common collocations
print('Most Common Collocations')
finder.ngram_fd.tabulate(3)
```

Sentiment Test:

```
import nltk

#Sentiment intensity analyzer object
from nltk.sentiment import SentimentIntensityAnalyzer
sia = SentimentIntensityAnalyzer()

stopwords = nltk.corpus.stopwords.words('english')

#reads external file: sample text
f = open('[add text file name here]', 'r')
text = f.read()

# positive or negative sentiment based on compound score
def is_positive(transcript: str) -> bool:
    '''True if transcript has positive compound sentiment, False otherwise.'''
    return sia.polarity_scores(transcript)['compound'] > 0

print('Is this text positive?', is_positive(text))

from statistics import mean

def is_senpos(transcript: str) -> bool:
    '''True if the average of all sentence compound scores is positive.'''
    scores = [
        sia.polarity_scores(sentence)['compound']
        for sentence in nltk.sent_tokenize(transcript)
    ]
    return mean(scores) > 0

def per_senpos(transcript: str) -> float:
    '''True if the average of all sentence compound scores is positive.'''
    scores = [
        sia.polarity_scores(sentence)['compound']
        for sentence in nltk.sent_tokenize(transcript)
    ]

    posen = 0
    for score in scores:
        if score > 0:
            posen += 1
    return posen / len(scores)

print('Percent?', F'{per_senpos(text):.2%}')

print('Are the majority of sentences positive?', is_senpos(text))
```

Reference

Fellbaum, C. (1998). A Semantic Network of English: The Mother of All WordNets. *Computers and the Humanities*, *32*(2), 209–220. HTTPS://DOI.ORG/10.1023/A:1001181927857

Silge, J., & Robinson, D. (2017). *The Tidy Text Format* (1st ed.). O'Reilly Media Inc. HTTPS://LEARNING.OREILLY.COM/LIBRARY/VIEW/TEXT-MINING-WITH/9781491981641/CH01.HTML

5J EEG Protocols

EEG recording has been used safely for many years. I am aware of no cases of adverse events. The headset was wireless, which removed any potential risk of injury that accompanies wired headsets. Headsets were only worn for short durations of time – less than 30mins – for each recording session. The headsets were cleaned using a medical wipe pre and post each use. Again, the main way to avoid risk is to adhere to a regime of hygiene. Hands were washed after any contact with the scalp of a participant and pre/post headset handling. Participants were asked to wash their hair, if possible, and it was explained that this aids in signal processing and recoding. During the recording session, participants were asked to indicate if they felt any discomfort, in which case the procedure was stopped. It was possible to pause the procedure if a participant needed to take a break or visit the bathroom, or for another reason, such as if the participant was in place when a fire alarm went off or in a similar situation.

The EEG (electroencephalogram) is a technique that enables the monitoring of real-time brain activity during cognitive tasks. This method involves the direct measurement of electrical voltage signals from the brain using sensors (electrodes) placed on the scalp. The EMOTIV Insight headset, a wireless EEG device that uses 5 channels, is used to record raw EEG data. The headset is guided by a mobile app or desktop software, allowing participants to adjust sensor placement until all position graphics indicate green, indicating proper positioning and sufficient signal strength. Unlike other techniques, the EEG does not require physical contact with the scalp.

To ensure participant confidentiality and anonymity, data were averaged together from multiple EEG recordings following specific events. This averaging procedure eliminates spurious signals (artefacts) from random electrical noise and ongoing mental activity unrelated to the event of interest and reinforces the consistent brain activity associated with the analysis of the event. Artefacts such as blinking and facial muscle movements can be separated from the EEG signals during post-processing. The resulting averaged waveform is called an ‘event-related brain potential’ (ERP) and is advantageous for studying cognitive functions and their neural bases. ERPs provide a direct measure of brain activity in real-time without requiring overt behavioural responses. This is particularly valuable for investigating cognitive functions such as perception, attention and language processing.

Reference:

NeurotechX *EEG Experimental Protocol*. (n.d.). NeurotechEDU. Retrieved 28 March 2023, from HTTP://LEARN.NEUROTECHEDU.COM/EEGEXPERIMENTALPROTOCOL/

6A Literature & Pilot findings

Figure 6A.1 DALLE-2 AI generated image with prompt ‘literature, education, computers, computing’.

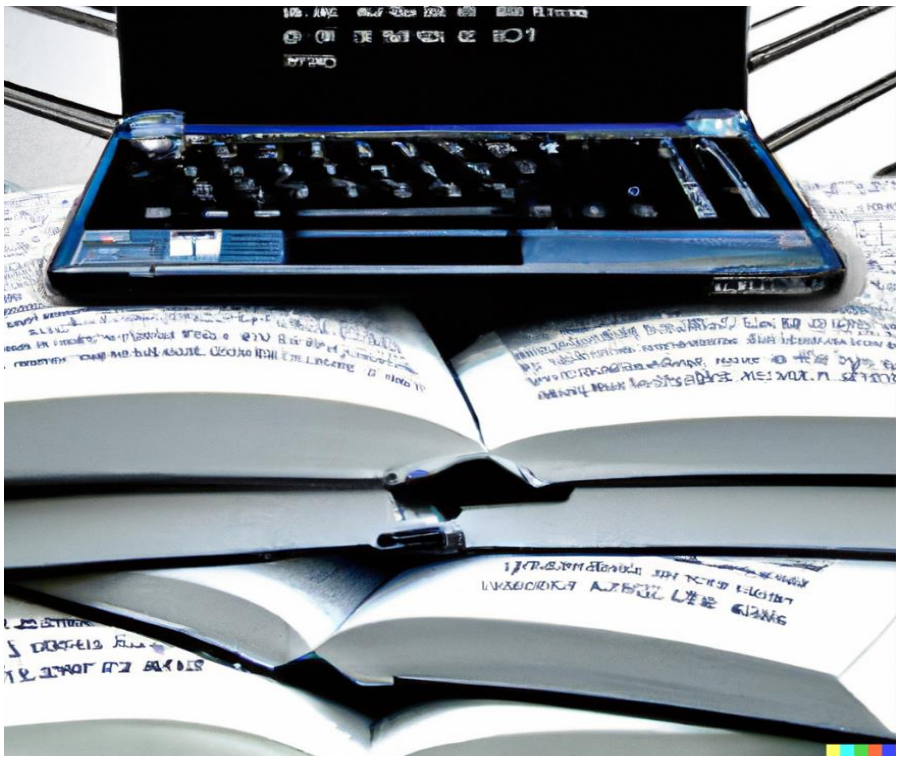


Figure 6a.1 generated from prompt ‘literature, education, computers, computing’ was the closest representation of the literature and pilot increment, particularly in the way the text looks like an alien language with two meanings as (i) many feel code is alien when first learning a programming language, and (ii) data-ethics as a topic for computing education is new and not fully accessible to all.

Below is an expanded discussion of the how the literature and pilot study occurred, in line with my AgileDBR methodology. As previously outlined, the literature review, chapter 2, is discussed in three parts: Components, Context, and Theory & Research Ethics. Each part was explored to develop the research questions/conjectures. The literature review was a continuous process, built into to each stage of the study from the 12-week Increments -macro level, to the one-four weeks Sprint -micro level.

Figure 6A.2 Literature review and pilot increment.

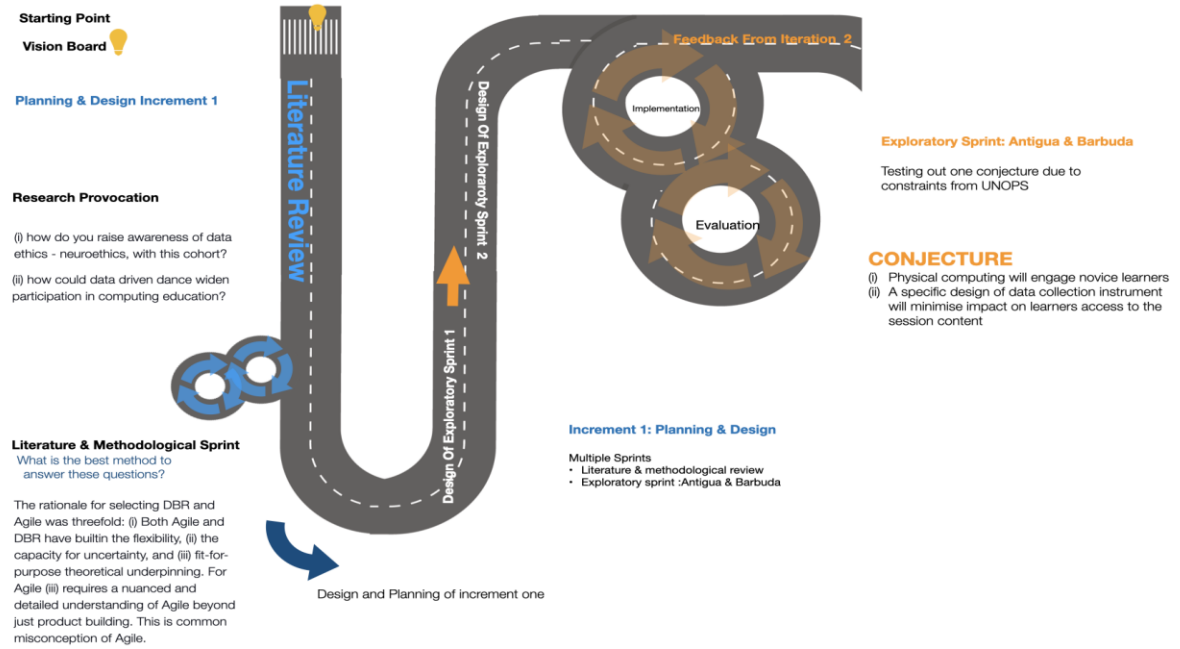


Figure 6A.2 illustrates the cyclic journey of increment one, the initial in-depth literature review and the development, design, and conjectures for the pilot study.

The literature review was achieved iteratively using keyword searches and then visualised to capture the connections between literature, including expanded searches. Online freemium tools, such as litmaps.com or connectedpapers.com, were used. However, this can also be achieved using python and textmining tools with literature databases, for example, Techminer (Velásquez-Henao, J.D, 2021). The visualisation helped me to see which papers I had incorporated and how they were connected, alongside extended searches showing addition related literature. The example below illustrates this process using a small sample of papers, although this study used considerably more papers.

Figure 6a.4 illustrates the Litmap online tool using only 14 papers for simplicity. This highlights the connection between 14 papers, on DBR, with each paper as a blue node and the connection shown by the faint grey lines. Figure 6a2 explores additional papers generated by the software, as shown by the grey icon. Figure 6a3 adds more connection through keyword searches to extend the visualisation and literature mapping even further. Again this technique was shared with the trainee computer teachers as an additional educational resource.

Figure 6A.3 Litmap visualisation of DBR principal papers.

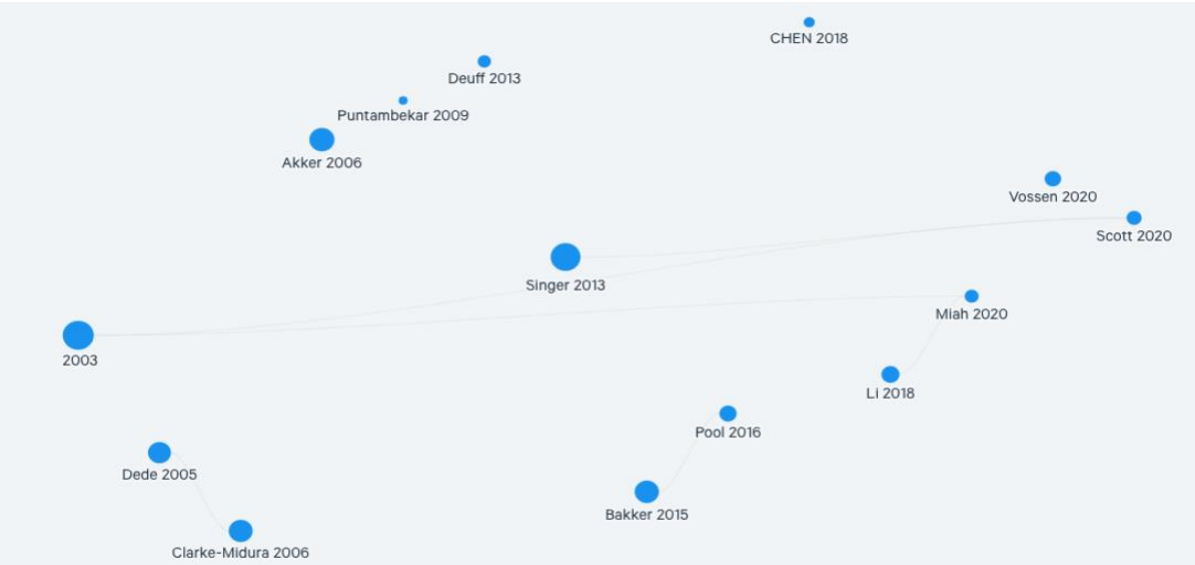


Figure 6A.4 with additional papers generated but the software.

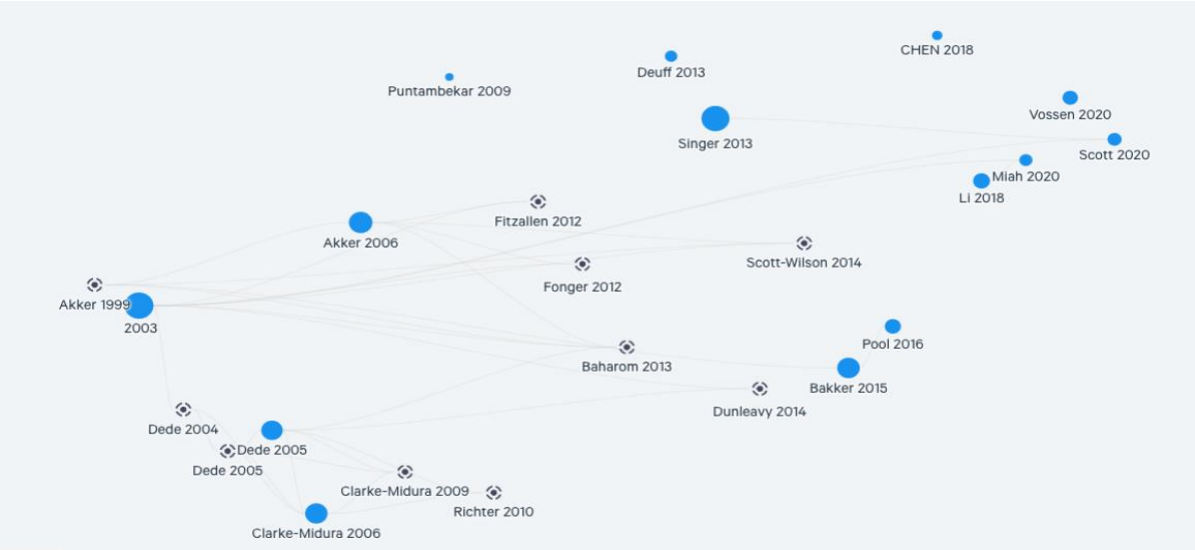
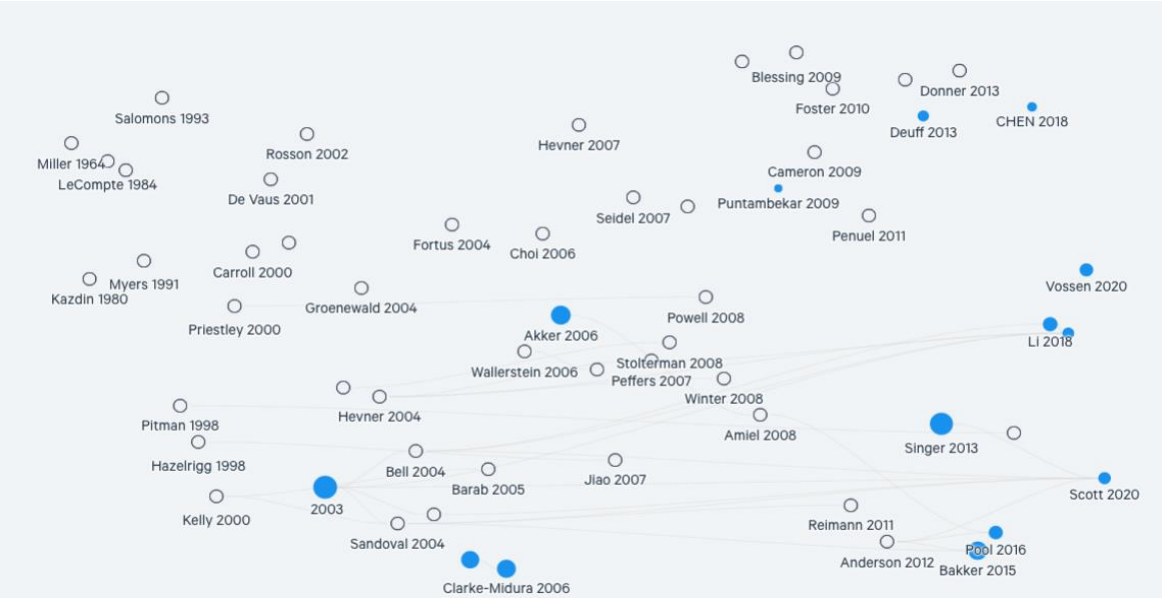


Figure 6A.5 with additional paper and keyword search ‘design-based research’.



This meshwork enabled both an expanded and refined review of the literature. Further, the processes added several papers to the review that I may not have discovered using traditional methods. This analysis was performed as part of the ‘inspect and adapt’ phase for all increments/iterations.

The following section covers the Pilot Study data analysis within the pre-Covid context. Conducted face-to-face but, inevitably, not all elements of this pilot were carried over into the main study due to covid restrictions. Note: The Pilot site was part of the original study which included Antigua & Barbuda, Dublin, and England. Due to Covid restrictions all sites bar England had to be removed.

6a.1 Pilot

The pilot was carried out in January 2020, pre pandemic restrictions. The purpose of the pilot was to test the questionnaire as a tool for data collection. Additionally, aimed to provide student and educators with physical computing and coding workshops/resources (see Figure 7.7) for teaching computing. Note comparable computing education in Antigua and Barbuda doesn’t start until Grade 10. This puts Antigua & Barbuda students at a disadvantage when solving problems with computers that potentially impacts the region as a whole.

The pilot study's specific literature addressed not just computing education, physical computing instructional tools, and studies, but also Caribbean education, including the difficulties of island education and the challenges of post-hurricane education. This collection of literature tackles the principles of connectivity and power difficulties in general for island schooling, as well as emergency situations.

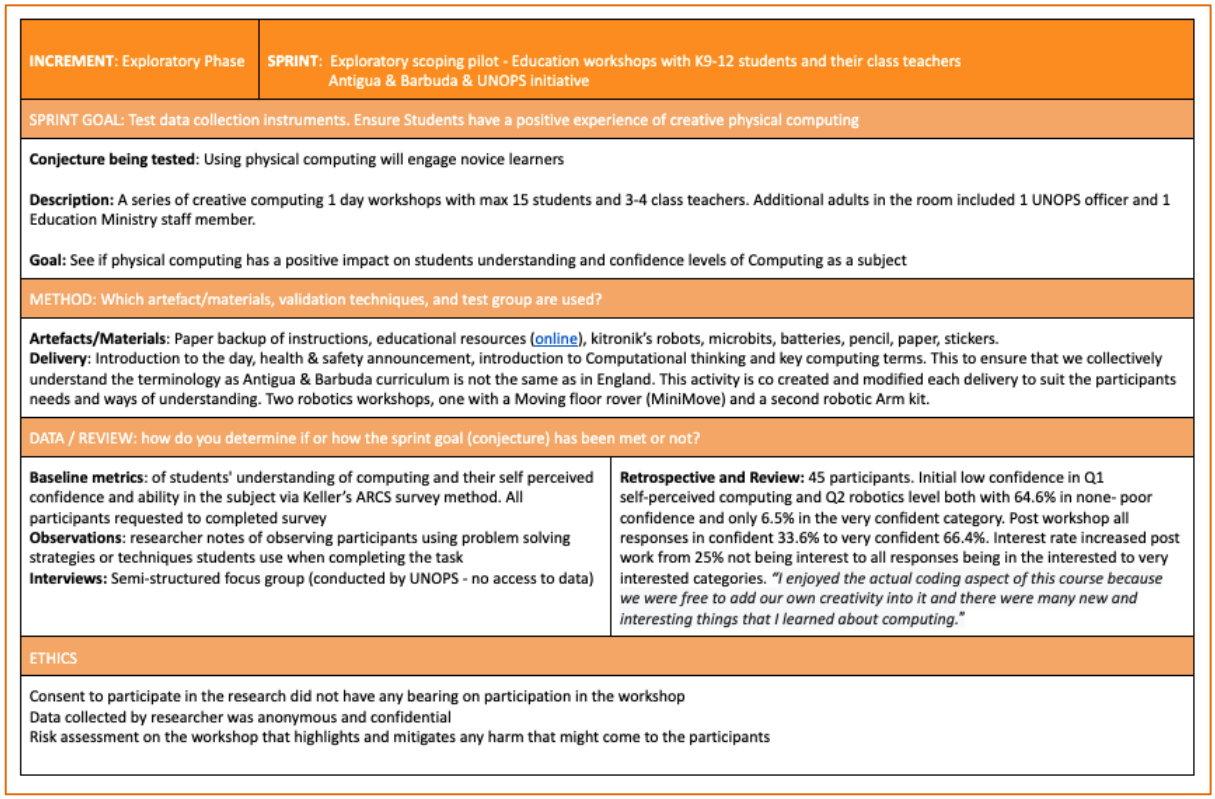
As the researcher, I was conscious of the colonial nature of what appeared to be a white British academic visiting the island to impart knowledge. However, my grandfather is/was Jamaican, so I have some kinship with the larger region which I believe allowed me to engage more authentically through respectful cultural exchange between the Antigua and Barbuda educational community and myself. As such, I felt like a colleague sharing ideas and practice, rather than a white saviour. Additionally, careful consideration was required when designing and creating the sessions to ensure that the cultural and socioeconomic aspects of students and teachers were considered. The participants were chosen by the Antigua and Barbuda government and represented all schools on the island, including private and state schools.

To gain some insight, I drew on Nechaul's qualitative case study and interactionist ethnographic research on the education of children of Caribbean descent (Nechaul, 1996), involving research on Caribbean-born children in the UK. It focused on racism and home life, and how such factors were perceived in the research environment. Nechaul states that this had the effect of ensuring all information, messages and materials were created with and for participants in this study.

The CSEC IT, the GCSE equivalent examination and several textbook publishers which produce resources specifically for the Caribbean region were reviewed. The government of Antigua and Barbuda requested new approaches to Computing for both students and teachers, rather than adhering to their CSEC content, which only uses the Pascal programming language. It was a privilege to teach and research with this community on behalf of UNOPS.

This phase of the literature review resulted in the following conjectures, structure, and design of the pilot study within the overall UNOPS programme restrictions (Figures 6a6, below, see 5.4.3.3 SPRINT BOARD EXPLANATION). Computing content was physical computing in disaster and island educational context. Pilot findings relating to this study were the design and testing of the questionnaire with the goal of minimising the participants' learning impacts.

Figure 6A.6 Sprint planning and review board for in person sessions Antigua and Barbuda.



INCREMENT: Exploratory Phase	**SPRINT**: Exploratory scoping pilot - Education workshops with K9-12 students and their class teachers Antigua & Barbuda & UNOPS initiative
SPRINT GOAL: Test data collection instruments. Ensure Students have a positive experience of creative physical computing	
Conjecture being tested: Using physical computing will engage novice learners **Description:** A series of creative computing 1 day workshops with max 15 students and 3-4 class teachers. Additional adults in the room included 1 UNOPS officer and 1 Education Ministry staff member. **Goal:** See if physical computing has a positive impact on students understanding and confidence levels of Computing as a subject	
METHOD: Which artefact/materials, validation techniques, and test group are used?	
Artefacts/Materials: Paper backup of instructions, educational resources (online), kitronik's robots, microbits, batteries, pencil, paper, stickers. **Delivery**: Introduction to the day, health & safety announcement, introduction to Computational thinking and key computing terms. This to ensure that we collectively understand the terminology as Antigua & Barbuda curriculum is not the same as in England. This activity is co created and modified each delivery to suit the participants needs and ways of understanding. Two robotics workshops, one with a Moving floor rover (MiniMove) and a second robotic Arm kit.	
DATA / REVIEW: how do you determine if or how the sprint goal (conjecture) has been met or not?	
Baseline metrics: of students' understanding of computing and their self perceived confidence and ability in the subject via Keller's ARCS survey method. All participants requested to completed survey **Observations**: researcher notes of observing participants using problem solving strategies or techniques students use when completing the task **Interviews:** Semi-structured focus group (conducted by UNOPS - no access to data)	**Retrospective and Review:** 45 participants. Initial low confidence in Q1 self-perceived computing and Q2 robotics level both with 64.6% in none- poor confidence and only 6.5% in the very confident category. Post workshop all responses in confident 33.6% to very confident 66.4%. Interest rate increased post work from 25% not being interest to all responses being in the interested to very interested categories. *"I enjoyed the actual coding aspect of this course because we were free to add our own creativity into it and there were many new and interesting things that I learned about computing."*
ETHICS	
Consent to participate in the research did not have any bearing on participation in the workshop Data collected by researcher was anonymous and confidential Risk assessment on the workshop that highlights and mitigates any harm that might come to the participants	

The conjecture tested was that Physical computing will engage novice learners into computing as a subject in *that physical computing has a positive impact on students' understanding and confidence levels of Computing as a subject*. Figure 7.6 encapsulates the planning and review from the pilot. The data showed a positive outcome for the students and their teachers with improved self-reported confidence levels in computing as a subject.

With a sample size of n45 participants, a pre-workshop questionnaire (appendix 6G) with Likert type item questions had a completion rate of 31 with males = n13, females = n16, and other= n2. The post-workshop evaluation questionnaire responses n24 with males = n9 and females = n15. Possible reasons for this low completion rate could be time constraints for the participants.

Once the data had been collected from the questionnaires, the mean and standard deviations were calculated as follows: N= pre-workshop, all relating to self-perception of coding ability. The results were as follows:

Q1 Current level of coding [What would you say is your current coding ability] (M = 2.40, SD = 1.32).

Q2. Current level of coding [Understanding of planning and coding for robotic] (M = 2.25, SD = 1.27).

Q3. How do you feel about coding in general? (M = 3.84, SD 1.37).

Q4. How do you feel about coding for robotics? (M = 2.40, SD = 1.34).

A paired-samples t-test was conducted to compare self-perception of coding awareness (ability) before and after the workshop. Interestingly, there was a significant difference in self-perception of coding ability between the pre- and post-workshop confidence in coding ability, with all responses being in the confident 33% and very confident 66% range in comparison to the pre-workshop with the highest figures of 34% representing poor confidence levels. This was similar for participants identifying as male or female.

Figure 6A.7 Physical computing workshop, Antigua and Barbuda, 2020.

6a.2 Findings

Two key features from the pilot that needed addressing: (i) the approach and method of the data generation; and (ii) the impact of questionnaire data generation on learning. I, therefore, performed a pre- and post-questionnaire to examine learners' self-perceptions of capability and enjoyment of Computing as a subject. Questionnaires were built into the workshop delivery as part of the content for the pilot study. As mentioned previously, this was to reduce the impact of the questionnaire on learner engagement, and was not a new observation;

similar effects had been observed in the previous two iterations of the UNOPS GISP (Global Innovations and Science project, separately from this study). The reduced item and the addition of emojis aided in the time spent and the completion rates.

The pilot study (see Figure 6a7) enabled the development of some but not all features to be brought into the next iteration. However, the onset of the Covid-19 global pandemic and the switch to a fully virtual study meant the pilot only served as a test of the survey tool. Any data relating to in-person teaching was no longer relevant and, therefore, not included in the main data analysis of this study.

The following initial conjectures were derived from the literature and pilot findings: (i) Computing Teachers improve their knowledge of data-ethics by participating in datadrivendance (DDD) modalities. (ii) DDD creatively enhances PGCE computing educator knowledge and modalities for widening participation in computing education.

Summary

The Literature Review and Pilot appendix focused on the initial pilot study and literature review as a continual process that is specifically necessary/required from AgileDBR methodology. As intended, the literature review of the subject matter and context of the study led to refining the research conjectures/questions. Additionally, the methodological developed in synergy with my approach both as a researcher and a practitioner - pracademic (Posner, 2009). The value (outcomes) from the pilot study led to the refinement of the survey tool used for this study (see CHAPTER 5 SECTION 6.1).

The first phase of the literature review led to the design choice of using biometrics and ballet to explore the raising of data-ethics awareness, specifically for computing education. The technical requirements corresponded with the computing curriculum and exam board specifications, as well as professional computing tools. Next, the theoretical subject knowledge for data-ethics for computing as a subject is reviewed.

Reference

Nechaul, K. (1996). The Schooling of Children of Caribbean Heritage. Trentham Books Ltd.

Posner, P. L. (2009). The Pracademic: An Agenda for Re-Engaging Practitioners and Academics. *Public Budgeting & Finance*, *29*(1), 12–26. HTTPS://DOI.ORG/10.1111/J.1540-5850.2009.00921.X

Juan David Velásquez-Henao. (2021). Analysis of bibliographic datasets using Python—TechMiner—A Package for Bibliographical Analysis using Python 0.0.0 documentation (0.0.0) [Python]. HTTPS://JDVELASQ.GITHUB.IO/TECHMINER/

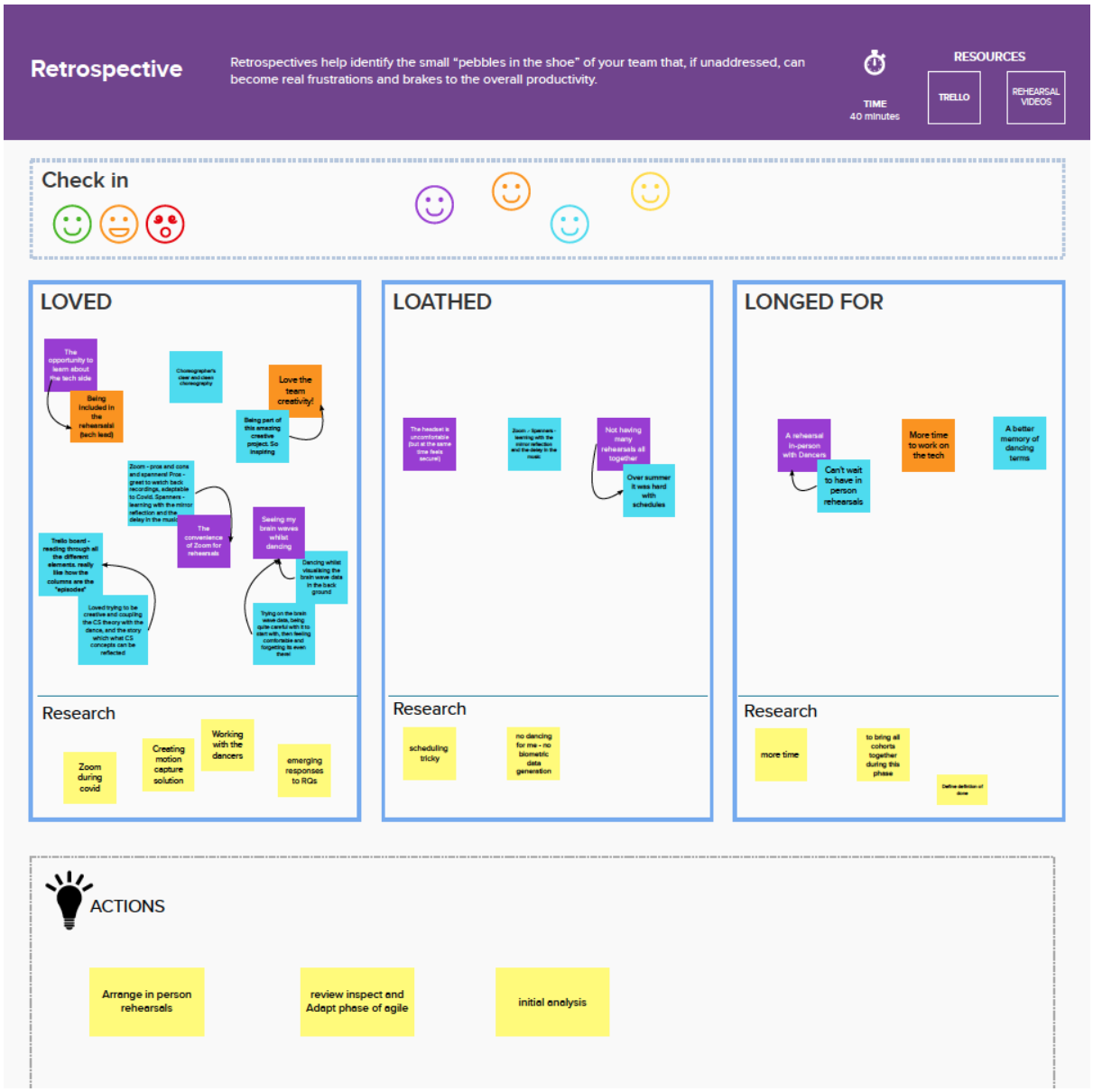
6B Pilot study Session Structure:

The structure of each session. Pre workshop survey (paper back in case of tech failure)

Health and talk, including where the toilets and drinking fountains were located.

Objectives/Outcomes	Teaching Guidance
1. Introduction to the computing terminology content of the workshop. 2. Understand the basics of programming 3. Introduction to physical computing **OUTCOME:** 1. Understand programming basics and terminology. 2. Be able to successfully code the Microbit to fulfil their desired outcome. 3. Be able to build 'minimove' and work as a team. **Rationale**: Programming used in digital media current and future technologies. Introducing programming and physical computing to students and teachers across Antigua and Barbuda KEYWORDS: Algorithm Abstraction Pattern recognition Debugging Iterative cycle Design Build Reflect Repeat	STARTER: Introduction to computational thinking using a paired activity to redefine the terms for their understanding and experiences. The use of Brain-Book-Buddy-Boss for working out problems of debugging for Computing terminology was not familiar to the students, as many students in Antigua and Barbuda do not start learning this until Year 9 or 10 in their schooling system. MAIN: Physical computing section. **Microbit** Introduction to Microbit: a walk-through of the Microbit; what is a microcontroller: Tour of the online coding platform achieved through a **guided collective activity**. Let the student choose which tutorial they want. Self-Guided Microbit project: A second activity of their choice using the self-guide tutorial projects on the microbit.org site. Self-guided activity time allowed me to move around the room and get to know the student participants as individuals. **MiniMOVE**: a short demo of a complete miniMove performing very simple movements and light pattern displays. The blended self and collective guided the build of the robot through demonstration, online presentation, and printed instructions. *The instructor pauses during the build stages, where there might be a need for further clarification or more detail. The minimove robot contains numerous small plastic (fiddly) components.* **Motors and Microbit**: back to working with the Microbit to keep up engagement following what could be a frustrating experience with building the miniMOVE. Connect motors to the Microbit via the control block. Configure the motors so that they move correctly when coded via the Microbit. **Assembly of the complete robot**: Placing the Microbit in the robot housing is the final step. To ensure all robots are working, students all coded their robot to complete a square motion with LEDs flashing certain colours. Free project: students were given 30 mins to create their own experiences. During this time, students are asked to complete the post-workshop survey, displayed on the board as a visual prompt. PLENARY Wrap up: recap what they have learned in the workshop(s) that day. Tidy up the classroom to make it ready for other students and educators. This step was important as the location was used for night school education.

7A Retrospective Example



7B PGCE lead extract.

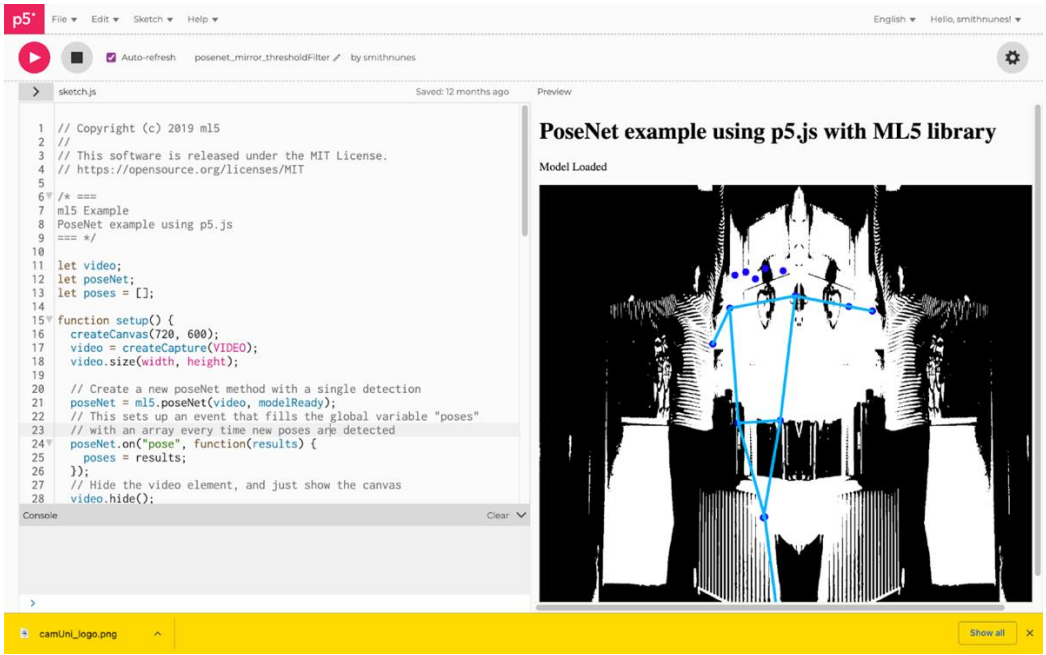
This is a written out version of the extract (Fig 7.15) for accessibility and readability purposes, if required

'Okay, so with regards to trainee teachers and [data] ethics in the, you know, in the actual curriculum that we cover? **It's very superficial**. I think that because the **emphasis now is currently on coding** and making sure that the trainees are able to go and perform coding activities in the classroom. That's very much a **bolt on ethics**. is very much a bolt on parts of the curriculum. And **I don't think the ethics aspect of the new relationships' curriculum has permeated yet through as a cross curricular requirements**. I think it's more that some think that belongs to RE (Religious Education). You know, and I think there is **a lot of emphasis on the law and GDPR (General Data Protection Regulation) and those kinds of things**, but actual ethical behaviour other than copying stuff. And yeah, and like how to look after data once you've got it. That's that seems to be the extent of what's covered. **It doesn't seem to cover what the principles of** [data] **ethics are and how those impact on what you should be teaching in the classroom**. And so, I just think that that's **something that really needs to be addressed**.'

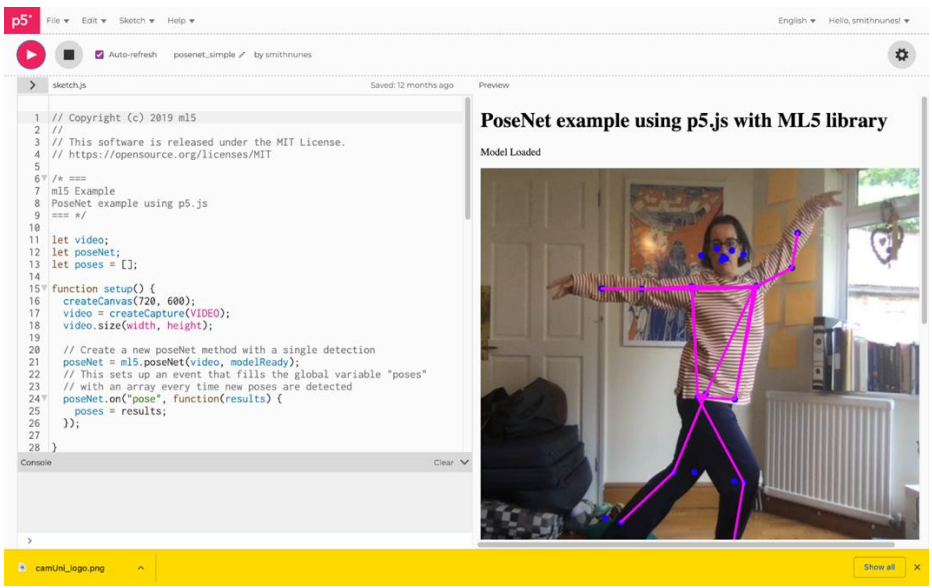
8A ML P5.js code

HTTPS://SITES.GOOGLE.COM/CAM.AC.UK/SINGULARITY/P5-JS

POSENET ML WITH FILTERS: HTTPS://EDITOR.P5JS.ORG/SMITHNUNES/SKETCHES/WZPSWLZ89

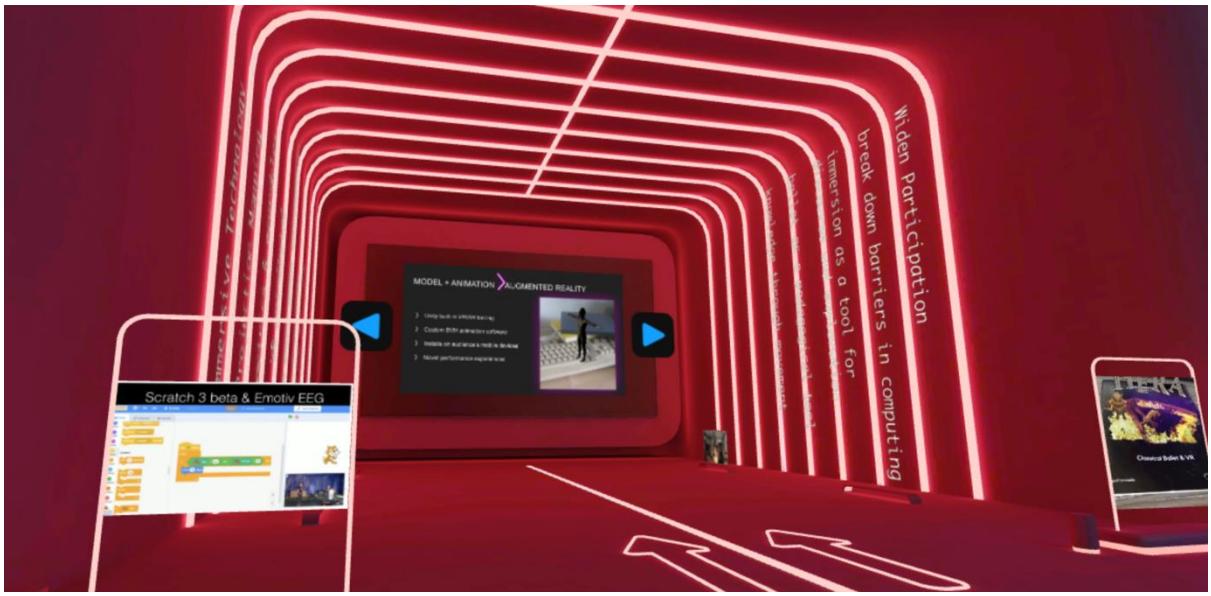


SKELETON TRACKING https://editor.P5js.org/smithnunes/sketches/Jr7dVR1Pv

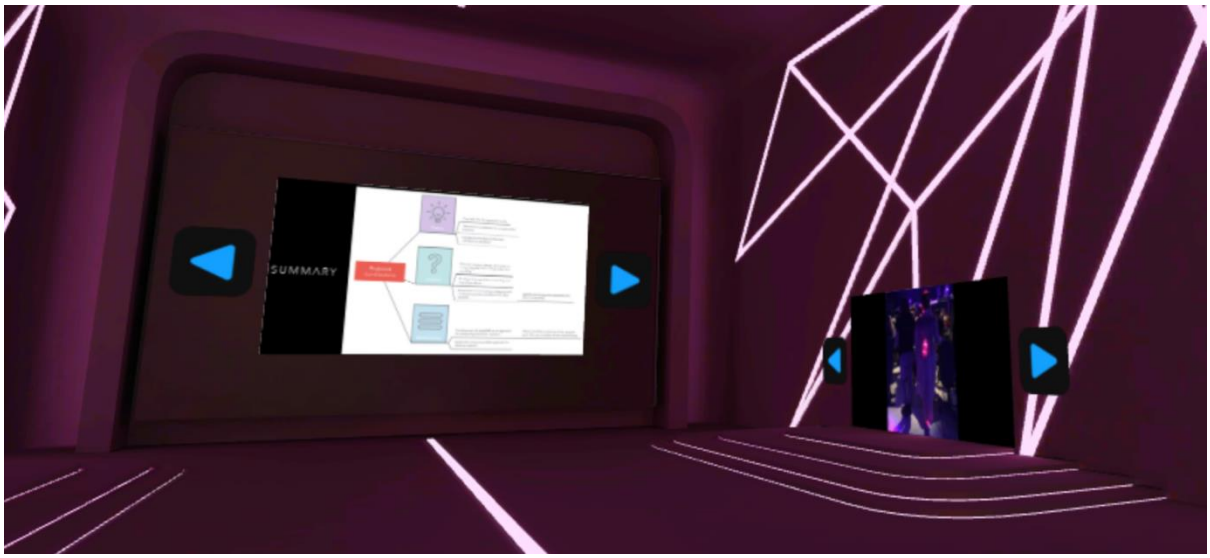


8B FrameVR with initial PPE model – Blue dancer

HTTPS://FRAMEVR.IO/ILRN2021-SHOWCASESINGULARITY

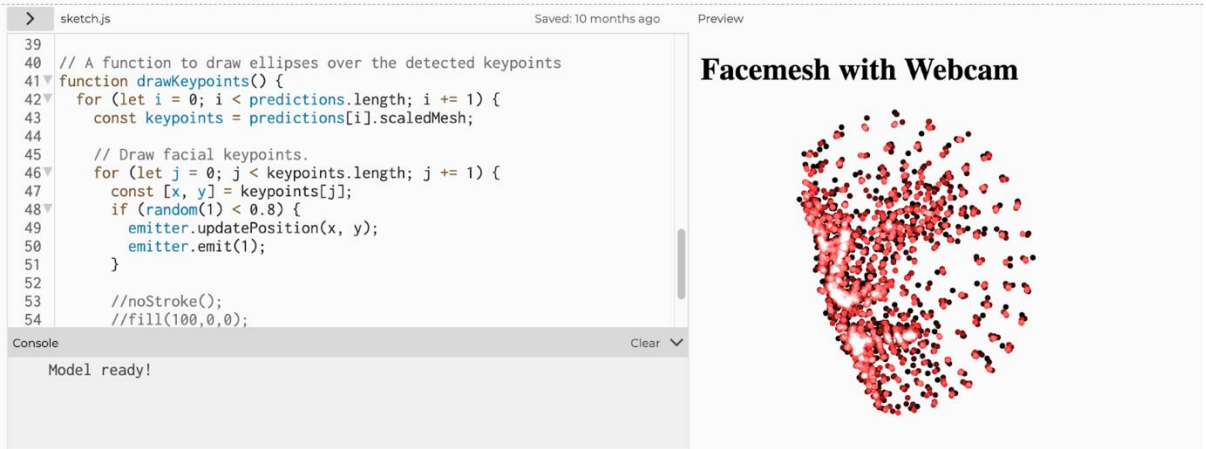


SINGULARITY

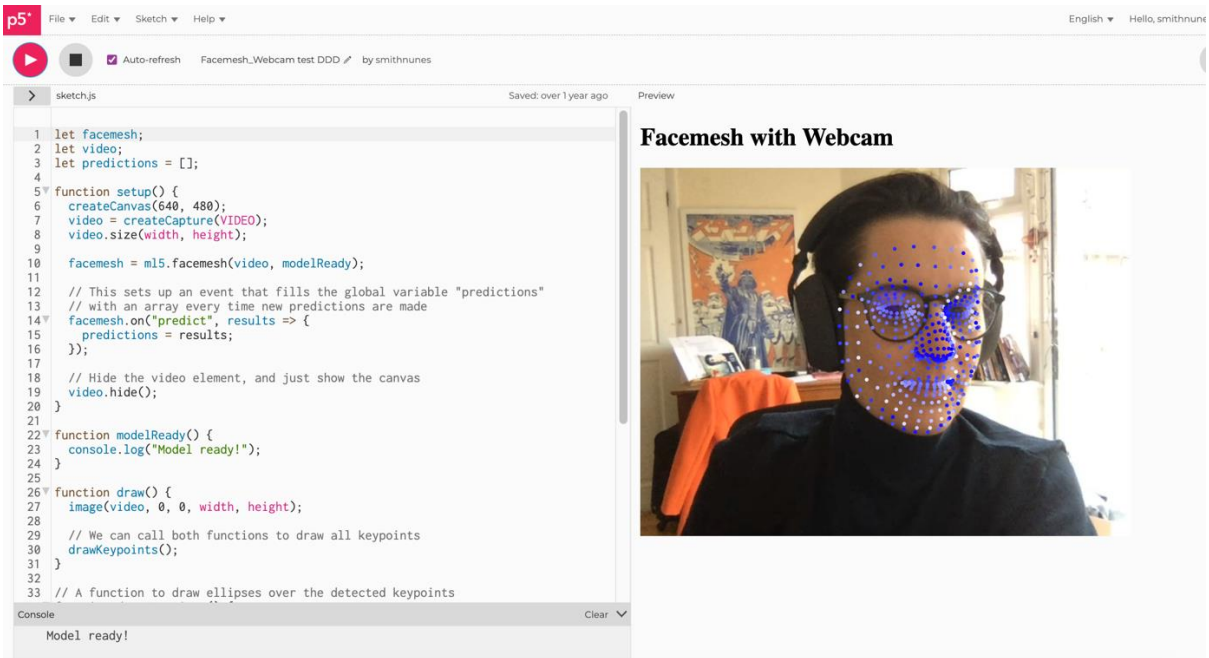

SUMMARY

9A Facemesh Code with & without video

FACE MESH https://editor.P5js.org/smithnunes/sketches/ZQSnnwFN6

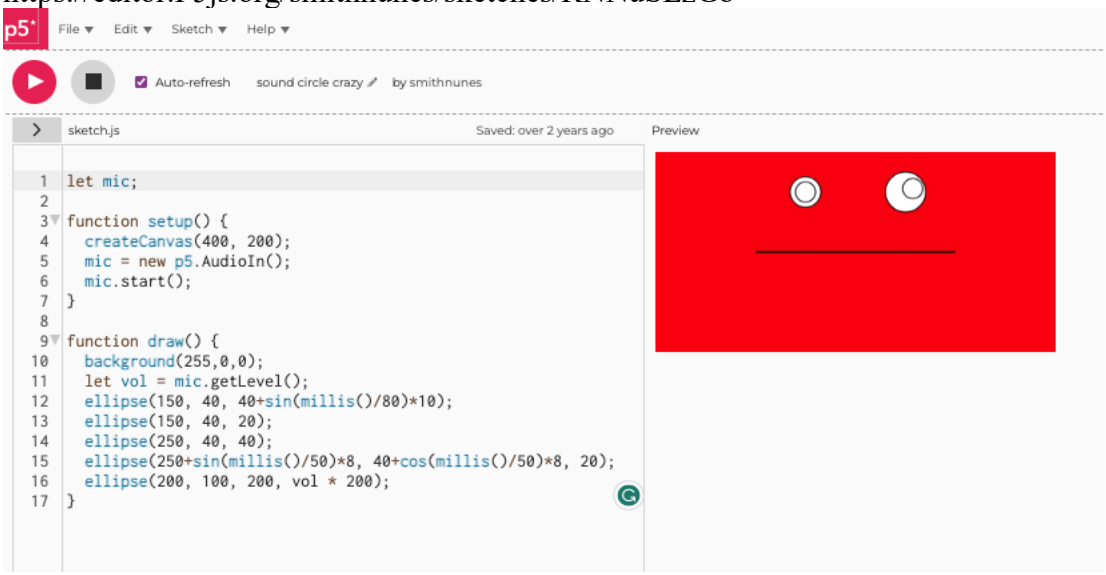


Facemesh with video: HTTPS://EDITOR.P5JS.ORG/SMITHNUNES/SKETCHES/XHD05BXZ8



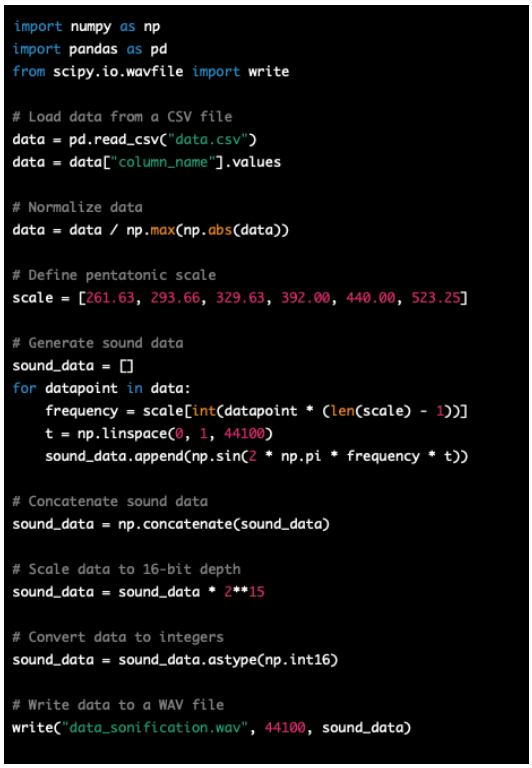
10A P5.js Mic Code

https://editor.P5js.org/smithnunes/sketches/RNNuSLzGb



10B: Data Sonification Python

```
import numpy as np
import pandas as pd
import ffmpeg

# Load data from a CSV file
data = pd.read_csv('data.csv')
data = data['column_name'].values

# Normalise data
data = data / np.max(np.abs(data))

# Define pentatonic scale
scale = [261.63, 293.66, 329.63, 392.00,
440.00, 523.25]

# Generate sound data
sound_data = []
for datapoint in data:
    frequency = scale[int(datapoint *
(len(scale) - 1))]
    t = np.linspace(0, 1, 44100)
    sound_data.append(np.sin(2 * np.pi *
frequency * t))

# Concatenate sound data
sound_data = np.concatenate(sound_data)

# Scale data to 16-bit depth
sound_data = sound_data * 2**15

# Convert data to integers
sound_data = sound_data.astype(np.int16)

# Export data to mp3
audio_stream = ffmpeg.input('pipe:', format='s16le', ac=1, ar='44100')
out = ffmpeg.output(audio_stream, 'output.mp3')
process = out.run_async(pipe_stdin=True)
process.stdin.write(sound_data.tobytes())
process.stdin.close()
process.wait()
```



This script exports it to an MP3 file using the **ffmpeg** library. The sound data is written to a pipe that feeds into an MP3 output file. The **audio_stream** variable specifies the format, number of channels, and sample rate of the sound data. The **out** variable specifies the name of the output file. Finally, the **process** variable runs the **out** command and writes the sound data to the pipe.

You should replace ‘data.csv’ and ‘column_name’ with the name of your csv file and the name of the column containing the data you want to sonify respectively. Also, you may need to install the **ffmpeg** library using **pip install ffmpeg** to run this script.

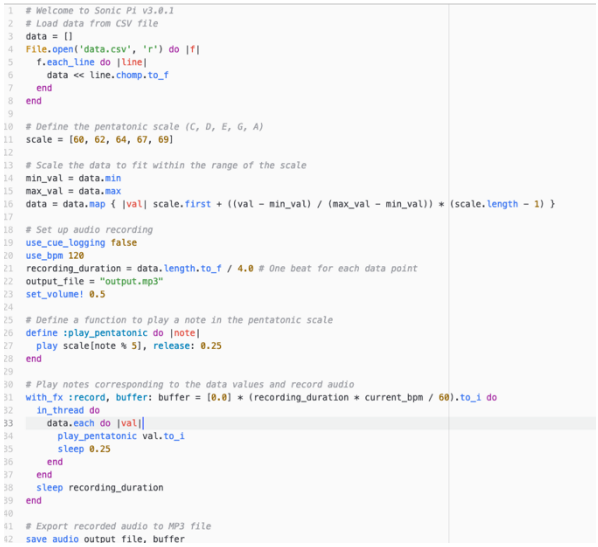
Another simple sonification file

```
import pandas as pd
from pydub import AudioSegment
from pydub.generators import Sine

# Load data from Google Sheets file
url = 'https://docs.google.com/spreadsheets/d/1-e5KYGjHWQkuQz0gJ-iWLQ8gj4kQ7CCVMW9YkC101tg/export?format=csv'
df = pd.read_csv(url)

# Define MIDI note range and duration of each note
note_range = range(60, 72)  # MIDI notes C4 to B4
note_duration = 1000  # milliseconds

# Map data values to MIDI notes
notes = [note_range[int((val - df['Value'].min()) / (df['Value'].max() - df['Value'].min()) * (len(note_range) - 1))] for val in df['Value']]

# Create audio file
audio = AudioSegment.empty()
for note in notes:
    freq = 440 * 2 ** ((note - 69) / 12)  # convert MIDI note to frequency
    sine_wave = Sine(freq).to_audio_segment(duration=note_duration)
    audio += sine_wave
audio.export('output.MP3', format='mp3')
```

10C: Data Sonification sonic pi

An example Sonic Pi script for data sonification using the pentatonic scale and exporting to an MP3 file. This script assumes that the CSV data contains a single column of numerical values:

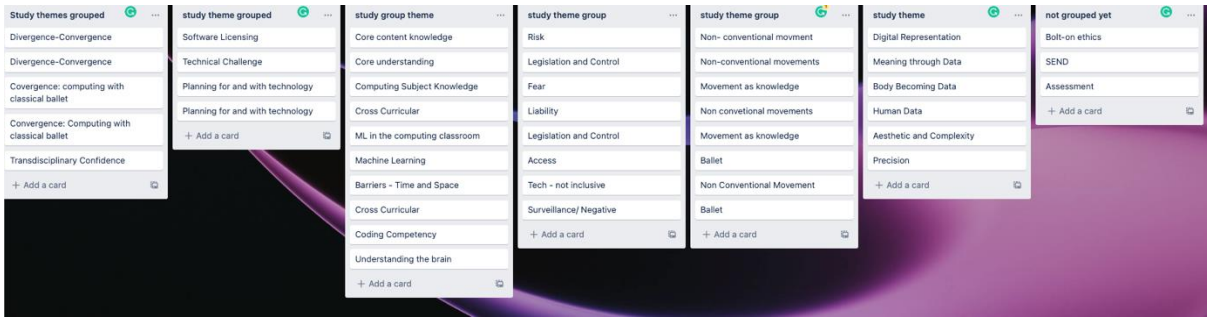
```
# Load data from CSV file
data = []
File.open('data.csv', 'r') do |f|
  f.each_line do |line|
    data << line.chomp.to_f
  end
end

# Define the pentatonic scale (C, D, E, G, A)
scale = [60, 62, 64, 67, 69]

# Scale the data to fit within the range of the scale
min_val = data.min
max_val = data.max
data = data.map { |val| scale.first + ((val - min_val) / (max_val - min_val)) * (scale.length - 1) }

# Set up audio recording
use_cue_logging false
use_bpm 120
recording_duration = data.length.to_f / 4.0 # One beat for each data point
output_file = 'output.mp3'
set_volume! 0.5

# Define a function to play a note in the pentatonic scale
define :play_pentatonic do |note|
  play scale[note % 5], release: 0.25
end

# Play notes corresponding to the data values and record audio
with_fx :record, buffer: buffer = [0.0] * (recording_duration * current_bpm / 60).to_i do
  in_thread do
    data.each do |val|
      play_pentatonic val.to_i
      sleep 0.25
    end
  end
  sleep recording_duration
end

# Export recorded audio to MP3 file
save_audio output_file, buffer
```



11A cross-iteration analysis development.

Initial cross-theme analysis was conducted both on Trello and on paper. I duplicated my data analysis Trello board creating a cross iteration board as part of the inspect and adapt process for the Retrospective of Retrospectives (Figure 11a.1 in the main chapter). With this, I looked for initial groupings and restructure the board to create unnamed groupings (see Figure 12a below). This first round looked for themes that connected in some way. Trello enabled the movement and restructuring of groupings in a free and quick manner. The vertical nature (see the figure below) of Trello is great for seeing cross list threads but I wanted a non-hierarchy approach to the inter- and intra-connections of the themes.

Figure 11A.1 Trello board initial unnamed cross iteration experiential theme



During this process, I went back to the participant extracts, the personal experiential statements, to ensure that the groupings held true. Figure 12a shows unnamed themes, as this was a living and iterative process; therefore, it was important to view the grouped themes as a meshwork, the intra and interconnect meta wholeness, before consolidating with the GET name. Other researchers may get different connections due to their ontological kaleidoscope, past experience and research aims, which is wonderful. These group experiential themes (GETs) reflect both me and me as part of the research, along with my participants. I don't stand outside looking in; I am within the meshwork (Ingold, 2011).

I printed out the themes using Table 12a, below, and cut them up as the IPA manual suggests (Smith, Flowers, Larkin, 2022, 100). Normally, I tried not to print out for environmental and cost reasons. The image below, Figure 12b following the table below, illustrates the groupings, with each strip listing theme name and iteration. This first phase created ten grouping, with bolt-on [ethics] on its own. This is an important idea, and I did not want to discard it or subsume it into another group. Each of the GETs provided a lens through which to view how the participants experienced the study; what they felt was important. The rest of

this appendix covers several sections: cross-iteration themes as whole; on a positive-negative continuum; initial GET generation; GET by cohort; and, lastly, the finalised study GETs.

Cross Iteration Themes

Table 11A Cross iteration themes.

iteration	***Iteration Experiential Themes***	***Iteration design implications***
Design	Divergence-Convergence	Constraint/ Opportunity
Design	Non-conventional movements	Opportunity / Somatic
Design	Convergence: computing with classical ballet	Opportunity/ Constraint
Design	Meaning through data	Fundamental
Design	Machine Learning	Opportunity
Design	Software Licensing	Constraint
Design	Tech – not inclusive	Constraint
Design	Bolt-on	Opportunity
Design	Barriers	Constraint
Design	Core	Opportunity/ Fundamental
Design	Movement as knowledge	Opportunity / Somatic
1	Cross Curricular	Constraint/ Opportunity
1	Ballet	Opportunity / Somatic
1	Fear	Constraint
1	Computing Subject Knowledge	Fundamental
1	Coding Competency	Constraint
1	SEND	Fundamental
2	Legislation and Control	Constraint/ Opportunity
2	Planning for and with technology	Opportunity / Somatic
2	Risk	Constraint
2	Assessment	Fundamental
2	Precision	Opportunity
2	Nonconventional movements	Opportunity / Somatic
2	Technical Challenges	Constraint
2	Digital Representation	Opportunity
2	Liability	Constraint
3	Access	Constraint /Fundamental
3	Surveillance / Negative	Opportunity
3	ML in the Computing Classroom	Fundamental
3	Understanding the Brain	Opportunity
3	Human Data	Fundamental
3	Transdisciplinary Confidence	Opportunity
3	Aesthetic and Complexity	Opportunity
3	Body Becoming Data	Fundamental / somatic

Figure 11A.2 Initial cross iteration experiential themes.

There ten initial groupings:

- Planning with and for technology
- External Factors – liability, legislation, and licensing
- Computing Subject Knowledge for raising awareness of data-ethics.
- Fear (risk)
- Barrier
- Bolt-on ethics
- Body becoming data
- Biometrics understanding
- Representation and Precision

- Convergence/ Transdisciplinary confidence

There were many reconfigurations before I settled on these initial ten GETs. Some groupings were more challenging than others. An example is meaning through data. This came from the design iteration, but also links with themes from other iterations such as ML in the computing classroom, coding competency or movement as knowledge. The following configurations started with using a positive to negative continuum for raising awareness of data-ethics, followed by in-content grouping and, finally, through the lens of each cohort.

Positive Negative continuum

Next was placing the themes on a short continuum positive to negative in relation to raising awareness of data-ethics for PGCE computing.

Figure 11A.3 *Positive negative continuum.*

The negative end has more to do with the challenges and barriers as opposed to being negative themes themselves. I was surprised at the weighting of this continuum, thinking that this would be the inverse of the actual outcome.

The next stage – another turn of the ontological kaleidoscope to reconfigure the patterns and connections – was looking for the similarities or closeness of the themes. This could also be achieved through computational social science methods, but using Trello and paper gave me a tactile interaction with my data.

Then I looked for inter-connections between the themes and grouped them under the one of the iteration themes. I selected one of the themes to act as the naming for each grouping. I felt that most did not capture the exact/true nature of the participants' experiential meaning. They acted as place holders during the cross-iteration analysis process. Meaning through data drew on technology and subject knowledge, confidence levels and the notion of biometric movement as knowledge. These three in some sense disconnected strands were more akin to the beads in the kaleidoscope generating the meshwork (Ingold, 2011) connections and patterns that form this GET, as exemplified by one of the dancers when they talked about how the technology could be used in dance studios to raise awareness of ethical implications:

> ‘Using the technology first hand with students and dancers helps with the understanding of biometric data and makes the impacts of that data being shared a more tangible concept’. [Dancer]

Their personal experiential statement (PES) draws on the tangible nature of dance as a tool for making meaning.

Meaning Through Data

Figure 11A.4 Meaning through data.

Meaning through data appeared across the iterations (see Figure 12d above) in various forms. This is one of the important ideas that permeated through the data generation period, from the positive through watching the PPE of dancers to P5.js skeleton and facial tracking code that brought the data to life, to the negative of ML and surveillance, the coding competency of the educators along with their students that potentially limited making meaning through data. Additionally, there were technical and subject knowledge barriers that could impede the raising of awareness of data-ethics. The next theme of risk/fear links to the barriers below, but is understood in a different way by me as the researcher.

Risk and Fear

Risks that would be present and the fear induced by the technical barriers were expressed in terms of access, coding competency, time for learning, time for planning, and time in the timetable.

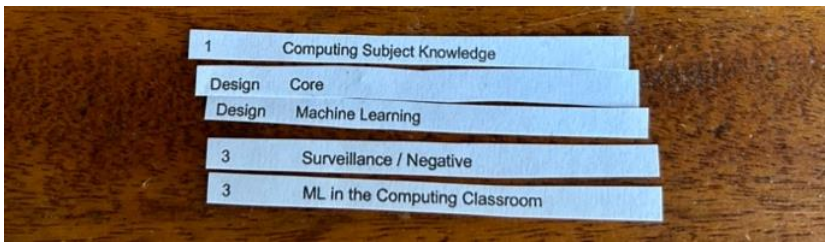
There was the fear of reprisal by their senior staff/PGCE mentors in attempting to do ballet and biometrics with programming to raise awareness of data-ethics. There was fear of failing their teaching practice, which had future employment implications. There was fear of performance management indicating that they are not meeting the required standards, which include curriculum content and assessment metrics.

Figure 11A.5 RISK and FEAR

I added bolt-on to Risk as this is my fear as the researcher, that data-ethics could become a bolt-on stand-alone lesson as opposed to something more integrated into the curriculum across all key stages (grades 7-13, UK). More challenging, if not impossible, for grades 12-13 as there are no compulsory lessons outside of the selected subjects.

Computing Subject Knowledge/Content

Figure 11A.6 Subject Knowledge.



Subject knowledge or content knowledge was important and appeared across the iterations and cohorts.

The three main areas in this configuration were (i) external software and regulation issues; (ii) computing subject knowledge including ML; and (iii) planning and assessment. That (i) external factors play a significant role in the technological development of the AR prototypes was a cause of frustration and blocks for the technologists. For the EDU cohort, subject knowledge was an expanding of data-ethics, beyond the confines of exam board specifications topic legislation and control. The trainee computing teachers suggested the need for awareness of ML for the computing classroom for both programming and wider societal issues. Lastly, there is (iii) planning and assessment, which are vital for any teacher: the planning of working biometric data that not only fit into the curriculum, but that the teacher has enough time to learn, understand and plan lessons. They spoke about the need to devise appropriate assessments that are perceived as fundamental to confirming knowledge

acquisition. Or to not assessment. This idea not to assess was sought by the majority of participants, but they felt unable to deliver something in their classroom without assessing it.

Convergence

Figure 11A.7 *Convergence.*

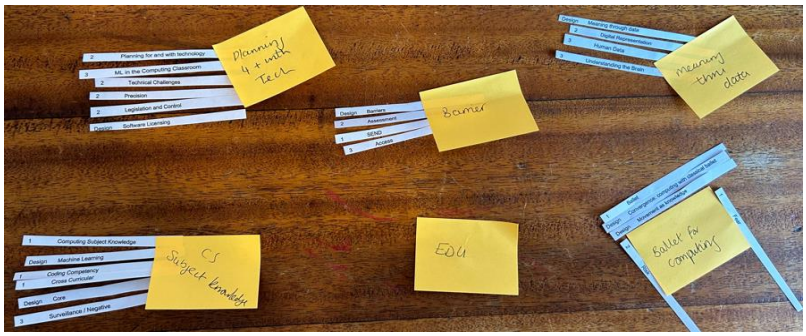
Convergence and alignment are the words often used when talking about classical ballet and computing. For the theme name, I felt convergence fitted better to how they described and discussed the two domains across the iterations. Additionally, alignment for me gives a sense of separation and concurrency that is linked but continues to be separate, whereas convergence is moving more towards the notion of a unified whole. To draw back to the kaleidoscope, it is the rematterring (Haraway 2006, 2016, Barad 2007) of the distinct part moving with the turn of the end cap to generate a unified whole new pattern, a new pattern of understanding through this lens of convergence.

I then moved on to viewing the cross-iteration themes through the lens of each cohort, education, dance, and technologist, to see what patterns and central themes developed. An interesting observation of this lens was that not all iteration themes were incorporated. When doing this rematterring exercise through the lens of the cohort, the principal themes seemed to occur differently. There were ancillary themes that did not play a central role in representing their cross-iteration experiential themes. I will discuss these ancillary themes collectively after presenting each cohort GETs, starting with education and then moving to dance and technologist. These GETs are not presented as a hierarchy; all have equal weighting. They are listed for the reader's convenience.

Education Cohort Themes

The five principal themes from the lens of the Education cohort materialise as: (i) Subject knowledge, (ii) Ballet for computing, (iii) Meaning through data, (iv) Barriers, and (v) Planning for and with technology (see figure 12h)

Figure 11A.8 Education cross iteration themes



Subject knowledge (i) incorporated core content knowledge, ML, coding competency and cross-curricular potentials. Core to content was the idea that data-ethics should be a primary idea permeated through computing across the key stages. Ballet for computing (ii) came with the sense of fear and risk when considering movement as knowledge for the computing classroom. They were clear in demonstrating the convergence of ballet and computing, including suggestions of use for and with computing.

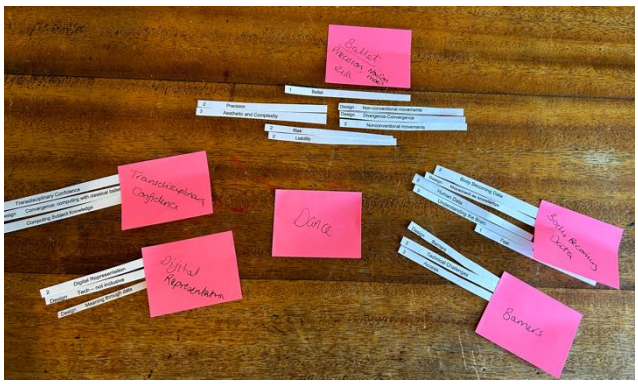
Meaning through data (iii) was both the making of meaning and understanding meaning through data, biometrics as leading to digital representation of the human and data-self. The ethical visual representation of the human data guided towards understanding biometrics for practical and theoretical purposes.

Barriers (iv) within the context of the whole study covered ballet as a pedagogical tool in relation to assessment, SEND, access to time in the curriculum and space to dance. Access to the technology is a considerable barrier, both in terms of cost but also, if open source, whether it is blocked by the network.

Lastly, (v) planning for and with technology, a twofold lens for educators one for themselves as learner and one as the educator transferring knowledge. The technical and potential coding competency required places limitations on the integration of this technology. It would need additional professional development and resources to support educators in planning the using of these types of technologies. Next is the Dance cohort lens.

Dance Cohort Themes

Figure 11A.8 *Dance.*



The five themes from the Dance cohort lens are: (i) Digital Representation, (ii) Barriers, (iii) Body becoming data, (iv) Ballet, (v) Transdisciplinary confidence. Digital representation (i) is an interesting theme, as I went to the PES to ensure that these two words reflected the statements of the participants. Both were required in the sense of the digital nature of the visual appearance and the digital nature of the data, the virtual human-self and data-self. It is not just data representation or virtual visualise represented but the whole representation of themselves as data and data dancer that were important, as well as how these digital representations are shared and viewed by the external world. Could they be recognised through the digital forms? Does the sharing have a future personal implication that is not yet understood?

Barriers (ii) had some differences from the education cohort in terms of how technology as a barrier impacted their own learning and creative development process via the Zoom dance studio, for want of a better term. The limiting nature of the Zoom dance studio reduced to a collection of rectangles played a role in the learning process and sense of dancing together due to the nature of the technology. As the researcher/observer, I found there were additional barriers, that of time and access to the participants, as participating in ballet productions is considerably time consuming. I was very conscious of the time the participants were giving me as the researcher.

Body becoming data (ii): This is the notion of their bodies becoming data not just the recording and generating files, but this recording became an inter- and intra-connected assemblage of body and data. This brought about ruminations of posthuman ethics, again looking through my kaleidoscope, this time with Barad, Bayley and Haraway enacting the patterns and ideas.

(iv) Ballet seems like an obvious one, but in the case of the dancers, it was how ballet differs from other dance forms, the non-conventional movements, effortless shape-making, along with the risk of injury when performing. This is concurrent with a different sense of risk/fear to ensure the data capture videos had full body data. Ballet for PPE and 3D model

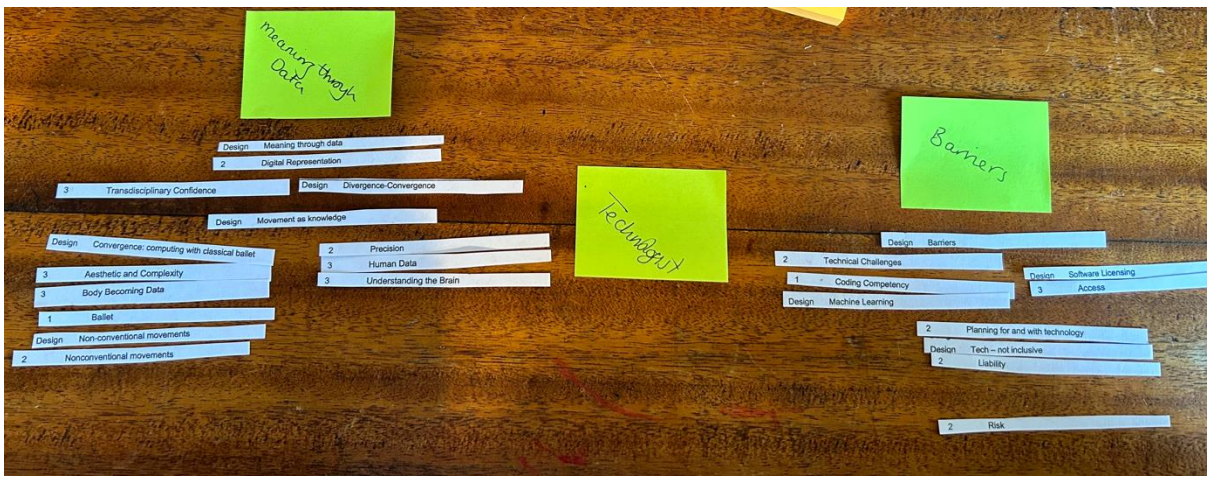
productions requires an increased level of precision. They had several of those ‘lightbulb’ or ‘of course’ moments throughout the study.

(v) Transdisciplinary confidence came through their ideas and thoughts on the aesthetic, complexity and systematic nature of ballet choreography. It was inherently clear to these dancers that they only saw these systems when discussing technology or computing concepts.

Technologist Themes

Next are the themes from the technologist’s lens. A different pattern developed when exploring the cross-iteration themes and the study as a whole. The themes were presented as two central lenses, with (i) meaning through data and (ii) barriers. It was interesting how these two materialised. I never had a fixed number of themes per cohort, nor did I think it would generate just two. The interaction with the technologist had a regular cadence: sometimes it was a short slack message; other times, it was a longer video call.

Figure 11A.9 *Technologist.*



Meaning through data (i) initially appeared during the design iteration and continued as a thread throughout the conversations with the technologist. These conversations, retrospectives, would always bring a new lens to what it meant to construct meaning through data. The changes in technology, the development of translational software to chats with the dancers, all brought different meanings from the data, sometimes new and sometimes iterations of similar ideas. This theme became one of the GETs of the study and is discussed in the main body of this chapter.

Barriers (ii) differed from the other cohorts, as they were dealing with creating the 3D models from PPE data generated via video. Additionally, the ML model that was not open source

created barriers to modification that would otherwise have enabled the model to work better with ballet dance data. Unfortunately, this is not an uncommon challenge with academic licensed software. As they were not ML experts, I arranged a discussion with Dr Sharmaniska, a reader in ML at Sussex University, regarding ML and the MocapNET2 PPE model. They suggested writing our own neural net, as we have a large dancer data set that could be used to train the model. This is a PhD unto itself and beyond the coding competencies of myself or the technologist. Time was a constant barrier, as this study was conducted outside of their full-time employment; therefore, their time was limited.

I cycled through various other groupings, including those discussed above, before the GETs coalesced to become the complex meshwork of finalised group experiential themes that represent all participant voices in the study.

References

Barad, K. (2007). *Meeting the Universe Halfway Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press. HTTPS://WWW-DUKEUPRESS-EDU.EZP.LIB.CAM.AC.UK/MEETING-THE-UNIVERSE-HALFWAY

Bayley, A. (2018). Posthuman Pedagogies in Practice: Arts based Approaches for Developing Participatory Futures. Springer.

Haraway, D. (2006). A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late 20th Century. In J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas (Eds.), *The International Handbook of Virtual Learning Environments* (pp. 117–158). Springer Netherlands. HTTPS://DOI.ORG/10.1007/978-1-4020-3803-7_4

Ingold, T. (2010). Bringing things to life: Creative entanglements in a world of materials (pp. 1-14). NCRM working paper. Manchester: Morgan Center University of Manchester. Recuperado de http://www. manchester. ac. uk/realities/publications/workingpapers.

Ingold, T. (2011). Being Alive: Essays on Movement, Knowledge and Description. Routledge.

Smith, J., Flowers, P., & Larkin, M. (2022). *Interpretative Phenomenological Analysis* (2nd ed.). SAGE Publications Ltd. HTTPS://UK.SAGEPUB.COM/EN-GB/EUR/INTERPRETATIVE-PHENOMENOLOGICAL-ANALYSIS/BOOK250130

11B Cross Iteration Themes relating to AI

The following aspects of AI were discussed in this study, wrapped in the ethical implications through the lens of the trainee computing teacher: How can ML be utilised in the classroom to assist students and educators and ethical implications of the ML assistant? What are the advantages for both (i) trainee computing teachers and (ii) their students? Firstly, teachers (i) ML/AI could be used as a tool to deliver real-time data on individual students, allowing them to personalise their instruction to each student's requirements and talents. It may assist in optimising each student's learning experience and increase the efficiency of the teaching process. Additionally, programming with biometric data as a way to cover the ethical issues of ML/AI was explored and was considered important during each iteration.

Secondly, for their students (ii), it was the ability of ML/AI to provide real-time feedback on demand, allowing them to track their progress and understand their strengths and weaknesses in real time. This could help to foster a more self-directed and autonomous approach to learning, as students are able to take control of their own learning journey and set their own pace. There were no comments or mentions of the future implications of those data and the potential impacts on the individual whose data were being used. However, real-time, personalised, *en masse* feedback without ML technologies would be very time consuming and nearly impossible in a classroom setting.

Overall, their discussion and comments on the use of AI/ML in education were about the potential and how it could enhance the learning experience for both teachers and students through its real-time nature and ability to provide personalised feedback and support. The ethics of ML/AI needed further development, as ML/AI was perceived as a tool to support teacher/student, with a limited emphasis on the ethical considerations.

Meaning through Data – Body becomes data

Meaning through data as a kaleidoscope of multiple meanings varied by cohort, data type (text, image, biometrics, XR), and even as analysis for me. Each participant's experiential statement added to the development of this cross-iteration theme. From the dance participants' perspective, it was body as a data artefact, motion capture, and ML/AI technical challenges (due to ballet's unconventional human movement), and EEG data and brain computer interfaces (BCIs). Then, for me, this was extended to AI-imagery as a researcher's tool for analysis,

For all participants, particularly the dancers, meaning through data manifests as the body as a data artefact. The face mapping code had a comparable effect on the trainee teachers as it did on the dancer experiencing the full biometric elements of the study. With regard to human motion datasets, the technologist was fully aware of the ethical issues during the motion capture process and the tooling, with both the technical and ethical considerations borne in mind.

Motion capture and ML/AI, Cheng et al. (2019) examine the issues of occlusion in 3D human posture estimation with single-view footage. They suggest a novel approach to the model, with the use of cylinders instead of points (coordinates), but state that 'there are still several unsolved problems and some failures' (Cheng et al., 2019) in their models, especially when it comes to working with more than one human. This was less challenging towards the end of the study due to the larger toolset, the video object abstraction, used in the motion caption pipeline, as discussed in the chapter.

Interestingly, L'Atelier Animation's animated movie, 'Ballerina' (Summer & Weiss, 2016), does not use motion capture or PPE. Instead, it uses an older, more traditional technique, keyframe technology, to translate the dancers' movements into character animation motion. Keyframe is the use of a drawing or shot [video] that defines the starting and ending points of a smooth transition. In 'Ballerina', the dance data were the inspiration, but it was not intended to be an exact rendering. In an interview with *The Montreal Gazette* (2017), lead animator Tyrell Ty explained: 'the point was not to copy their [the dancers' exact technique] movements but to be accurate while making it emotionally potent'. Ty goes on to recall conversations about rendering the principal dancer Dupont's movements. Dupont's beautiful response was: 'I want you to animate the way I dream of dancing' (Dunlevy, 2017).

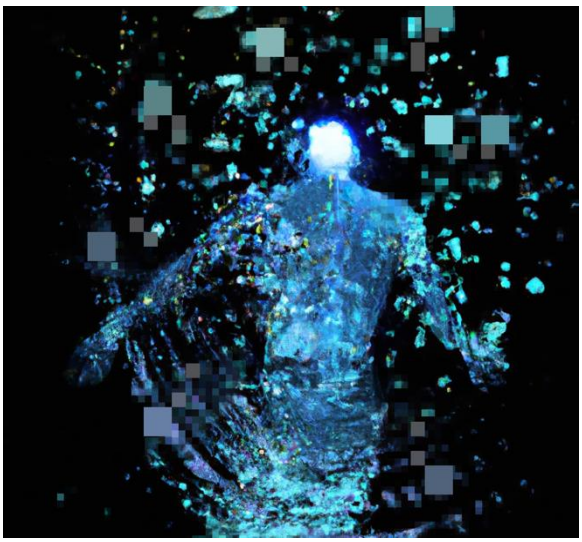
The role of BCI is becoming an increasingly important part of neurotech and edtech developments, with potential implications for trainee computing teachers. The use of BCIs may aid in understanding how learning occurs in the brain. The CEN cognitive educational neuroscience centre at UCL, UK, is dedicated to this aim, with the goal of explaining how the brain works and its learning priorities. Rogers and Thomas (2022) discuss how thinking is difficult and learning is even more difficult. Chapter Five demonstrates how educational neuroscience, when combined with existing knowledge of human and social psychology and teacher expertise, can [potentially] 'improve outcomes for students' (Roger and Thomas, 2022, pp. 88-133). Neuroscience in educational settings needs careful consideration before it

enters any classroom. There are currently not enough checks and balances or training in place for educators to effectively judge BCI use for themselves or their students.

Meaning through EEG data, that is, the education cohort could potentially benefit the teacher through real-time individualised instruction that better meets the needs of the students and would ensure that all students could make progress using EEG data. Furthermore, understanding what is happening in the brain (in real time) during learning processes could lead to a more in-depth examination of how young people learn. as well as to developments in theory and practice for computing educators. This futurist viewpoint cannot be knowable with our current understanding of technology and how humans learn. The ethical considerations of individuals' brain data being recorded, stored and used need greater oversight, especially for young people.

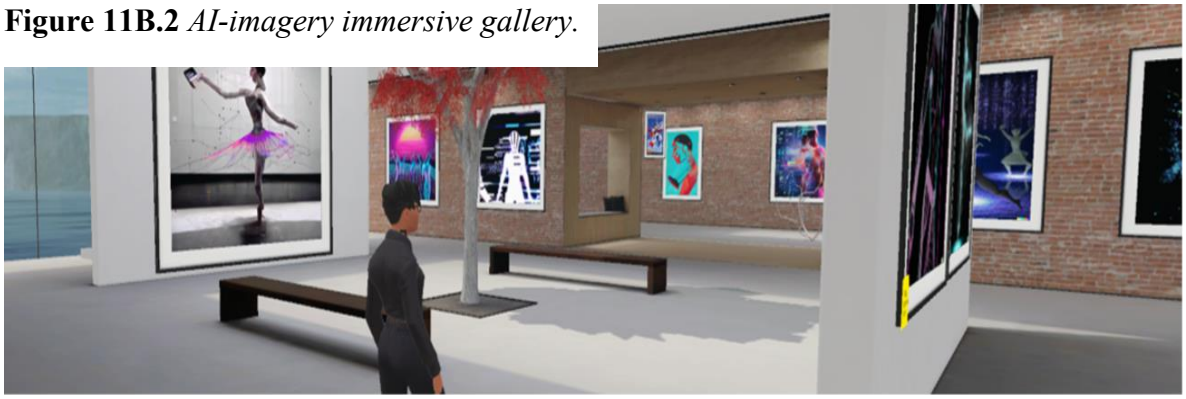
AI-imagery, or me as the researcher, presenting meaning through development into the use of AI-imagery (see Fig. 11B.1 (theme, chapter header, and XR gallery images)) as a form of computational analysis that empowered another or an alternative turn of the endcap of my or the ontological kaleidoscope. AI-imagery generation as a form of computational analysis gave a new materiality to the findings that words alone could not provide for me (Smith-Nunes, 2023). This approach includes text-to-image generation, which allows for the discovery of the prompt, word order and image style that corresponded to how the findings were presented to me. Figure 12.3 was generated using Dalle.2 with the text prompt 'digital art, futurism, abstract, dancing with data'. It was then edited in Photoshop to add pixelation. The pixelation made the theme image more reminiscent of digital and data, bits, and bytes than the original image. The image has several layers, with pixelation of various sizes occurring. In order to increase the top layer of pixelation, some contrast editing was performed. This is a subjective process, as the AI-generation did not always produce the results based on the findings I had envisioned leading to additional post-processing (Smith-

Figure 11B.1 *Body Becomes Data.*



Nunes, 2023). The use of Spatial.io as an immersive gallery (Fig 11B.2 below) experience is new for exploring and sharing findings with others.

Figure 11B.2 *AI-imagery immersive gallery.*



Making Space for Ethics – PGCE curricula

This research is situated in the particular site, as many PGCE programmes have similarities, but when it comes to data-ethics or the philosophy of computing, they are unique to their institution. Across the iterations and the cohorts, the findings suggest that the need to make space for data-ethics considering the technological advances and our interactions within digitally mediated environments. To make space was not to delete other aspects but to map to the current content and enhance areas to include data-ethics across the curriculum, not necessarily as a separate topic.

Integrating data-ethics into their PGCE course would be a critical step towards ensuring that future generations of trainee computing teachers have the information and skills needed to make responsible judgements regarding data and technology use. To effectively incorporate these concepts, trainee computing teachers need to seek to gain a deeper understanding of the ethical principles and frameworks that underpin data-ethics for computing. Trainee computer science trainee could help shape a more ethical and responsible future for technology and society by the inclusion of data-ethics in their PGCE training. Integration at PGCE means they would start their teaching careers with an awareness of data-ethics, which would enable them to see opportunities to explore/discuss this in their own classrooms.

Convergence: Computing with Arts Based Practices–Classical Ballet

The principles and specificity of step, movement, body posture and choreography in classical ballet converge with those of programming and algorithm design in computing. This convergence of computing with ballet was evident in all participants, which was somewhat

surprising. The fact that the PGCE cohort, which was mostly male and varied according to age, was able to see the alignment of ballet choreography with algorithms and programming so early in the process was a wonderful surprise. The cross-curricular link to subject such as PE, Dance, and Music have the following implications, table 11B.1

Table 11B.1

Study implications for PE, Dance, and Music

Subject	Implication
PE – physical education	Dance is part of the KS3 curriculum but does not specify the form. The use of *choreographic algorithms* would facilitate a cross-subject use of terminology. The PE teacher would be required to become familiar with some computing and ballet terminology which may not be practical. Also, the booking and timetabling of the physical spaces large enough for ballet may not be practical within the context of the whole school PE timetabling
Dance (GCSE)	At the pre-university examined level (UK context) GCSE, grade 11, would facilitate both in dance form and time for ballet to be included. Again, this would require time and effort on the part of the dance teacher. Schools offering Dance GCSE would allow do so if their staff were skilled in the appropriated examined dance forms. When I was working at the secondary the PE department often brought in dance experts for their GCSE Dance students. Dance and Technology is not new but is becoming of some Dance undergraduate course (Roehampton for example). One of dancers that performed in the [Data]storm ballet (2015) used the Microsoft™ Kinetic and ballet as part of their extended project qualification (EPQ) to talk about muscles.
Music	Music and coding is becoming part of many K-12 classroom through the free and accessible tools such as SonicPI. The learning materials and example project make this a very easy way to incorporate computing into the music classroom.

Finding space for ballet-based learning activities within the existing curriculum, particularly at the GCSE level, was considered a significant challenge. At the GCSE level, in particular, the schedule is frequently designed in such a way that there is little room for extracurricular activities, particularly those that may necessitate specialised resources or expertise, such as ballet instruction for computing.

As a result, the PGCE course has the potential to think creatively about how non-traditional methods such as ballet-based learning activities could be added into the curriculum without jeopardising the integrity of the existing schedule. This may entail creative scheduling or

curriculum restructuring to allow for greater flexibility, as well as allocating resources to support the inclusion of ballet-based learning activities. Ultimately, overcoming the challenge of timetables is critical to facilitating the integration of ballet-based learning activities into the current curriculum, a goal that may not be achievable.

References

Cheng, Y., Yang, B., Wang, B., Wending, Y., & Tan, R. (2019). Occlusion-Aware Networks for 3D Human Pose Estimation in Video. *2019 IEEE/CVF International Conference on Computer Vision (ICCV)*, 723–732. HTTPS://DOI.ORG/10.1109/ICCV.2019.00081

Dunlevy, T. (2017, February 23). Ballerina brings Disney/DreamWorks animator back to Montreal. *Montreal Gazette*. HTTPS://MONTREALGAZETTE.COM/ENTERTAINMENT/MOVIES/BALLERINA-BRINGS-DISNEYDREAMWORKS-ANIMATOR-BACK-TO-MONTREAL

Summer, E., & Weiss, E. (Directors). (2016) *Ballerina* [Film]. L'Atelier Animation

Rogers, C., & Thomas, M. S. C. (2022). *Educational Neuroscience: The Basics* (1st ed.). Routledge. HTTP://WWW.ROUTLEDGE.COM/EDUCATIONAL-NEUROSCIENCE-THE-BASICS/ROGERS-THOMAS/P/BOOK/9781032028552

Smith-Nunes, G., (2023) DC: AI-imagery as a form of secondary computational analysis. *iLRN2023 Proceeding of Ninth International Immersive Learning Research Network*, (preprint).