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A critical analysis of how Knowledge Organisers and Recall Practice can be used to facilitate learning. An Action Research project of Year 7 pupils studying cells and organisation

Nathan Smailes

(PGCE Physics, 2016-2017)

email: nathanjacksmailes@gmail.com

Abstract

The use of cognitive methods has been studied in detail in psychological research, yet there have been few studies that have attempted to implement them. This paper analyses some of the ways in which knowledge organisers and recall practice may be used in a classroom setting. Multiple cognitive methods are applied such as low-stake testing, quizzing and knowledge organisers. Analysis was conducted using exit-tickets, interviews, summative assessments and journal entries. Overall 72% of the pupils improved their average score from assessments conducted before and after the teaching sequence. Additionally, the cognitive methods appeared to help pupils remember a greater amount of content. The isolation of individual effects of the methods was outside the scope of this study and limits the conclusions drawn. What is clear from this research however, is that cognitive methods can be implemented into a classroom and if applied well may lead to significant improvements in learning.

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Introduction

Pupils can find it difficult to cope with many of the concepts applied across science; often emerging from school with a fragmented knowledge littered with common misconceptions. There has been a great effort in research to improve scientific education by looking at how to both prevent pupils' misconceptions and best instruct various scientific topics. However, there has been little research regarding the cognitive issues in knowledge, thinking and learning, that are important in gaining an understanding of science. This is an area in which there is a substantial body of research in psychology, yet it has not been linked to education in any significant frequency. The effect of applying cognitive methods in the day to day science classroom is therefore largely unknown. Cognitive methods cover a broad range of topics in psychology but generally refers to the study of the mind as an information processor. Here a particularly focus is placed on cognitive methods that aim to improve pupil's memory storage and retrieval.

This study aims to explore how some cognitive techniques can be implemented into the teaching of science. It focuses on recall practice as well as the use of knowledge organisers in the teaching of cells and organisation to a group of 18 Year 7 pupils. Research has been conducted over a six-week period in a Secondary Academy Converter, in Hertfordshire. It is believed that the integration of these techniques will assist a pupil in their recall ability, as well as providing a template for pupils to more easily interconnect scientific ideas across topics. A multi-methods approach has been used to analyse how they can implemented and what effect this has on pupils' knowledge and their perception of learning in the classroom. The research conducted is small in scale but it aims to provide an opening to possible methods that can be applied in science education using cognitive research.

Literature Review

Introduction

This review aims to establish the research that has previously been conducted into cognitive methods in education, with a focus on its application in science. Many of these discussions rely heavily upon previous research carried out by Reif, (2010); being one of the only pieces of cognitive methods research that has been conducted specifically for science education, it has a greater relevance to this study. However, it is largely theoretical and little evidence to its practical applications within the classroom is researched. A monograph by Dunlosky and others (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013) analysing cognitive methods is equally prominent in this review, which provides an in-depth analysis of the practical applications of these methods in the classroom. It is hoped that the combination of these key sources will help to provide both a theoretical approach to cognitive methods in science education as well as its implementations within the classroom. These two sources have been combined with literature conducted by other leading researchers in cognitive research, notably Alloway, Gathercole and Willingham, all of whom provide an experienced viewpoint on current cognitive theory and how this may be best applied to improve learning.

Defining Knowledge and Learning in Science

To measure the facilitation of learning, the concept of ‘learning in science’ must be defined. Learning can be viewed as a change in pupils’ knowledge that is attributable to experience (Mayer, 2011). In accordance with this definition, knowledge is used interchangeably with learning throughout this study. Looking more specifically to science, it can be argued that everyday knowledge and science are comparable. The whole of science has been described as “nothing more than a refinement of everyday thinking” (Einstein, 1936, p. 59). Yet the fact that the principles which underlie science have been developed over the years means that this is not always the case (Reif, 2010). Furthermore, it is not often considered that it takes time and practice to become proficient in science and gain what may be termed a ‘strong scientific knowledge’. To attain the skills that scientists have at their disposal, such as being able to predict and analyse various scenarios and experiments, takes time (Willingham, 2010). We cannot assume too much of the capabilities of novice scientists who have not had the time and opportunities of experts

(Willingham, 2010). Particularly during education scientific knowledge should be seen in this way, a skill where the pupils are novices training to be experts.

Learning can be visualised as a process, in which there is movement from an initial performance to a final performance (Figure 1). This is often implemented by processes such as teaching and instruction, yet is not limited to it (Reif, 2010).

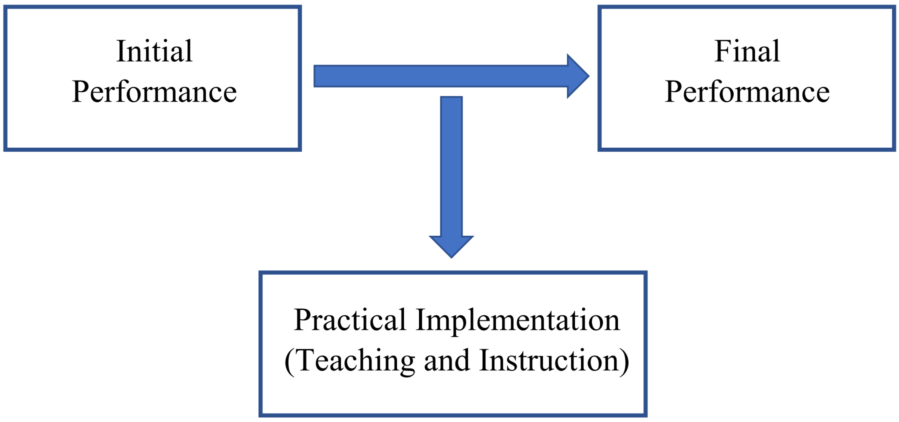


Figure 1: A simplified approach to the process of learning, adapted from Reif (2010)

One key measure of learning is the ability to recall and retain information; if a pupil cannot do this after a period, they are unlikely to have conducted learning (Pomerance, Greenburg, & Walsh, 2016). Recalling and retaining information does not provide the full picture for effective learning but it can provide a measure of it. To effectively understand these measures, a deeper consideration of the working and long-term memory is required.

The workings of the Working Memory

The process of learning is complex but as one team of researchers summarised "learning doesn't happen without working memory" (Shell, Brooks, Trainin, Wilson, Kauffman, & Herr, 2010, p.13). Human memory can be described as consisting of a long-term and working component. Memories initially pass from the environment to the working memory, where they can then be processed into the long-term memory (Figure 2). The working memory accounts for the short-term storage of small amounts of knowledge; which has been suggested could be as little as seven pieces of information (Reif, 2010). It increases with both age and expertise, yet there is no evidence to suggest what causes an initial good or poor working memory (Blakemore, 2005).

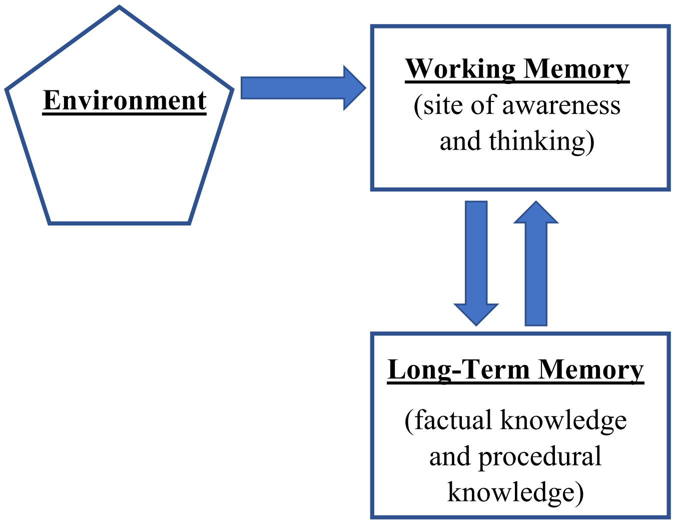


Figure 2: A simplified model of how memories are stored in the brain adapted from Willingham (2010)

In contrast, long-term memory is thought to have near unlimited amounts of 'storage space' and memories can be stored here for a significantly longer period (Gathercole & Alloway, 2007). Here, memories are stored in an unconscious state until required, where they are then transferred to the working memory. This combination of information from the long-term memory and the environment within the working memory can be defined as 'thinking' (Willingham, 2010). The relative 'strength' of the memories can be analysed by looking at the time it takes for them to be recalled and the number of errors made upon recall (Reif, 2010). It has been shown that memory improves with practice and decreases at an exponential rate with time, illustrated graphically in Figure 3.

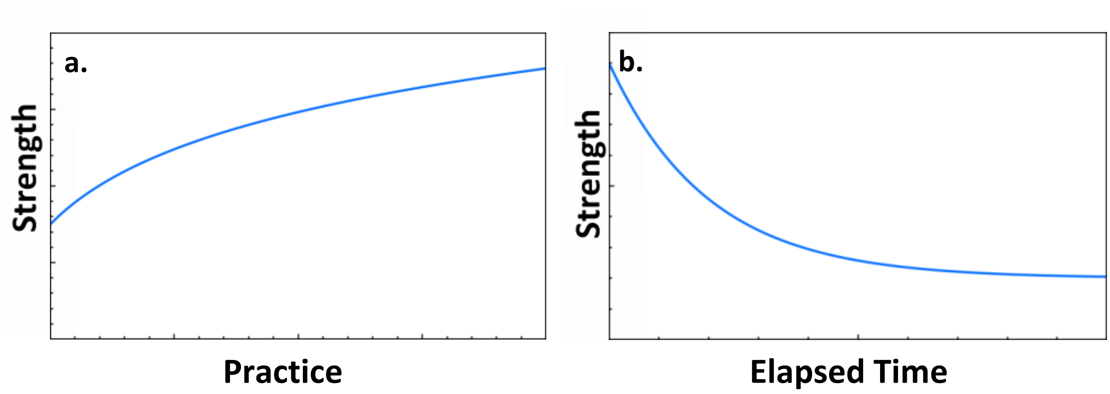


Figure 3: Graphical representations of a. an increase in the strength of memories with practice and b. a decrease in strength of memories with time, adapted from Reif, (2010)

Working memory is significant in the classroom because of its relationship with learning and other key measures. Examples of this include its connection with learning disabilities (Alloway, 2009), mind wandering during focused tasks (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004) and general intelligence (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). It can therefore be a useful tool in understanding and improving several key factors in a pupil's development.

Practice Makes Perfect

As illustrated in Figure 3, a principle way of improving the strength of memories is by practice. Without this it would be near impossible to become proficient at recalling and retaining information (Willingham, 2010). A study by Roediger & Butler, (2011) combines large-scale data from both college and 6th grade pupils to show that the active process of trying to remember allows memories to be more engrained in the long-term memory. Examples of this used effectively include low-stake quizzes and self-tests, which have been proven successful over the course of a 5-year applied research project involving over 1,400 middle school students (Agarwal, Bain, & Chamberlain 2012). The implementation of practice can be focused on low-stake testing, which has no summative element. A monograph carried out by Dunlosky et al. (2013), synthesises a great amount of previous research and compares and weighs the conclusions drawn from the various sources. It is concluded from this monograph that low-stake testing has a positive effect on learning. This may be attributed to either the direct effect of taking the test; or a mediated effect caused by the influence of the test (Dunlosky et al. 2013). There are, however, two factors that are clearly identified as having a positive effect, the dosage and timings of practice (Agarwal et al., 2012).

Increasing the amount of testing has been shown to have a positive effect in several studies, including a multi-method study of forty-eight undergraduate pupils (Karpicke & Roediger, 2007). Practice can be split into massed practice, large amounts of practice in relatively short-time intervals and distributed practice, repeated practice with greater time intervals between sessions (Reif, 2010). It is currently thought to be more beneficial to space practice over longer time periods (Cepeda, Pashler, Vul, Wixted, & Rohrer 2006), with distributed practice typically quoted as benefiting long-term retention more (Dunlosky et al., 2013). An example of the improvement of distributed practice has been shown with new material being reviewed twice weekly, increasing the recall ability and knowledge retention of students (Pomerance, Greenburg, & Walsh 2016). Furthermore, 8-minute daily reviews of maths material conducted with elementary pupils, was shown to be effective in freeing up working memory (Rosenshine, 2010). Although the spacing needs to be substantial and longer appears to be better, the optimal spacing is under constant debate (Lindsey, Mozer, Cepeda, & Pashler, 2009). Pupils often also have misconceptions about the effect of distributed practice and, even after exposure to the benefits, it has been shown that they may still believe massed practice to be more effective (Kornell & Bjork, 2008). Additionally, pupils are often keen to receive feedback on how to implement frequent practice. There are techniques for this, such as flashcards or the 'Cornell Note-Taking System' but these take guidance to have the greatest effect (Dunlosky et al., 2013).

Distributed practice is likely to have its greatest effect when combined with active processing tasks, which test and pose knowledge in a variety of ways. Without this, practice can become dull and unengaging, making the learner inflexible with their learning (Alloway, 2006). Active processing can be undertaken by using free-recall, which provides no external cues making it much harder to retrieve memories. This is often effective in improving the quality of learning but may be negatively viewed by pupils who struggle with the more difficult tasks typically involved as part of it (Koriat & Levy-Sadot, 2001). Another technique is to use quizzing, which can ensure pupils are more attentive, since they are expecting to be quizzed (Weinstein, Gilmore, Szpunar, & McDermott, 2014). It also enables formative assessment to take place, allowing for the teacher to see what the pupils are struggling with (ibid.). The format of the quizzing whether multiple-choice, short-answer etc. seems to have little effect on memory; it is the action of quizzing that improves it (Smith & Karpicke, 2014).

Knowledge Organisers

Another essential element of cognitive psychology in allowing for the efficient recall and retaining of information is an organised cognitive system of prior knowledge (Reif, 2010). New knowledge is most easily acquired when it is built upon what we already know and perceived as concrete knowledge (Willingham, 2010). It can be thought of as a process of identifying what the learner already knows, ascertaining it and teaching the learner accordingly (Ausubel, Novak, & Hanesian, 1968). Often teaching does not adhere to this, especially when it is taught in a series of analogies. The only way in which these analogies can be effective to learning is if there are similarities between the existing knowledge pupils have and what is being taught (Richland, Zur, & Holyoak, 2007). Organising knowledge is not a simple task, yet it is often left to pupils with a lack of efficiently taught techniques. Pupils can therefore often struggle to organise their knowledge, making it harder for them to access and retrieve knowledge (Reif, 2010).

There is currently no proof of the often-referenced cognitive styles and multiple intelligences influencing learning and background knowledge may therefore be the only difference between pupils understanding of new content (Willingham, 2010). This has been illustrated by the 'Doctor and Fortress' problems (Gick & Holyoak, 1983), described in Table 1. Here, the same problem is posed in different contexts, with it expected to be easier to understand the second time once the solution had been explained. The results did show a marginal improvement with a 30% increase in success rate however, this was not as great as expected (ibid.). It is thought that merely describing the solution had not changed the deep-set understanding as it had not been organised/processed into an effective manner in the long-term memory (Willingham, 2010).

Description of Problem	Solution and Results from Study
1. You are a doctor with a patient who has a malignant tumour. It is impossible to operate but unless it is destroyed the patient will die. A kind of ray can be used to destroy the tumour; if it reaches the tumour at a significantly high intensity then the tumour will be destroyed. However, at this intensity the healthy tissue the rays pass through will also be destroyed. At a lower intensity, it will pass through the healthy tissue but also not have an effect on the tumour. How can the tumour be destroyed?	The solution here is to fire many rays at lower intensities, which will not individually effect healthy tissue but together can destroy the tumour. Most did not provide the correct solution to the problem. For those who did not solve the problem, the solution was explained before moving onto the next problem.
2. A dictator ruled a small country from a fortress. The fortress was in the middle of the country with many roads stretching out from it. A general vowed to capture the fortress and knew if his whole army attacked at once he could capture it. A spy reported that mines were placed on each of the roads, small bodies of men could pass over these but a large force would detonate them. How could the fortress be attacked?	The solution for the general here requires a similar solution with small forces attacking from many directions. This will prevent the detonation of the mines whilst still allowing a large enough force to attack. Even though the problems have the same deep structure and the solution to problem 1 had been explained. Only 30 percent could solve the second problem, even after hearing the solution to the first.

Table 1: Description and results of the doctor and fortress problems, studying the way in which we solve problems (Gick & Holyoak, 1983)

The access of background knowledge has a special significance in science. One makes science with facts in the way that one makes a house with stones, but an accumulation of facts is no more science than a pile of stones is a house (Poincaré, 1902). This illustrates the importance of having a good organisation of scientific knowledge and one method of doing so is in a hierarchical structure (Reif, 2010). This is close to how we would imagine a concept map as learning is most effective in this format (Novak, 1990). A schematic diagram of a hierarchical structure is shown in Figure 4. The most central knowledge structure is shown at the top of the figure, which then splits into smaller clusters of subordinate knowledge. The subordinate knowledge can be then split again creating a hierarchical organisation of knowledge. Different colours here represent different pieces of knowledge that can be accessed. The main advantages to this structure are: it is compact and easier to access knowledge, it is easier to retrieve information as only a few pieces of information have to be made at each branch and it is easier to modify and change knowledge. This is a beneficial structure in longer problems, where pupils can have a detailed route of the pathway taken and the stages used to get to the answer, rather than just the final goal (Reif, 2010). This structure has been shown to help pupils' cognitive load and improve their success rate in a study involving solving complex mathematics problems with and without a clear structure (Rosenshine, 2010). It is clear that memory plays a fundamental role in the ability for pupils to recall and retain information and therefore for pupils to learn effectively. Whilst an understanding of memory is important other factors such as how pupils perceive learning can influence learning, the possible effects of this will now be considered.

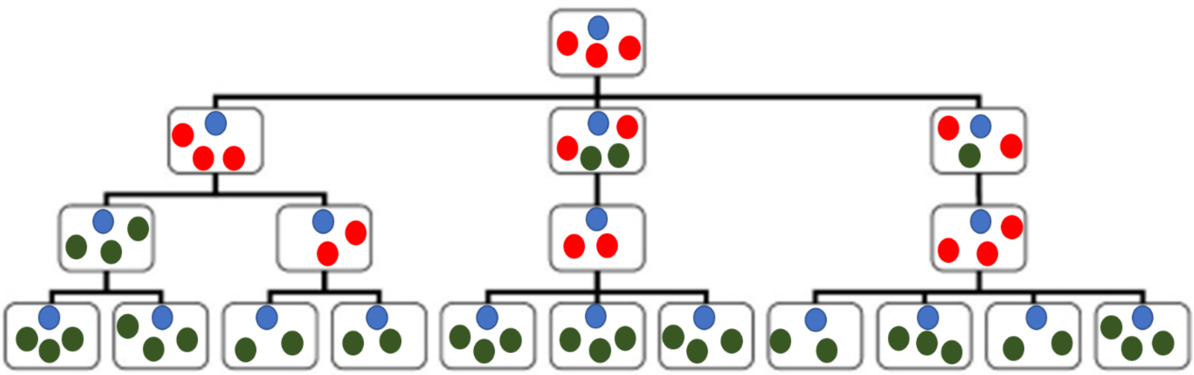


Figure 4: Hierarchical structure of knowledge, adapted from Reif, (2010)

Pupils' Perception of Learning

A pupil's belief in their own intelligence and ability is a factor for both their behaviour and learning (Ruddock & McIntyre, 2007). For example, meta-analysis of motivation in physical education has shown that performance can improve if they feel that it is reliant on their own hard work (Burnette, O'Boyle, VanEpps, Pollack, & Finkel, 2013). There has been some success in improving a pupil's perception of their learning by teaching university students' cognitive techniques and study skills under the broader term of 'self-regulation' (Paris & Winograd, 2017). These study techniques can change pupils' attitudes towards learning and cognitive techniques both inside and outside the classroom (Entwistle, Meyer, & Tait, 1991). The implementation of cognitive techniques that focus on pupil-centred motivational learning approaches has not however been commonly researched (Wolfe, 2017). The lack of the appropriate study skills can have a detrimental impact on the academic success of pupils, it has been shown that pupils who arrive at university with poor study skills are more likely to perform poorly on academic testing (Meyer, 1992). Additionally, if pupils are not enjoying the challenge, they are unlikely to effectively learn (Willingham, 2010). Both challenging and varied tasks are required for pupils to successfully engage and improve in their learning when applying cognitive techniques in the classroom (Willingham, 2010). Having broadly considered the effect of memory and student perception on learning, it is important to also look at the specific content that is to be learned. This will identify subject specific issues and misconceptions that may affect a pupil's learning.

Understanding Cells and Organisation

Misconceptions and difficulties encountered when teaching the topic of cells and organisation has been widely researched. Below are outlined some of the common challenges that are often found prior to and during teaching:

- Everything that moves is alive. Plants, seeds and eggs are not living (Squires, Driver, & Rushworth, 1994).
- Only certain parts of the body are made up of cells. Cells consist of amorphous jelly. Conceptual difficulties with the small scale. (Squires, Driver, & Rushworth, 1994).
- Difficulty in relating structure to function (Squires, Driver, & Rushworth, 1994).
- Misunderstandings of diffusion including diffusion being caused by the weight/mass of the liquids and the cells mixing with each other during diffusion (Marek, Cowan, & Cavallo, 1994).
- Difficulties in differentiating the roles of organelles in plant and animal cells. Photosynthesis takes place in mitochondria, as this is the 'powerhouse' of the cell. The nucleus is the site of all production in the cells (Hailegebriel, 2014).

- A large cell has a larger surface area to volume ratio than a small cell because it is bigger (Hailegebriel, 2014).

Research Design and Methodology

Research Outline

The literature has demonstrated a variety of methods to integrate recall practice and knowledge organisers into a teaching sequence, including pop quizzes, frequent formative testing and a hierarchical organisation structure of knowledge created for a topic. It is suggested that these can help to improve a pupil's ability to effectively retrieve material from their long-term memory and consequently improve their learning. In addition to this, pupils often have misconceptions of effective learning. Considering these themes within the literature, three more specific research questions have been developed for this study, shown in Table 2. Each of these questions will focus on the learning of cells and organisation and will explore how these answers may or may not be applicable to other topics.

Research Question 1 (RQ1)	What techniques may be used to implement knowledge organisers and recall practice in a classroom?
Research Question 2 (RQ2)	What are some of the effects that knowledge organisers and recall practice may have on pupils' learning?
Research Question 3 (RQ3)	Can an understanding of recall practice and knowledge organisers help to improve pupils' confidence and perception of their own learning?

Table 2: Separate research questions considering during this study

The project was conducted using action research; a process of repeated cycles of planning, observing and reflecting to improve practice (Hine, 2013). In education, this can be defined as a process which provides new knowledge and understanding about how to improve educational practices (Mills, 2011). It is often viewed as a cycle or a helix model and can be thought of as a repeated process of 'Look, Act, Think' (Stringer, 2008), shown in Figure 5.

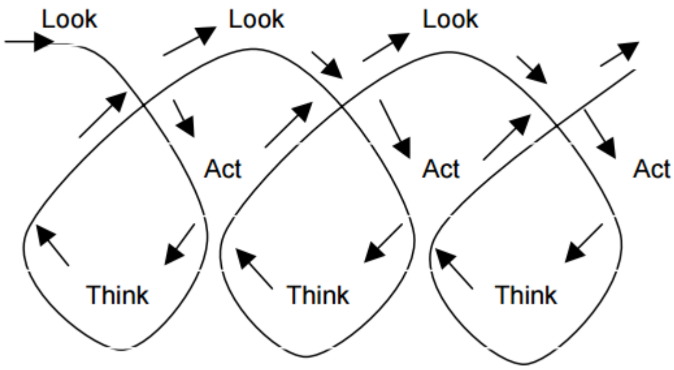


Figure 5: The 'Look, Act, Think' model of action research (adapted from Stringer, 2008, p.4)

Due to time limitations, only the first cycle of the action research could be carried out in this study. Observations and information will be gathered in the 'Look Stage', followed by analysis of this in the 'Think Stage'. Newly found information and possible recommendations for the next cycle of action research will then be proposed in the 'Act Stage' (Stringer, 2008). However, this cyclic approach has been taken across the lessons taught to allow for adjustments on a lesson-lesson basis. This method of research was chosen as it provides a simple method of observing what is happening in the classroom (Hine, 2013). It further allows for an emphasis to be placed on the methods used and for considerations to be made on how they may be improved upon through further cycles. This ensuring a way of producing effective change in this area.

In the planning stage of the action research cycle lessons were planned to address the research questions, incorporating techniques/methods to aid pupils. Table 3 outlines the taught with a brief description of the content. Appendix 1, shows a detailed version of one lesson plan with key phrases highlighted, that relate specifically to the research questions.

Lesson	Overview of Content
1. Microscopes and Introduction to Cells	Describe the key features of a microscope, be able to prepare a slide, understand all living things are made up of cells which are not visible to the naked eye
2. Animal Cells	Describe the key features of an animal cell, use analogies to understand the role of organelles in a cell
3. Plant Cells	Distinguish the differences between plant and animal cells, understand what is meant by a specialised cell
4. Unicellular Organisms	Describe organisms that are made up of a single cell, understand how these cells and different and similar to animal/plant cells
5. Organisation	Be able to use hierarchy to classify objects, understand why it may be useful to organise organisms, use and recall the levels of organisation
6. Bones	Identify some of the different bones of the body, understand why we need bones
7. Skeleton	Identify the key features of a human skeleton, create a skeleton model and describe some of the key bones
8. Muscles	Define a muscle and describe why we need muscles, use practical dissection techniques to identify muscles, describe how muscles tire
9. Joints	Understand why we need joints and where the key joints are, describe the different types of joints
10. Breathing	Describe the process of breathing, understand how we get oxygen in the blood, describe how the diaphragm relates to breathing

Table 3: Overview of lesson content in the teaching sequence

Various techniques of recall practice were used including several quiz formats, free recall questions and low-stake testing. The knowledge organisers used for cells is given as an exemplar in Figure 6 (See Appendix 2 for the knowledge organiser relating to organisation).

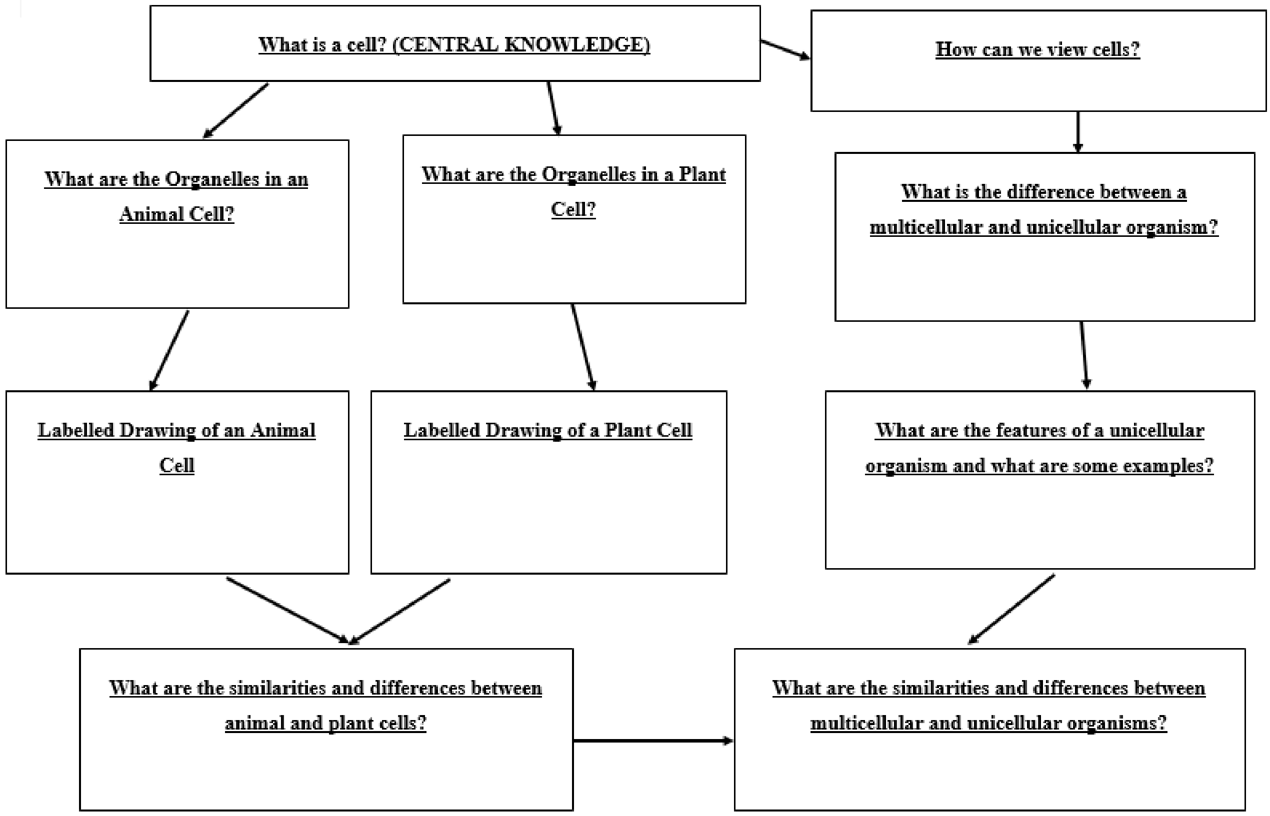


Figure 6: Knowledge organiser used for the cells topic

Targeting Misconceptions and Difficulties

The misconceptions and difficulties highlighted on page 12 are shown alongside the measures that will be put in place to attempt to reduce the effect in Table 4. These methods will be employed with the cognitive techniques discussed. For example, the use of frequent questions for cells, tissues and organs will be conducted using several different recall practice techniques spaced out over the course of the sequence. This will help to both target pupils' misconceptions whilst also implementing the cognitive methods.

Difficulties and Misconceptions Pupil's May Have in Understanding	**Measures to Reduce Effect of Difficulties and Misconceptions**
Everything that moves is alive. Plants, seeds and eggs are not living (Squires, Driver, & Rushworth, 1994).	Demonstrate to pupils how there are different criteria needed not just movement to show that something is living (Squires, Driver, & Rushworth, 1994). Look at plants in detail and show how they fit all the characteristics of life.
Only certain parts of the body are made up of cells. Cells consist of amorphous jelly. Conceptual difficulties with the small scale. (Squires, Driver, & Rushworth, 1994).	Teaching cells using examples of building models that pupils can relate to, giving an idea of scale (Squires, Driver, & Rushworth, 1994).
Difficulty in relating structure to function (Squires, Driver, & Rushworth, 1994).	Frequent questioning for cells, tissues, organs and organ systems on how the structure of different parts at all these organisational levels relates to function.
Misunderstandings of diffusion including diffusion being caused by the weight/mass of the liquids and the cells mixing with each other during diffusion (Marek, Cowan, & Cavallo, 1994).	Pupils understanding diffusion through practical experimentations and demonstrations as well as teacher-led discussions. Relating ideas back to everyday examples. (Marek, Cowan, & Cavallo, 1994).
Difficulties in differentiating the roles of organelles in plant and animal cells. Photosynthesis takes place in mitochondria, as this is the 'powerhouse' of the cell. The nucleus is the site of all production in the cells (Hailegebriel, 2014).	Careful examples of the roles of organelles in each cell. Constant checking of pupil's knowledge on the roles of organelles within the cell.
A large cell has a larger surface area to volume ratio than a small cell because it is bigger (Hailegebriel, 2014).	Practical demonstration using diffusion cubes to show how size does not relate to an object having a large surface area to volume ratio.

Table 4: Common pupil misunderstandings of cells and organisation and how these may be accounted for in the teaching sequence

Ethics

The planned research was discussed and agreed with the subject lecturer, mentor and professional tutor. Additionally, the faculty ethics form was completed and the research was approved as part of the school's general research ethics. Discussions were held between the professional tutor and the head teacher to ensure that the research adhered to the school's policy. The study followed BERA's, (2011) ethical guidelines throughout. Both the class teacher and pupils were informed of the purpose of the study being undertaken. It is important that the ethical guidelines were followed to ensure that moral and social values were upheld throughout (Resnik, 2015). Pupils were consequently informed that the information collected would be anonymous and would not be used to assess their progress within school. Additionally, pupils who were selected to conduct working memory assessments were not told their working memory score, which may have affected their confidence in their ability to learn.

Class and School Information

The research was conducted at a single sex girls' Academy for 11-18 years, in a home county. This school was publicly rated as outstanding with both the proportion of special educational needs and EAL (English as an additional language) pupils are far below the national average. This study was conducted as part of the PGCE training course and focuses on a small class of 18 Year 7 pupils, who are classified as a lower attainment band in the school. CATs (cognitive ability tests) are viewed as a reliable measure for predicting pupils' progress and current level (Moody, 2001). A combination of both CATs and KS2 (key stage 2) test scores allows for a more accurate barometer of pupils' current attainment levels (Strand, 2006). The ranges for both are show in Figure 7.

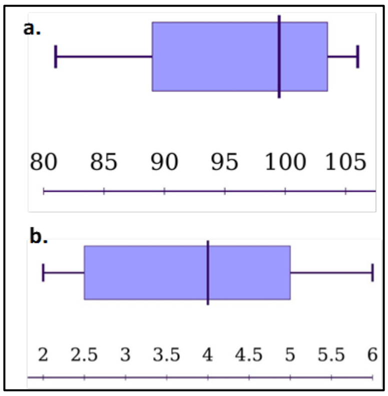


Figure 7: Box plots showing the range of results for a. average scaled scores and b. CATS scores

There is clearly a large range of ability in the class between the lower and highest attainers, with scaled scores i.e. ranging from 82 to 105 and CATS scores from 2 to 6. The median shown by the central line in plot a for scaled scores falls only slightly below the expected average of 100 (Department of Education, 2016).

Data Collection

A variety of data collection methods were used in the study, with some whole-class and some focused-on case-study pupils. This approach was taken to allow an overarching viewpoint of the class but also to provide a basis for a more in-depth analysis of certain aspects of the process. For the three case studies, one representative pupils (pupils D, I and J respectively) from each of the low, middle and high attaining groups for the class was selected using CATS and KS2 data. The main limitation of this approach is that generalisations can occur; only a small proportion of the class is considered (Yin, 1984). Overall it was felt that the advantages of analysing quantitative and qualitative data in greater detail for these pupils outweighed some of the costs of not increasing the sampling size (Yin, 1984). A summary of the data collection methods is summarised in Table 5. This table also indicates whether the methods have been used to collect data for the whole-class or case study pupils and the research questions (see Table 2 earlier) they correspond to.

Data Collection Method	Whole Class (WC) or Case Study (CS)	Research Question 1	Research Question 2	Research Question 3
Summative Assessments	WC		✓	
Pupil Questionnaire	WC	✓		✓
Individual Pupil Interviews	CS	✓	✓	✓
Exit Tickets	WC			✓
Journal Entries	WC	✓	✓	✓
Focused Observations	WC	✓	✓	✓
Memory Tests	CS		✓	

Table 5: Overview of the data collection methods used in this study

Summative Assessments

Summative testing was used at three points along the teaching sequence to gauge pupils' performance at the beginning (prior to lesson 1), midway (lesson 5) and final point (following lesson 10). Two of these tests were multiple-choice tests conducted using online Alfie Software (AlfieCloud, 2017). Between these was the mid-point test, which consisted of longer written 'exam-style' questions. The mid-way test was designed to allow for adjustments and alterations of the cognitive techniques, in accordance with the process of active research (Stringer, 2008). Summative assessments are useful methods to understand and evaluate learning at a point in time (Garrison & Ehringhaus, 2007), helping to provide a measure of any changes in learning or understanding. There are limitations to the use of summative assessments, as it is often difficult to provide tests and questions that target understanding effectively (Murphy, 1990). Pupils can also often find these tests stressful and therefore not perform as well as their understanding warrants (Gauld, 1980). The use of multiple tests with different structures has been put in place to account for some of these limitations.

Pupil Questionnaire

The questionnaire was administered at the start of the sequence, which totalled twenty questions split into two sections. These questions were taken from a similar study carried out into learning for 352 undergraduates (Wolfe, 2017). Due to the different age range previously administered by Wolfe (2017), some questions were modified to be more suitable for Yr 7 pupils. The questions are designed to assess pupils' attitudes towards learning; methods they administered to study and how they preferred to study and felt they learnt best (Wolfe, 2017). The first section consists of statements about study habits, which pupils may either agree or disagree with. This includes both positive statements such as 'I know how I learn best' and negative statements such as 'I find it difficult to connect topics'. The second consists of open-ended qualitative questions (see Appendix 3). Some limitations here are that open-ended questions can often result in vague answers (Johnson & Turner, 2003). Additionally, there may be reactive effects if pupils feel the results could be used to grade them (ibid.). To attempt to reduce the effects of this, the questionnaire has been conducted anonymously.

Pupil Interviews

Case-study pupils were interviewed at the beginning and end of the sequence (see Appendix 4). Interviews were designed to be a standardised open-ended interview, allowing for a structured interview that still allowed for the expansion on any points of interest (Johnson & Christensen, 2008). There are limitations to this, as it can lead to a broad range of often irrelevant answers and be challenging to develop relevant probing questions (Johnson & Turner, 2003). Care was taken in the interviews to follow the guidelines for successful interviewing to improve the validity (Berry, 1999). Questions in the interview conducted before the teaching sequence began focused on finding whether pupils had any prior understanding of how they best learn. In general, the questions aimed to decipher whether pupils were competent with study skills such as; memorising and retrieving information on demand, organising and managing activities efficiently and locating required information (Hoover, 1989). The interview conducted at the end of the study aimed to address RQ1 and RQ3, seeing if the confidence of pupils had increased and to gather some information of whether the cognitive methods used had been successful.

Exit Tickets

Exit tickets were administered at the end of each lesson with pupils rating their confidence between 1 and 5 on the different topics covered (Appendix 5). This allowed for comparisons to be made across the sequence and to see whether the use of cognitive techniques helped pupils perception of learning (RQ3). Two open-ended questions were included on the exit tickets which asked pupils to identify areas they found difficult and what helped them learn most in the lesson. This meant that lessons could be adapted if necessary in accordance with the process of action research (Stringer, 2008). Here, exit tickets were used to provide information on the instructional strategies used and allow for pupils' self-analysis (Marzano, 2012). However, there was no opportunity for communication between the pupil and the teacher (Marzano, 2012). Another issue is that the quality of response can often be lower, since they are conducted at the end of the lesson (Angela, McCoy, & Weed, 2016).

Journal Entries and Focused Observations

A key identifier in ensuring that cognitive psychology techniques are being implemented effectively is to keep a journal of thoughts (Willingham, 2010). A detailed journal of each lesson has been created to allow for immediate self-reflection; providing a method of analysing the research and adjusting it when necessary (Ortlipp, 2008). Self-reflection has been combined with focused observations by an observing teacher; removing one of the biggest limitations of self-reflection in that it can be biased (Johnson & Turner, 2003). The observer was made aware of the three research questions (Table 2), to make the observations structured and applicable to the study. Care still needs to be taken however, as it is often difficult for the observer to correlate events to the research questions (Treanor, 2010).

Memory Tests

To understand the working memory levels of the class, pre-testing was carried out using three different barometers for working memory capacity. There are several validated tests that can be used, examples include the Automated Working Memory Assessment (Alloway, 2007), and the Observation Based Working Memory Rating Scale (Alloway & Gathercole, 2008). A series of batteries developed by Stone & Towse (2015), were selected, as they provide free to use validated software, which can be flexibly altered and used with ease by pupils and researchers.

The first test selected was the Operation Span, a complex span task (Daneman & Carpenter, 1980). For this a series of digits must be recalled, whilst additionally processing whether simple mathematical calculations are true or false (Turner & Engle, 1989). The Operation Span is designed to test working memory storage, whilst a distraction in the form of processing is also occurring (Conway, Cowan, & Bunting, 2001). This method of moving backwards and forwards between multiple operations is a key determinant of testing processing and storage (Clair-Thompson, 2006). A review of this method has shown that it is a reliable comparative measure of working memory (Conway et al., 2001). This has been combined with the Digit Span, which removes the processing phase of the Operation Span, allowing for comparisons to be made on the effect of the processing stage (Wilhelm, Hidldebrandt, & Oberauer, 2013). Lastly, a Matrix Span was administered; this is a spatial complex task where grid locations must be remembered (Stone & Towse, 2015). It aims to focus on the visuo-spatial side of working memory, which can show great variation across individuals (Clair-Thompson, 2006). The three tests were carried out by case-study pupils in the class and comparatively assessed to determine an overall assessment of working memory.

Data Analysis and Findings

In the following section, each of the research questions will be considering individually. For this the findings from the acquired data will be presented and analyzed below each of the research questions.

What techniques may be used to implement Knowledge Organisers and Recall Practice in a classroom?

Pupil Questionnaire

The written responses provided a detailed view on pupils' preferred methods of learning and their methods of revision, prior to the teaching sequence. The results are shown in Figure 8. From this the most popular method of learning was practical work and many pupils described in greater detail how they felt that this was most beneficial to their learning. This result is likely due to practical work often being enjoyed by pupils' due to its varied and active approach (Braund & Driver, 2005). A lack of variation and activeness was considered one of the key issues with the successful implementation of recall practice (Willingham, 2010).

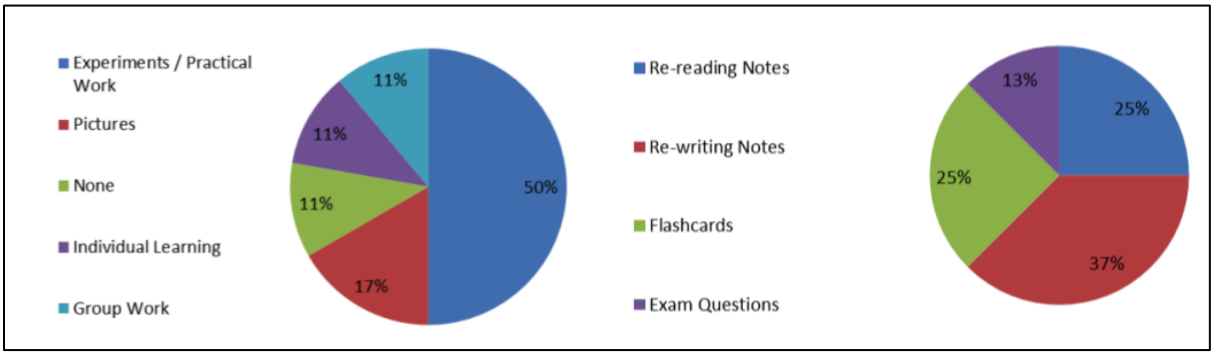


Figure 8: Data gathered from pupil questionnaire at the start of the teaching sequence.
a. Pupils responses to their preferred method of learning
b. Pupils responses to their preferred method of revision

The results from this questionnaire were used to ensure that the variation in activities was kept high. The responses for revision showed that some pupils utilised methods of recall practice, for example 25% identified flashcards as their preferred method. However, many pupils merely re-wrote or re-

read notes. These results agree with some of the common misconceptions pupils have of learning, with them often not knowing the benefits of recall practice techniques (Dunlosky et al., 2013).

Journal Entries and Teacher Observations

Journal entries and the teacher's observations matched on several points, regarding the use of recall practice and knowledge organisers. The strengths and weaknesses identified during the sequence are synthesized in Table 6. Findings have been presented in this manner, as there was insufficient validity to conduct further analysis.

Identified Strengths of Knowledge Organisers and Recall Practice	Identified Weaknesses of Knowledge Organisers and Recall Practice
Can be easily implemented into a lesson, without taking up significant periods of time or disrupting the flow	Pupils sometimes struggled with a large amount of quizzes and low-stake testing as they felt they didn't want to get answers wrong
Improved formative results in general, when content repeated over a sequence e.g. knowledge of the structure of the animal and plant cell vastly improved	Difficult to implement with more complex questions
Pupils became more used to not using notes for answers and appeared to do more thinking to access the relevant content in their memory	Pupils were reluctant to use the knowledge organisers until prompted to do so

Table 6: Strengths and weaknesses identified as trends from the combination of journal entries and the teacher's observational notes.

From this it can be suggested that there were some positive effects on pupils' memory such as the increase in pupils' thinking. An identified weakness was the implementation of recall practice with more complex questions, an area which has not been researched as thoroughly as shorter questions (Rosenshine, 2010). Additionally, pupils struggled with using the knowledge organisers and getting used to the different methods of recall practice. This may relate to pupils often not being aware of the techniques to help their memory (Wolfe, 2017). Personally, it was felt that it took time to get pupils used to the different methods and it was not always easy to get them to see the benefits of them immediately.

Interviews

Individual interviews with case-study pupils showed that none had previously been taught any ways to help improve their memory. However, all the pupils felt that knowledge organisers had provided them with some guidance with how to improve linking topics together:

> *Pupil D: 'they helped me to connect things for cells'*
>
> *Pupil J: 'it helped me to connect more easily what I was learning'*

Here 'connect' is used by both pupils in the interview, highlighting how it helped them to structure ideas together (Rosenshine, 2010). In terms of recall practice the pupils agreed that they enjoyed doing the quizzes and that they provided some benefit:

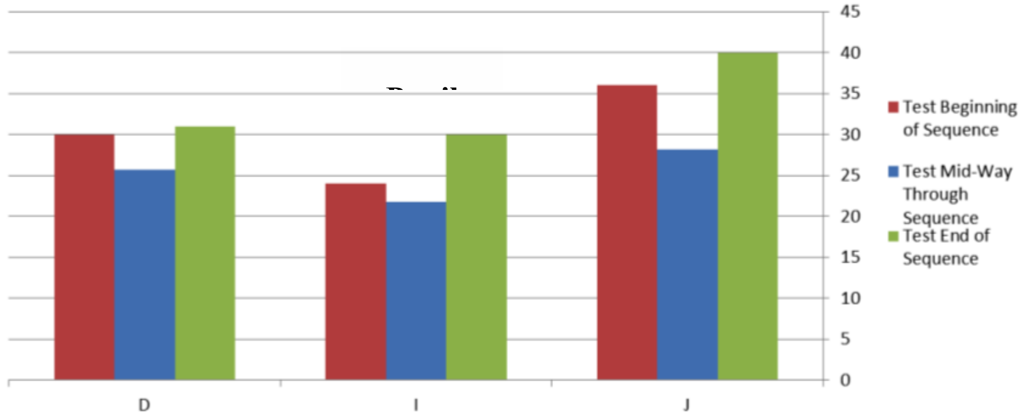
> *Pupil J: 'The mini-quizzes have helped but quizzes always help me check what I have learnt'*
>
> *Pupil I: 'Quizzes help me to check what I do and don't know'*

However, pupils did not identify other methods of low-stake testing as helping them to learn in the classroom or during revision. This suggests there may be a lack of variety in pupils understanding of recall practice techniques (Reif, 2010). Each of the pupil further commented that they would like to know more about how to improve their memory. Even though pupils were exposed to several recall practice techniques they did not clearly make the link with being able to use these to improve their memory.

What are some of the effects that Knowledge Organisers and Recall Practice may have on pupils' learning?

Summative Assessments

The scaled scores for the summative assessments for the three case-study pupils along with the average score, standard deviation and range are shown in Figure 9. The maximum score attainable for each of the tests was 50 marks. Averages, standard deviations and ranges for each of the tests across the class are shown in the table under the graph.



	Test Beginning of Sequence	Test Mid-Way Though Sequence	Test End of Sequence
Average	25.1	21.0	28.4
Range	28	29	22
Standard Deviation	6.3	6.7	6.4

Figure 9: Case-study pupil results for three tests taken across the teaching sequence.

Pupils generally performed considerably lower on the second assessment, with a lower average of 21. This is due to it including a higher order of thinking, with longer written questions challenging pupils understanding more. Comparisons can be made between the beginning and end tests in the sequence, as these were similar in structure (AlfieCloud, 2017). The case-study pupils all improved on their results in the sequence. This matched that seen across the class, with 72% of pupils showing an improvement between the two tests, with an average increase of approximately three marks. The standard deviation was similar for both tests, suggesting that the pupils were similarly distributed around this mean value. This result must be taken with some care however, as the tests were composed of different topics.

The content of the mid-way and end tests was broadly similar and the strengths and weaknesses of pupils across these two tests are shown in Figure 10.

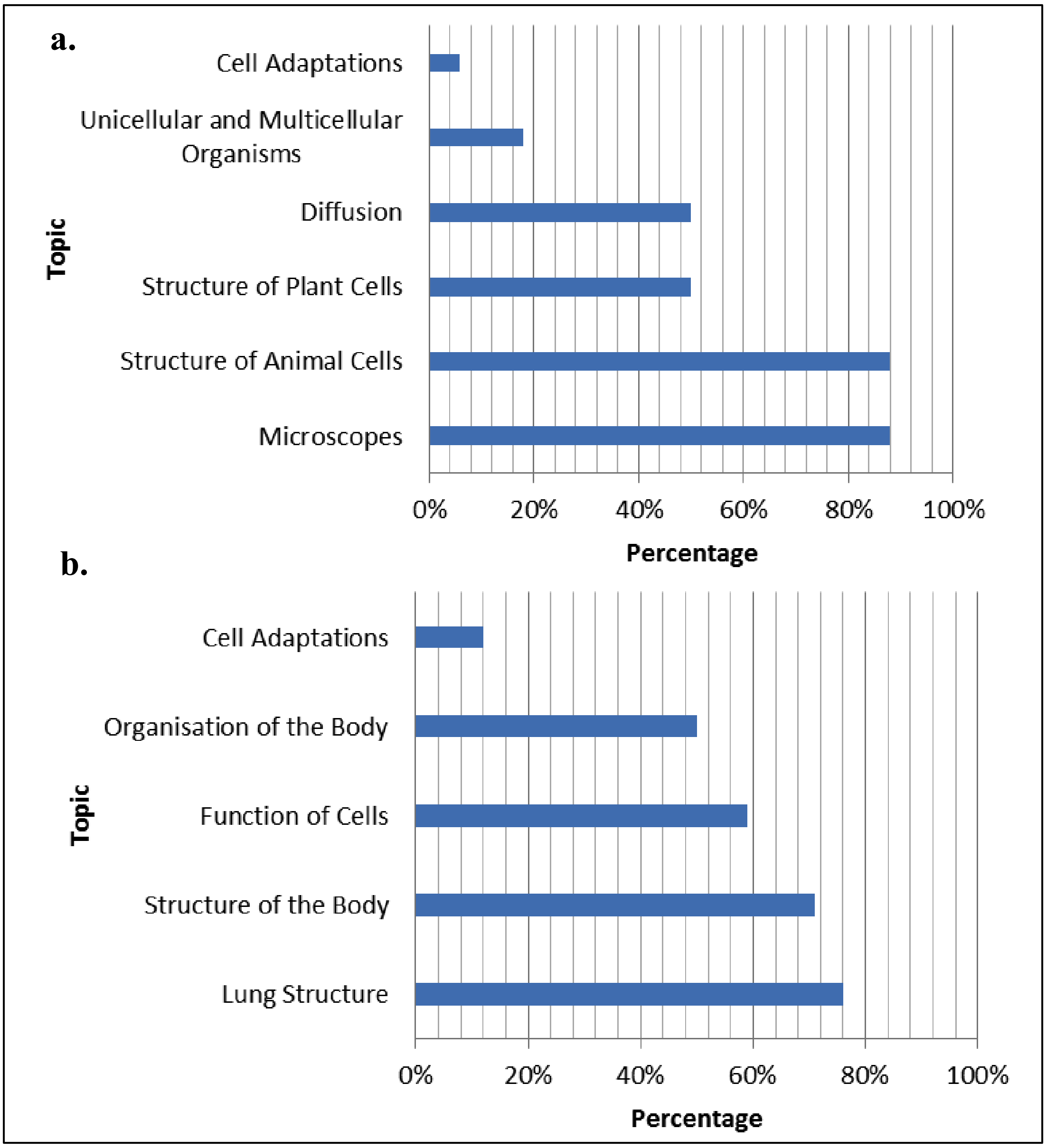


Figure 10: Percentage of pupils who achieved a high mark (above 80%) in questions relating to specific topics.
a. Test mid-way through sequence and b. test end of sequence

What is apparent from this is pupils struggled and performed well at similar topics. Cell adaptations proved tricky for pupils in both tests, whereas structures of either the cells or the body/lungs were generally areas of good performance. These topics focus more on remembering knowledge and the cognitive methods appear to have had some effect on the knowledge retention of pupils, matching previous studies (Pomerance, Greenberg, & Walsh, 2016). However, it appears to have had little effect on pupils' performance on more complex understanding questions. This was despite the revisiting of cell adaptations more frequently after the mid-point test, in accordance with the active research process (Stringer, 2008).

Pupil Interviews, Observations and Journal Entries

As previously mentioned, each case-study pupil felt that both the knowledge organisers and the use of mini-quizzes helped their learning. A surprising finding was that pupils found that tests were helpful, something which is usually viewed as stressful by pupils (Gauld, 1980). When asked about the helpfulness of tests:

> *Pupil I: 'Yes, if you get them wrong you can go back through them and work them out. Then next test I would be able to improve on them'*
>
> *Pupil D: 'I find tests do actually help me to learn things'*

This question was asked at the end of the sequence but not the beginning, which limits the conclusions that can be drawn from the responses. However, it may be suggested that recall practice with frequent low-stake testing may have altered some of the perceptions that pupils have of tests.

There were several trends seen between the journal entries and observations in terms of pupils learning across the sequence. Formative assessment of pupil's responses during class showed a marked improvement in their knowledge retention between lessons. This was monitored through the observations and as expected the more pupils answered similar questions and practiced the greater their success rate (Dunlosky et al., 2013). Due to time constraints data was not gathered to validate this but it was noted in both journal entries and observations of pupil's work made by the observer.

Memory Tests

The performance of the three case-study pupils for the memory tests are shown in Figure 11. To get a clearer individual perspective of the working memory of each pupil, a summary of the results and average for each individual is shown in Figure 12.

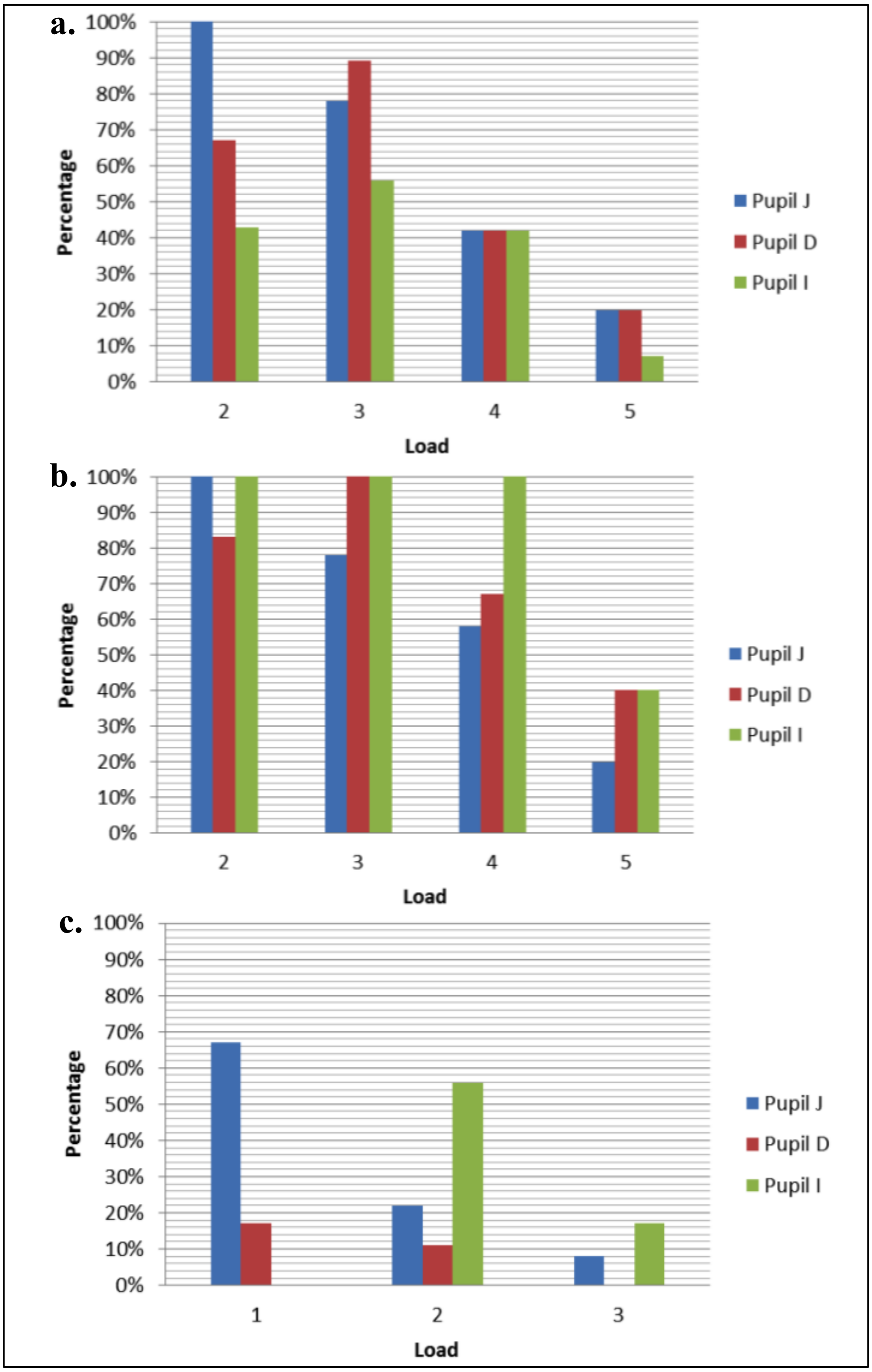


Figure 11: Results for each of the working memory tests.

The load indicates the amount of items a pupil must remember, plotted against their success rate: a. Digit Span. b. Matrix Span. c. Operation Span.

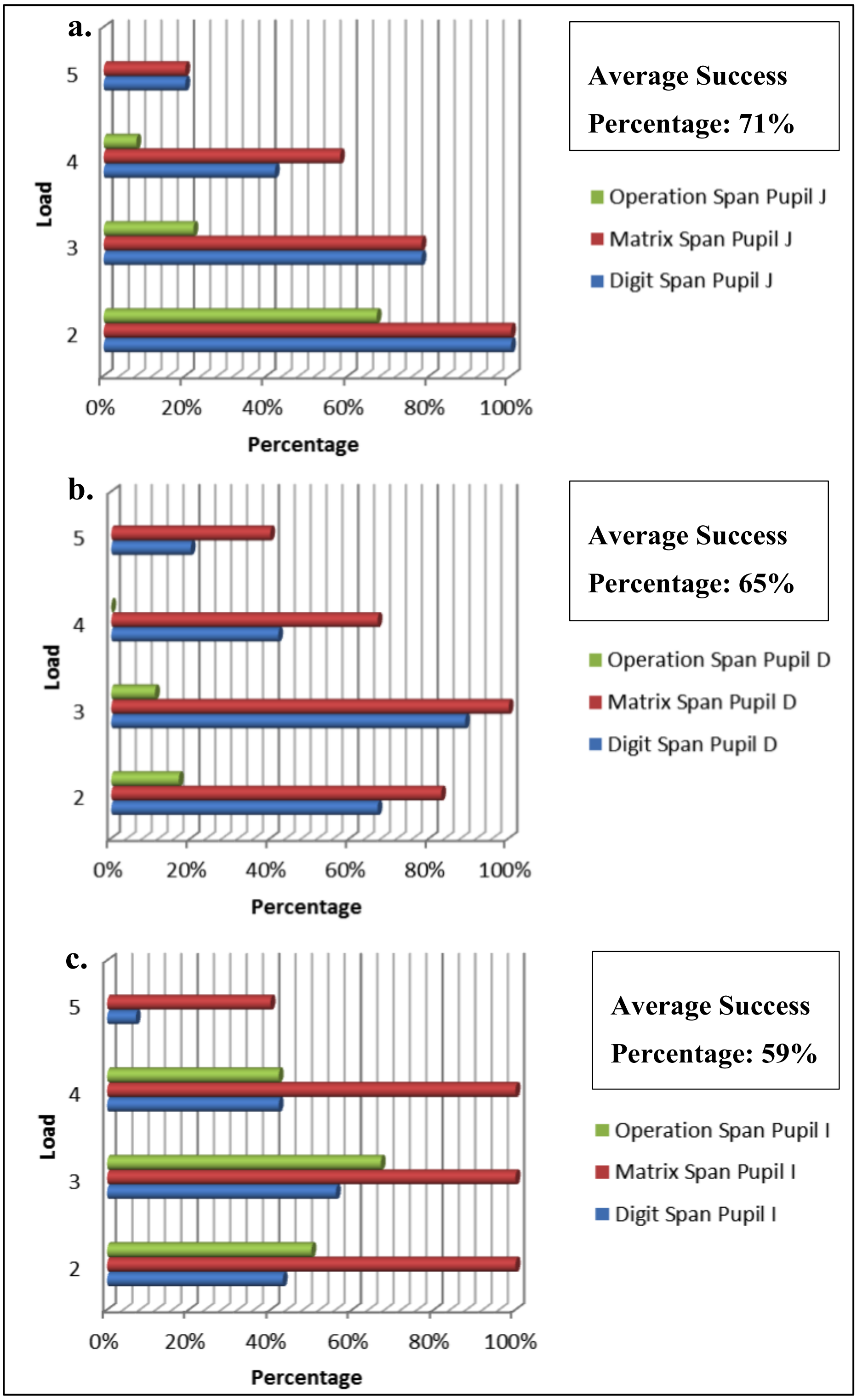


Figure 12: Results of the working memory tests for each individual pupil. The load indicates the number of items a pupil must remember, plotted against their success rate. Average success percentages for each pupil across the tests are shown alongside the graphs: a. Pupil J b. Pupil D c. Pupil I

Pupils generally performed better at the Matrix Span, indicating that they had a stronger visuo-spatial working memory (Clair-Thompson, 2006). Further, the pupils all struggled in the Operation Span, as expected when an additional level of processing is added (Wilhelm et al., 2013). An interesting feature is the variation in different aspects of working memory that each pupil had. For example, pupil I performed strongest at the Matrix Span but was the weakest performer in the Digit Span. It was expected that by picking a high, middle and low attaining pupil that the higher attaining pupil would achieve the highest results in each of the tests but this was not the case.

Working memory scores are compared to the average test scores of the case-study pupils in Table 7. This shows a clear correlation between the two, with a higher working memory leading to a better performance in tests.

Pupil	Working Memory Success Percentage (%)	Average Test Score
Pupil J	71	35
Pupil D	65	29
Pupil I	59	22

Table 7: Working memory success percentage compared against average test scores for each case-study pupil

The results correspond to what is expected with a higher working memory, leading to better test performance (Conway et al., 2001). This data can only suggest there may be a link between the two, it is limited in the fact that it does not provide any evidence as to whether the knowledge organisers and recall practice helped to improve the pupils working memory, with the tests being administered at the beginning of the study.

Can an understanding of Recall Practice and Knowledge Organisers help to improve pupils' confidence and perception of their own learning?

Pupil Questionnaire

The questionnaire looked at both pupils own study habits and the way they learn, this helps to give an idea of how pupils perceive how they learn best (Wolfe, 2017). The percentage of pupils that agreed with the different statements is shown in Table 8.

Statement	Percentage of Class Agreeing with Statement (%)
I know how I learn best	90
I enjoy learning new things	80
I find it easy to learn new content	73
I find it more difficult to answer longer questions with several steps	73
I find it difficult to connect topics	62
I repeat similar practice questions to learn	50
I find it confusing to determine how topics link	45
I have difficulty determining the important points in class	23
I revise the key points of the previous lesson	23
I struggle to know how to revise	15

Table 8: Statements given to the class at the start of the teaching sequence and the percentages of pupils who agreed with each statement

A high majority of pupils in the class believed they knew how they learned best, however only 15% agreed to successfully knowing how to revise. This suggesting that pupils often struggle when left to learn individually, not having the skills required to effectively learn new content (Wolfe, 2017). Pupils also seemed to struggle with longer questions and 62% found it difficult to connect topics. These are two areas in which the knowledge organisers can be effective in assisting with the high cognitive load involved (Reif, 2010). However, only 23% of pupils agreed to having difficulty determining the difficult points in class and only 45% in seeing how topics link. Again, these are issues that can be assisted using knowledge organisers. These pre-sequence results suggest that the use of recall practice and knowledge organisers may be useful at improving the confidence in some areas but not in others.

Pupil Interviews

Pupil interviews conducted prior to the teaching sequence showed similar results to those gathered in the questionnaire. Practical activities were most prominent when asked about what they believed was their best way of learning:

Pupil I: '... doing the actual experiment'

Pupil J: 'Practical activities, you are more involved in them and you can do them yourself'

Additionally, individual revision techniques were similarly identified as not involving a high level of recall practise, except for the use of flashcards:

Pupil J: 'I have a homework book where I write stuff down and rewrite notes, my Mum may occasionally use flashcards'

Pupil D: 'I make posters as well as my flashcards'

Interviews following the teaching sequence revealed that the case study pupil's confidence was high on the topics covered and the questions had helped to improve it. The pupils' all stated that they enjoyed the lesson as well, a key concern with the implementation of cognitive techniques (Willingham, 2010). The use of the cognitive methods did not appear to affect their motivation:

Pupil J: 'Getting questions right and doing quizzes to check that I can get them right does help to build my confidence'

Pupil I: 'I feel confident on what we have done; I would give myself an 8 out of 10'

Care must be taken with these results, as pupils may be biased by the interview and the non-anonymity of it (Johnson & Christensen, 2008). Overall however, pupil's confidence from the interviews was high and they felt that the lessons were enjoyable. More data would be required to assess whether this could be isolated to the effects of the cognitive methods.

Exit Tickets

Confidence ratings from the exit tickets have been averaged for different topics and are shown in Figure 13. Results were averaged from the whole class, with pupils being able to place a confidence rating of 1 lowest to 5 highest. Some of the data is limited due to the nature of teaching the topics in a sequence. Pupil's confidence with the structure of animal and plant cells as well as with microscopes improved across the sequence, rising from an average of 4.1 to 4.6 and 3.6 to 4.1 respectively. One possibility for this is confidence levels increased as pupils were continually exposed to previously covered material, via the use of recall practise and knowledge organisers (Dunlosky et al., 2013). Data is minimal for this however and a greater length of time would be needed to draw a more valid conclusion.

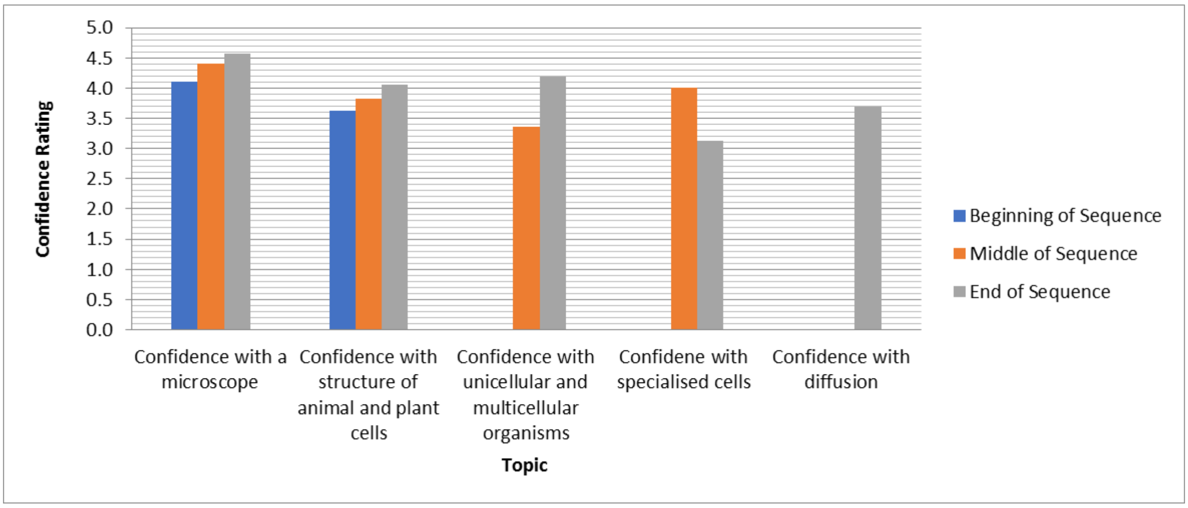


Figure 13: Confidence rating of pupils for a variety of topics across the teaching sequence (rating of 1 lowest to 5 highest)

Journal Entries and Focused Observations

One pattern in the observations and journal entries shown was pupils not initially being confident with low-stake testing. This is likely being due to them not having experienced a high amount of this in the past. It meant that they were tentative with writing incorrect answers and it took a significant amount of time for them to understand that it was not being used to grade them (Gauld, 1980). Once pupils had a clearer understanding of it being a method of analysing what they knew, they grew in confidence. Additionally, it was felt that as a class there was a greater confidence in pupils answering questions. Emphasised when they answered questions that they had recently covered during low-stake testing.

Discussion

What techniques may be used to implement Knowledge Organisers and Recall Practice in a classroom?

Data from the questionnaire such as only 15% of pupils agreeing to know the best way to revise, suggests that pupils did not recognize the benefits of recall practice. Additionally, it was shown in the interviews that pupils had not been given the relevant information to allow them to learn effectively using these methods, with flashcards being the only recall practice technique discussed by the pupils. This result is to be expected, especially with this still being the case for most college students (Wolfe, 2017). It additional corresponds to the fact pupils may have other misconceptions in how they best learn, as it is what they become used to (Kornell & Bjork, 2008). When implementing knowledge organisers and recall practice in the classroom, it is likely that time will have to be taken accounted for, to allow pupils to acclimatize to it. Pupils may also initially worry about getting answers wrong in the low-stake assessments, part of the negative perception of testing (Gauld, 1980).

The pupil interviews, journal entries and observations provided qualitative results that indicated that pupils found the techniques useful. Pupils stated in the interviews that they found both quizzes, re-testing and knowledge organisers helpful, with one pupil detailing how it was useful to know what they had got right and wrong so they could then improve. Pupils also described how knowledge organisers helped to provide structure and links, corresponding with one of the main aims of it (Novak, 1990).

It is not appropriate to draw any firm conclusions from this research question. This study suggests some methods that can be used but there is not enough statistically significant data to attest to which may be most effective. The techniques implemented also need to be personalised, for example the knowledge organisers designed were specific to the topic and attainment level of the class. It does however provide one template in a field which is currently gathering momentum in the educational research community (Brunskill & Enser, 2017).

What are some of the effects that Knowledge Organisers and Recall Practice may have on pupils' learning?

There was shown to be a link between performance in tests and the working memory of the three case-study pupils. This was demonstrated with an average score on the tests of 35 which matched with the highest success rate in the working memory tests of 71%. The same was true for the lower attaining pupil, whose average was 22, matching with a lower working memory success rate of 59%. This corresponding to what would be expected, with connections previously being shown for general intelligence and working memory (Conway et al., 2002).

The marked improvement between the two similarly structured summative assessments (AlfieCloud, 2017), at the beginning and end of the sequence suggests that there was a positive effect on pupils' performance. Overall 72% of pupils improved their score and on average the marks improved by three points across the tests. These tests consisted of mainly knowledge based questions and it is here where pupils were noted as having the biggest improvement in learning, from observations and journal entries. Concurring with the findings of previous studies where they have been shown to effectively improve pupils' knowledge retention (Agarwal et al., 2012; Dunlosky et al., 2013). Studies have previously been able to isolate the effects of these techniques (Roediger, Putnam, & Smith, 2011), here the effects cannot be isolated with any cetainty, only a general improvement can be concluded.

Pupils saw the positive effects of the knowledge organisers and recall practice. The case-study pupils discussed how they felt they were beneficial to them within the interviews, commenting on how they could see what they got wrong and 'improve on it'. It showed in the test scores, as they all improved or kept level with the score they had achieved at the beginning of the sequence. This awareness the pupils had of their improvement is not always apparent, with previous studies showing pupils may be oblivious to it (Karpicke & Roediger, 2008).

Can an understanding of Recall Practice and Knowledge Organisers help to improve pupils' confidence and perception of their own learning?

Data gathered from the questionnaire and interviews at start of the study suggested that pupils struggled with longer questions, however felt more comfortable connecting topics between lessons. This was illustrated with 73% of pupils stating that they struggled to answer longer questions but only 45% agreeing to finding it difficult to connect topics between lessons. This in part agreed with prior research, where the higher cognitive load involved in these tasks (Reif, 2010), means that pupils often struggle more. For this reason, it was unexpected for most pupils to feel that lessons were easy to connect. It could be due to previous teaching in science following a logical scheme, or the previous teacher frequently revising past content. Case-study pupils stated following the sequence that they felt confident with the topics covered and suggested that their confidence increased by conducting the low-stake assessments. Additionally, the exit ticket data showed an improvement in the confidence pupils felt they had in each topic. This was shown with the confidence pupils had in their understanding of animal and plant cells rising on average from 4.1 to 4.6 during the sequence. It could be tentatively suggested that this is due to pupils getting questions right more often and therefore having a more available knowledge of what their relative strengths and weaknesses are (Burnette et al., 2013). However, more data would be needed to confirm this suggestion.

In terms of the perceptions pupils had of their own learning, the initial questionnaire found that most pupils did not frequently use recall practice techniques as their preferred method of learning. This was shown with 50% of pupils stating practical work as their preferred method of learn and 37% described re-writing notes as their choice method of revision. It was apparent from the observation and journal notes that pupils were unfamiliar with these methods, as when low-stake testing was implemented in the classroom pupils were unsure of why it was being used and were concerned it was for grading. This is not typical, where often the issue involved in low-stake assessments is a lack of effort with no consequence for poor performance (Wise & DeMars, 2005). The effort may have been due to other facts, such as pupils seeing their knowledge improve and therefore believing the tasks had utility value (Wigfield & Eccles, 2000). What was also apparent in the interviews was pupils' enjoyment in the lesson sequence was not affected. This alleviating one of the concerns with recall practice becoming 'dull' if not implemented with enough variation (Willingham, 2010).

Recommendations for Further Research

An overriding limitation with this study was its inability to isolate the effects of different recall practice methods. Suggested further research would include dividing individual recall practice techniques or the single use of knowledge organisers and determining their effect. Additionally, there were time constraints with the study and as an active research project this report only provides the first stage of research. There are many considerations for the next cycle of research. For example, conducting a second whole class questionnaire to see whether pupil's attitudes towards learning had changed. As well as this, a more detailed analysis in interview scenarios of why pupils did or did not find recall practice and knowledge organisers useful could be researched. Both could be applied to provide more validated evidence on the effects that the cognitive techniques have in the classroom.

Due to their being relatively few classroom-based studies for secondary school pupils involving these techniques the scope for wider research is vast, as there are still a great number of unknowns in the strengths and limitations of cognitive approaches. This research has highlighted three important recommendations for those considering using knowledge organisers and recall practice in the classroom (Table 9).

	Recommendation
1.	It is unlikely that pupils will be familiar with recall practice and the use of knowledge organisers and they may have misconceptions about the usefulness of them. It is recommended that pupils be taught how to use these techniques outside of the classroom, for them to be most effective for learning.
2.	It is important to keep the use of knowledge organisers and recall practice varied and engaging. Without these pupils are less likely to engage, which could affect the success of them. Examples can include pop quizzes, use of revision style memory games and starter formative assessments.
3.	Ensure that pupils' confidence is not being affected by frequent testing. This can be monitored by using exit tickets for example, which can also act as a measure of where pupils believe their understanding level is at.

Table 9: Recommendations for the implementation of knowledge organisers and recall practice based upon the findings of this study

Conclusions

Undertaking the first cycle of this action research study has provided some suggestions into the implementation of knowledge organisers and recall practice in the classroom. Although multiple methods may be used, it has been observed that pupils may be unfamiliar with them and therefore it can take them time to for them to be effective. It is therefore recommended that they are introduced gradually, for pupils to become accustomed to them. Pupils did see the positive effects of them by the end of the study but no firm conclusions can be drawn for why this was case, opening an area for future research. Confidence of pupils did increase over the course of the study, which may be a key benefit of using these techniques.

As the research suggested the link between the working memory of pupils and their performance in assessments was clear. The performances showed an improvement during the study and it is suggested that the combination of factors lead to some improvements in the pupils learning. However, there are limitations to this conclusion, as there is insufficient evidence to confirm that this was the sole reason for the improved results. Pupils additionally discussed that they felt it was beneficial to their learning and their perception of the methods appeared to change across the sequence. Isolation of different methods of recall practice and the implementation of knowledge organisers would be needed to determine the effects of the individual techniques.

Overall the use of knowledge organisers and recall practice in this study has suggested that pupils' confidence and learning may be improved. These claims are made tentatively due to several mentioned limitations but it is recommended that these could be two of the key benefits. The study has touched some of the key benefits that can be gained from the use of cognitive methods in a classroom setting but many more doors are open to be explored, providing rich ideas for further action research cycles.

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Appendix 1

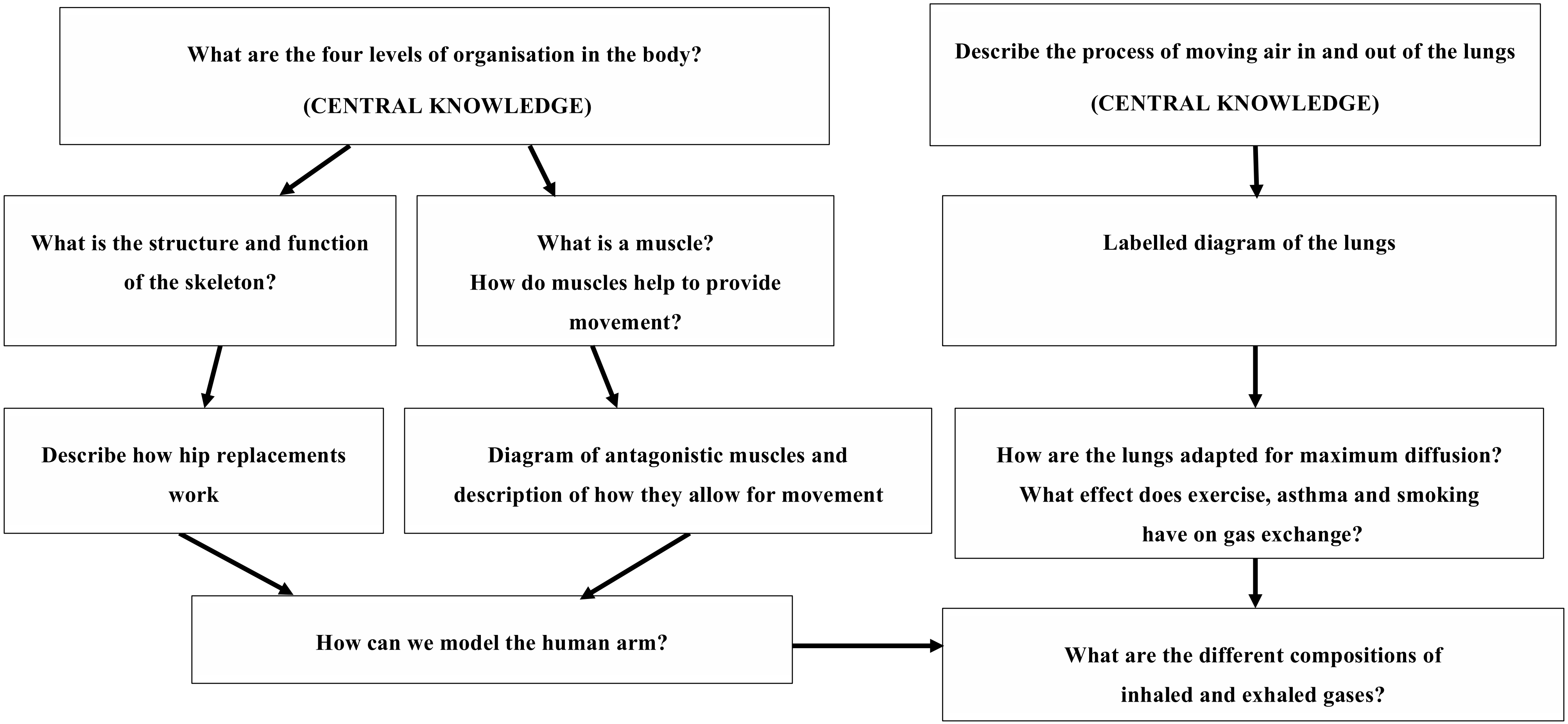
Example Lesson Plan for Teaching Sequence

Lesson Plan: Animal and Plant Cells **Date:** 23/02/17 **Period:** 1 and 2 **Time of the Day:** Morning **Teacher:** x **Group:** 7N **Lab/Room:** S1 **Success Criteria:** Explain that living things are made up of tiny cells. Describe that cells are that make up living things. Know that animal and plant cells are different and identify some key features of them.

	Teacher activity: What I will do?	Pupil activity: What will the students do?	Resources
5-7 mins	Instruct pupils to not look back in their books and try and label the microscope and identify some of the features of it from memory. Challenge questions to remember what a cell is and to think about some of the differences between a plant and animal cell. Random questioning / differentiated for the challenge questions to gather answers.	Pupils to try and remember the correct labelling and purpose of each part of a microscope. Initially working on it individually then some time to work with the person next to them. Self-marking when running through answers as a class. (Score for their quiz).	-PPt Slides
3-5 mins	Explaining how we calculate the magnification. Give 2 examples of the board and ask pupils to copy them down into their books. (This depends on whether this could be covered last lesson).	Pupils to copy down 2 examples of magnification in their books.	-Magnification Examples
3-5 mins	Pupils to complete the matching activity for magnification. Showing their calculations.	Completing magnification sheet, sticking into books with shown calculations. Extension activity on board as well.	-Magnification Sheet
1-2 mins	Hinge point, ask pupils to give a score on firstly how comfortable they feel with the different parts of a microscope and then how comfortable they feel with calculating magnifications. Either go over any issues if class is struggling or move onto next activity.	Giving a rating on how they feel with magnification and microscopes.	
3-5 mins	Knowledge organisers given to pupil explain why we are using these. Working memory introductory slides what it is and how we can improve it.	Pupils sticking knowledge organisers in their books.	
3-5 mins	Refresh what a cell is (building blocks of living things). Bring in analogy of cells being like a house, they are the bricks and come together to make the house.	Pupils linking together and counting how many of them it takes to get from one side of the room to the other.	
8-10 mins	Ask pupils to line up in the classroom, we are determining how many of us are needed to reach from one side of the room to the other. Count and then show the number for how many cells to give pupils an idea of the scale of cells		
8-10 mins	Reference back to cheek cells looked at last lesson. Describe that we were looking at an animal cell. Introduce analogy of a cell being like a chocolate factory. Questioning here ask pupils to describe the process: -What do we need first (Recipe Nucleus) -Now we have the recipe what do we need to do (Factory Floor – Cytoplasm) -What do we do once we have made it (Leave the Factory – Cell Membrane). Write flow diagram on the board. Pupils to copy this in their books using the analogy of the chocolate factory. Challenge: Can pupils think of any other analogy for how a cell works from the chocolate factory analogy.	Pupils to offer answers to what is happening at each stage. Pupils copying the flow diagram into their books with the analogy of the chocolate factory. Important here to include the key words nucleus, cytoplasm and cell membrane. Pupils to if they can think of another analogy of how a cell works. Any real-world examples of following instructions.	
3-5 mins	Demonstration if possible of a cell in 3D (either make one or use an example from school). Show pupils that although they look flat in the microscope we are only seeing a section of them and they are 3D.		-3D model of cell

20-25 mins	Pupils conducting research task on animal cells. Interactive website with the different parts of animal cells (see PPt). Instruction sheets given out and pupils to fill out the table and draw their own picture of an animal cell in their books from the research. There is a lot of new vocab for pupils here, good descriptions on website but some pupils may still need a lot of help.	Logging on to the website learning the different parts of an animal cell from it. Using this to fill out the information in their table. Opportunity to ask any questions. Also, memorisation game to play if they have finished.	-Laptop -Tables to Fill Out
HW 3-5 mins	Explain to pupils that their homework for the next couple of weeks will be to develop a model of an animal cell. Make it 3D can use their imagination it needs to include the labels and explain what each part of the cell does. Show some examples	Pupils noting down their homework.	-Picture and Video Examples of Cell Models
Extension	If there is time move onto how a plant cell differs. Use the website animation on front board with the plant cell. Get pupils to identify without clicking on anything what looks different. If time give pupils labelling activity for a plant cell, may be too much new content for one lesson so probably best saved for next lesson. Alternatively, repeat pop quizzes on laptops, pupils practising to see if they can remember the features and functions of the different organelles of the cell.		-Plant Cell Animation
2-3 mins	Exit Tickets given out to pupils. Rate how confident they are with microscopes and with animal and plant cells How confident are you with the topic? What would help your learning?	Pupils filling out the exit tickets.	Exit Ticket

Appendix 2: Knowledge Organisers



Appendix 3

Initial Questionnaire

Read the following statements and tick whether you:

completely disagree (1), slightly disagree (2), neither agree or disagree (3), slightly agree (4) or completely agree (5).

Statement	1 – Completely disagree	2 – Slightly disagree	3 – Neither agree or disagree	4 – Slightly agree	5 – Completely agree
-I take time to study everyday					
-I prefer to listen rather than take notes					
-I have difficulty determining the important points in class					
-I revise the key points of the previous lesson before each lesson					
-I know how I learn best					
-I find it confusing to determine how topics link					
-I struggle to know how to revise					
-I repeat similar practice questions to learn					
-I take regular breaks when I revise					
-I wait until the night before to revise before a test					
-I plan when I am going to revise over a period of time					
-I find it difficult to connect topics					
-I enjoy learning new things					
-I find it easy to learn new content					
-I find it more difficult to answer longer questions with several steps					

Answer the following questions. Providing as much detail as you can.

1. Do you think you have a learning style? E.g. do you learn best through pictures or through doing experiments etc.

   ____

2. Have you ever been taught techniques to help improve your memory and learning?

   ____

3. How do you revise? E.g. flashcards, practice exam questions etc.

   ____

4. Do you have enough support to learn effectively?

   ____

5. Would you want to know methods that help improve your memory and make it easier for you to learn?

   ____

Appendix 4

Interviews Conducted at both the Beginning and End of the Teaching Sequence

Interview – Beginning of Study

1. How do you best learn in the classroom?
2. What activities do you feel help you to learn new things best?
3. Have you even been taught any ways to help your learning?
4. Do you find tests helpful to your learning?
5. Do you find quizzes helpful to your learning?
6. Does it help you to revisit topics that you have covered in a previous lesson?
7. Do you ever revise topics at home if you don't have a test?
8. How do you revise?
9. Does the way you revise help you to learn?
10. Do you ever struggle to connect ideas to one another?

Interview – End of Study

1. Have the knowledge organisers helped to connect what you have been learning?
2. Have the mini-quizzes that test your previous knowledge helped you to learn?
3. Do you feel confident on what we have learnt about cells and organisation?
4. Does getting a question right help with your confidence?
5. Would you still like to no more on how to help improve your memory?
6. How much have you enjoyed the lesson taught?

Appendix 5: Example Exit Ticket

How confident are you with using and labelling a microscope?

1 2 3 4 5

How confident are you with labelling and understanding the components of an animal and plant cell?

1 2 3 4 5

How confident are you with the difference between a unicellular and multicellular organism?

1 2 3 4 5

How confident are you with describing why cells are specialised?

1 2 3 4 5

How confident are you with describing diffusion?

1 2 3 4 5

Is there any area you are finding confusing?

What helped you learn the most this lesson?