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A critical analysis of the impact of implementing feminist teaching pedagogies on Y10 girls' attitudes towards mathematics

Rachel Burns

(PGCE Secondary Mathematics, 2021-2022)

email: rachelsigourneyburns@gmail.com

Abstract

The proportion of girls choosing to do A Level mathematics has remained stagnant at around 40% for at least the last ten years. Given that girls outperform boys in both GCSE and A Level mathematics, the literature suggests that the reason fewer girls are choosing to do mathematics is because they do not enjoy it as much as boys. This action research project works to establish whether implementing feminist teaching pedagogies can improve girls' attitudes towards mathematics. Lessons were devised and taught using four identified tenets of feminist mathematics pedagogies: social learning, connected knowing, a reflective and low-pressure environment, and problem solving with multiple routes. Data was collected by interviewing girls before and after the lesson intervention, collecting student work, and from teacher observations. The results suggest that feminist pedagogies can improve girls' attitudes towards mathematics. Activities that helped girls understand content deeply were particularly effective.

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Introduction

As highlighted by Boaler and Sengupta-Irving (2006), in the UK, girls have been passing GCSE mathematics at a higher level than boys for quite some time. More recently, girls have outperformed boys at every level of GCSE and A Level Mathematics (Adams, 2021). Despite this, girls have chosen to do A Level mathematics at a much lower rate than boys: 43% of girls and 65% of boys with an A grade in GCSE mathematics continue to study mathematics to at least AS level (FMSP, 2015). These trends are showing no sign of changing, with the percentage of girls taking AS and A Level Mathematics and Further Mathematics remaining almost constant for the last 10 years (ibid.). It is important to close this gender gap in students choosing Mathematics A Level for several reasons. It has been shown that women earn more in STEM fields than non-STEM fields (for example, Beede et al., 2011) and so it is critical to close gender gaps in STEM fields in order to decrease the well documented gender pay gap that persists in society at large. In order to access many key STEM fields, students will need A Level Mathematics (IMA, 2022).

Many researchers have argued that to increase girls' uptake of mathematics, it is important to increase efforts to encourage a more positive attitude towards mathematics. For example, Solar (1995) argues that using ideas from feminist pedagogy, an inclusive feminist mathematics pedagogy can be implemented to improves girls' attitudes towards mathematics and encourage them to pursue it further. Feminist pedagogy refers to a progressive pedagogical framework based on feminist theory, which first arose from women's studies courses in the late 20th century. It focuses on the social construction of knowledge and aims to liberate and empower learners (ibid.). Since its origins, many researchers within mathematics education have built on the idea of subject specific feminist mathematics pedagogies and what features should be incorporated in order to help women enjoy mathematics more (ibid.).

The aim of this project is to investigate the impact of implementing feminist teaching pedagogies on Y10 girls' attitudes towards mathematics. The girls are in a mixed gender middle set in a mixed gender school and are in the upper half of their year for previous attainment in mathematics but hold very diverse views on mathematics. The purpose of introducing these feminist strategies will be to improve their attitude towards mathematics. First, the literature on feminist teaching pedagogies is reviewed and five recurring themes are identified. These themes are then used to plan a series of lessons for the Y10 class. The girls were interviewed before and after the sequence of lessons and evidence was collected during the lessons. Then the results of the data collection are presented and discussed. Finally, conclusions are drawn about the utility of implementing feminist teaching pedagogies to improve girls' attitudes towards mathematics.

Review of the Literature

This study works to investigate whether implementing feminist teaching pedagogies can improve girls' attitudes towards mathematics. In this chapter, the five unifying features of feminist teaching pedagogies in mathematics that have been identified in the literature are explored. Explicitly feminist concerns and their role in the classroom are detailed in section 2.1. In section 2.2, the role of social learning is explored. The feminist concept of 'connected knowing' is defined and examined in section 2.3. The importance of girls having a reflective and low-pressure atmosphere is discussed in section 2.4. In section 2.5, the function of problem solving with multiple routes is reviewed. Finally, a summary is provided in section 2.6.

Explicitly feminist concerns

The origins of feminist pedagogy in mathematics began with a focus on concerns of an explicitly feminist nature. Explicitly feminist concerns are not related to mathematics teaching approaches themselves but more broadly to classroom practises that may disadvantage women. Mostly these issues are raised in the 20th century literature whilst the more recent literature tends to focus on the pedagogical features highlighted in the following subsections. A thorough overview of the role of both pedagogy and environment is given by Solar (1995). She analyses the emergence of feminist pedagogies, that first began in women's studies courses, and discusses how these ideas (along with non-discriminatory classroom practices) can be applied to mathematics classrooms to create a feminist mathematics pedagogy. With reference to four feminist pedagogical themes of participation, inclusion, speech and empowerment, Solar makes recommendations for teaching, learning, curriculum and educational environment. Many of the teaching and learning examples given are covered in the following subsections. However, what this paper, and much of the literature from before 2000 add is a focus on explicitly including women in the classroom. Examples given by Solar include avoiding stereotypes, making women visible in mathematics, creating space for women to speak and using inclusive language.

Some literature from around the nineties identifies this focus as a worthwhile one. In their paper comparing feminist pedagogies with invitational and cooperative learning, Jacobs and Ilola (1991) highlight that although feminist pedagogies overlap with these two other approaches significantly and are therefore valid and helpful for use with students of any gender, the additional focus on eliminating female oppression in the classroom is valuable. On the other hand, literature from the post 2000 resurgence of feminist pedagogy in mathematics puts less of a focus on explicitly feminist concerns. For example, Schettino (2013) studied the journeys of five adolescent girls who were being taught mathematics through Relational Problem-Based Learning (RPBL) to improve their interest in mathematics. In her argument, she highlighted that RPBL draws on ideas from previous feminist pedagogies but stands apart from them due to its approach of not separating men and women. This inclusive approach aims to view mathematics learning in a less oppositional way and cater to the needs of a broader range of individuals, as reinforcing gender differences is seen as unproductive (ibid.). Despite this criticism, some modern authors continue to support the concept of feminist mathematics pedagogy. For example, Cantley, Prendergast and Schlindwein (2017) discuss the merit of feminist pedagogies in their 6-week intervention with two student groups to determine whether collaborative cognitive-activation strategies could be used to improve female students' enjoyment of maths. They contend that the strategies that arise from feminist pedagogies overlap significantly with those from other pedagogical approaches which strengthens its validity.

Social learning

A key feature of feminist teaching pedagogies in mathematics identified in the literature is the concept of social learning. In the literature, two methods for facilitating social learning are most frequently discussed: cooperative learning and whole class collaboration. Cooperative learning techniques include any activity where students in small groups share ideas with each other and work together to complete a goal (Smith, Cornelius & Hines, 2014). Some scholars identify cooperative learning specifically as an important feature of feminist pedagogy (Solar,1995). Other authors stress the importance of open dialogue and collaboration within the whole class, including the teacher, in order to reduce the hierarchy in the classroom through dissemination of power and knowledge (e.g., Kellermeier, 1996).

There is some research into exactly how cooperative learning should be carried out in order to benefit girls most. Hahn, Islam, Patacchini and Zenou (2017) found in a study of 6000 primary school students that low attaining girls working in prior attainment balanced groups outperformed their solo counterparts, and this effect was increased if they were working with their friends. Webb (1991) did an analysis of 17 previous studies on group interaction to determine which features lead to most interaction. She found that gender balanced groups promoted explaining and homogeneous medium ability groups promoted active participation from all or most members.

Many authors espousing social learning techniques within feminist pedagogies reference prominent research that shows that women both prefer to learn and learn more whilst using these techniques. In her case studies of two schools in England, Boaler (1997) found that girls much preferred group work as they felt it helped them access more tasks and understanding than they could on their own. She also found that boys were much more ambivalent towards collaboration. This is similar to the findings of Smith, Cornelius and Hines (2014) in their examination of over 7000 US eighth grade students' Trends in International Mathematics and Science Study (TIMSS) data. They found that students who cooperated in group learning had higher achievement scores, that girls benefitted more from group work, displaying increased attainment and attitudes, and that a moderate amount of group work was best. The research seems to agree with the hypothesis of Cantley et al. (2017). In structuring their research framework, they argue that the social learning aspect of feminist pedagogy is closely related to Vygotskian sociocultural framework. Vygotsky's theory of social constructivism is underpinned by the idea that knowledge is constructed through verbal interactions with other people (Vygotsky, 1978). Therefore, Cantley et al. (2017) put forth that since Vygotskian sociocultural framework is an approach in its own right, including social learning opportunities in mathematics lessons should benefit women by allowing deep construction of knowledge without penalising men. Similarly, Jacobs and Ilola (1991) argue that feminist pedagogy is very similar to cooperative and invitational pedagogies, but it has additional feminist concerns that do not detract from the value of cooperative and invitational methods.

Connected knowing

The feminist concept of “connected knowing” was first coined as part of the research conducted by Belenky, Clinchy, Goldberger, and Tarule (1986) who interviewed 135 women of diverse ages and backgrounds to try and learn more about how women come to acquire and interact with knowledge. In particular, they suggested that a good model for women’s acquisition of critical knowledge is “connected knowing”, where the thinker focuses on understanding the object of knowing, making connections to it, including emotional, and generating meaning. This is in contrast to the model of “separate knowing”, suggested by the authors as being more masculine, where the knower tries to use logic and deduction to view the object of knowing in a detached way. They are also careful to emphasise that although either of these kinds of knowing may be broadly associated with men or women, this is not to say they apply to all individuals within a gender or exclusively one gender.

Several authors highlight connected knowing as an important approach when considering feminist teaching pedagogies but have subtly different focuses on how connected knowing should be integrated in mathematics. Cantley et al. (2017) emphasise that the importance of connected knowing is allowing students to gain knowledge within appropriate contexts based on personal experiences and that permit “intellectual attachment to the object of study” (p.7). On the other hand, Boaler and Sengupta-Irving (2006) highlight that activities incorporating connected knowing might involve intuition, creativity, hypothesizing and induction. They also suggest students should be involved in the process of problem solving. Many of the aforementioned features of teaching that encourage the development of connected knowledge are mentioned in other reports as strategies which can help girls to enjoy mathematics. For example, many authors suggest the importance of using real life contexts that matter to women in mathematics problems and examples (e.g., Kellermeier, 1996; Solar, 1995; Spielman, 2008).

Zohar (2006) provides perhaps the most comprehensive consideration of how connected knowledge as a feminist concept might be best applied to mathematics education in her review of the literature on connected knowledge and learning for understanding. She presents her previous research where she found that more girls than boys needed to understand mathematics and science to enjoy them and that girls felt more strongly about needing to understand them. She argues that in mathematics, connected knowing manifests itself as this need to understand. Furthermore, the subjectivity often emphasised in connected knowing theories is replicated by the subjectivity created by learning STEM subjects deeply, and integrating that knowledge into one's own individual conceptual framework. Zohar also argues that there is therefore a huge overlap between the perhaps controversial suggestion of connected knowing and the entirely accepted notion of learning for understanding and that viewing feminist pedagogy in this way can help broaden its appeal to mainstream education. This is similar to Spielman's (2008) claim that features of connected knowing have a lot in common with recommendations given by the American organisation, the National Council of Teachers of Mathematics, to improve mathematics education generally. That is, feminist mathematics pedagogies intersect with recommendations given to improve mathematics teaching for all students.

Reflective and low-pressure

Another emphasis in the feminist literature identified was around creating a low-pressure environment where students feel they can work at their own pace and make mistakes. In her book *x+y*, Cheng (2020) argues that girls are dissuaded from pursuing competition mathematics because of the high pressure and time-limited nature of such competitions. This notion of pressure appears in the work of a number of authors who write about encouraging girls in mathematics. Garcia-Luis and Dancstep (2019) discuss the importance of creating a low-pressure environment in STEM exhibits. In his discussion of how he implements feminist pedagogy, Kellermeier (1996) writes about the need to create a classroom where students feel safe to take risks. He suggests doing this by modelling risk taking and using quick informal written assessment at the end of class. Other authors mark the importance of eliminating speed so girls can take time with the work in a low-pressure environment (Garcis-Luis & Dancstep, 2019; James, 2009; Karp & Shakeshaft, 1997).

On the other hand, other researchers writing about feminist pedagogies focus more on allowing time for students to reflect in order to create a low-pressure atmosphere. Cantley et al. (2017) highlight the importance of allowing students to reflect on their work, arguing that it gives groups the opportunity to engage more deeply with the mathematical ideas. In their study, they discussed how groups benefitted from an 'evaluative loop' where students planned work, carried it out, reviewed it and then made sense of it. Similarly, Solar (1995) states the importance of allowing students to talk through their processes when solving problems to give them the opportunity to reflect on their methods.

Some authors argue that creating a low-pressure and reflective atmosphere is important as it helps students deepen their understanding (Goldburg & Bush, 2003) whilst others stress it can aid students in enjoying mathematics more because it can combat feelings of maths anxiety. Maths anxiety is a well-established phenomenon involving heightened feelings of anxiety when attempting to do mathematics (Richardson & Suinn, 1972). Maths anxiety is a gendered issue in that several studies have found that girls experience more maths anxiety than boys (e.g., Miller & Bichsel, 2004). However, many of the recommendations given to teachers to help reduce maths anxiety for all students, including creating a slower, more relaxed atmosphere (e.g., Woodard, 2004) and using low-stakes informal assessment (e.g., Marshall et al., 2017), overlap heavily with the feminist pedagogical features discussed in this subsection.

Problem Solving with multiple routes

Providing opportunities for problem solving was a theme identified often in the literature on feminist pedagogy in mathematics. Anderson (2005) interviewed seven girls at a mathematics summer camp that was organised around feminist pedagogy. In her study, she used a theoretical framework of feminist standpoint theory to value women's voices in the classroom and help women rather than create a model of comparison. Students that were interviewed emphasised that they liked that their teacher would guide them without giving away answers, that students could solve problems in their own way, and they felt they grew in confidence from being able to overcome their struggles. Many of the points identified by these girls are also recommended by other authors. Solar (1995) argues that problems chosen within a feminist pedagogy should encourage students to realise that there are multiple ways to approach and solve a problem to "demystify" mathematics. Similarly, James (2005) recommends that students are given variety in how they approach problems. Cantley et al. (2017) stress the importance of incorporating varied problem solving and guiding students through problems.

Problem solving is a key feature of the curriculum in England. The ability to solve problems is one of the three core aims of the mathematics curriculum, with an emphasis all students being able to solve "a variety of routine and non-routine problems with increasing sophistication, including breaking down problems into a series of simpler steps and persevering in seeking solutions." (DfE, 2013, p.3). Despite the importance placed in curricula worldwide, many students struggle to solve non routine problems (Fuchs et al., 2016). Researchers have suggested different strategies to help students in solving problems. Some authors argue that students understand problem solving more deeply when they are shown multiple routes to solving them (Lynch & Star, 2014). Kojo, Laine and Näveri (2018) found that activating probing and guiding questions can also help guide students when problem solving. These recommendations appear to overlap with feminist approaches to problem solving.

Summary of findings

Five key features of feminist mathematics pedagogies have been identified in the literature: explicitly feminist concerns, social learning, connected knowing, a reflective and low-pressure environment and problem solving with multiple routes. This literature suggests that implementing these features of feminist pedagogies can improve Y10 girls' enjoyment of mathematics. This motivates the formation of an initial research question (RQ1): Can feminist teaching pedagogies improve Y10 girls' attitudes towards mathematics? Although there is much theoretical discussion of feminist pedagogies (e.g., Solar, 1995) there is much less literature on the effect of implementing a feminist mathematics pedagogy on KS4 girls' attitudes, which this paper will seek to add to.

When implementing features of feminist mathematics pedagogies with a particular group, it is reasonable that some strategies may be more appealing than others. It is also useful to determine in what way certain features impacted girls' attitudes towards mathematics. This leads to the formation of a second research question (RQ2): How did particular features of feminist teaching pedagogies impact Y10 girls' attitudes towards mathematics? Whilst there is research on the effects of individual aspects of feminist pedagogies on girls' attitudes towards mathematics (e.g., Hahn et al., 2017), there is little research into how the features of feminist pedagogy might interrelate and impact Y10 girls' attitudes towards mathematics. This paper seeks to fill this gap in the literature.

Methodology

Lesson Sequence

Once the literature review had taken place, the lessons were designed to incorporate four different features of feminist pedagogy: social learning, connected knowing, a reflective and low-pressure environment and problem-solving with multiple routes. I decided that in light of modern research using feminist pedagogies, there was not a need to incorporate an explicitly feminist aspect to activities. Instead, I focused on the other four features within the lesson and tried to be conscious of any bias or stereotypical language that might be present in my own behaviour or the classroom. The planned sequence of lessons is outlined below:

Lesson Number	Subject Content / Lesson Activity	Feminist Pedagogical Features	National Curriculum Content (DfE, 2013)
1	Starter: Revise vector notation iPads activity: Exploring multiplication by a scalar Reflection: Written exit ticket on multiplication by a scalar	iPads activity: connected knowing, social learning Reflection: a reflective and low-pressure environment	Geometry & measures: diagrammatic and column representations of vectors, multiplication of vectors by a scalar
2	Starter: Revise previous lesson Teaching portion: Demonstration of addition of vectors, AfL Navigation Activity: "Real-life" example	Teaching portion: connected knowing, a reflective and low-pressure environment Navigation Activity: connected knowing, social learning, problem solving with multiple routes	Geometry & measures: diagrammatic and column representations of vectors, apply addition (and subtraction) of vectors
3	Starter: Revise work done so far Navigation Activity: continued Flipped Classroom: understanding subtraction of vectors Reflection: written exit ticket	Navigation Activity: connected knowing, social learning, problem solving with multiple routes Flipped Classroom: connected knowing, social learning Reflection: a reflective and low-pressure environment	Geometry & measures: diagrammatic and column representations of vectors, apply addition and subtraction of vectors
4	Starter: Revise previous work Reflection Activity: discuss previous exit tickets & improve them Problem Solving: activity on adding vectors to show vectors in quadrilaterals Activity: Completing questions & problems	Reflection Activity: a reflective and low-pressure environment Problem Solving: social learning, problem solving with multiple routes, connected knowing Activity: problem solving with multiple routes, connected knowing	Geometry & measures: diagrammatic and column representations of vectors, use vectors to construct geometric arguments and proofs

Table 1: Y10 Lesson Sequence with content and feminist pedagogical features identified

Context & Methodological Approach

The school in which this study was carried out is a large school serving a city area. Over 60% of students are from wards with high poverty indices and over a third of students receive pupil premium status. It is a very diverse school, with roughly three quarters of students from a minority ethnic background and half have English as an additional language. The Y10 class are a set 3 of 6, with many students aiming to take the higher GCSE paper at the end of Y11. The Y10 class has 28 students, 14 of which are girls.

The purpose of this study is to see whether feminist teaching pedagogies can be implemented with girls in a Y10 mathematics class to improve their attitude towards mathematics. Therefore, the methodological approach I have chosen is action research. Cohen, Manion, and Morrison (2017) define action research as a small-scale intervention in a real life setting and a systematic analysis of the effects of the intervention. They also say that the aim of undertaking action research should be to improve practice and may have a focus on political emancipation. This aligns exactly with the purpose of this research: to undertake an intervention in my classroom to reflect on and improve my teaching practice with the hopes of empowering girls in mathematics. Of course, an issue with action research is that it is taken over such a small scale that it could not result in generalisable claims. However, this is also the strength of action research: the researcher reflects on their own practice in detail and thus helps their students, which is the goal of this study.

Choice of Data Collection Methods

To answer RQ1 about whether feminist teaching pedagogies improve Y10 girls' attitudes towards mathematics, it was necessary to select a kind of data collection that would capture what Y10 girls' attitude towards mathematics were both before and after invention. Traditionally, the two main methods for collecting data on student attitudes are questionnaires and interviews. In the context of empowering girl in mathematics, a critical lens of feminist theory is useful when considering the choice of data collection. In feminist research, a naturalistic approach is usually taken to capture rich, descriptive data that centres the experiences and feelings of women (Cohen et al., 2017). Therefore, in order to amplify the voices of the girls and generate thick data collection, an interview was chosen as the main method to get a picture of the girls' attitudes towards mathematics.

The next choice about the data collection was whether to interview participants individually or as a group. Whilst both methods would produce qualitative data, the purpose of the interviews was for students to feel comfortable speaking about their experiences, feel empowered about their education and so I could get a picture of what girls in the class valued in mathematics lessons. With that in mind, group interviews were preferable in creating a sense of community and making the students feel comfortable sharing how they felt (Guthrie, 2020). There is a risk with group interviews that one participant may dominate interactions or that some interviewees may not feel comfortable expressing their opinion in front of the others (Cohen et al., 2017). However, because the girls chosen study mathematics together, they know and trust each other which I had observed during my time with the class. I also was prepared to mediate the interview with direct questions to students who may not feel as confident speaking.

The post-intervention group interview was also used as an opportunity to aid answering RQ2: How did particular features of feminist teaching pedagogies impact Y10 girls' attitudes towards mathematics? Although this helps address the research question, in order to fully answer this question, it was also necessary to collect data on how students engaged with particular tasks during the lessons. This was done by collecting student work and reflections from the intervention lessons to analyse how students engaged with the tasks they were set. Also, another teacher in the room took observation notes on how students engaged with the tasks and each other during the lessons. This allowed direct analysis of which features of feminist pedagogies were impacting the girls' behaviours and attitudes.

Ethical Considerations

Ethical considerations were a major driver in research design. Before undertaking any research in the school, I reviewed the schools' ethical literature. Then I ensured all students in the target class had given ethical clearance to be involved in research activities as well as video permissions.

A broad ethical concern in this project was whether implementing teaching pedagogies to encourage girls to enjoy mathematics would cause other students in the class (namely boys) to be hindered in their mathematics learning as a result. As discussed in the literature review, this risk was mitigated by using aspects of feminist pedagogy which have large overlaps with other progressive gender-neutral pedagogies. In the classroom itself, I was also careful to include all students in discussions, call on boys and girls equally for answers and to devote my time and attention evenly to all students.

In action research, a large ethical consideration is the blurry line between the teacher and the researcher (Cohen et al., 2017). With this in mind, chosen interviewees were well informed that they were in no way obliged to take part and there would be no negative repercussions if they chose not to, which also adheres to educational research guidelines (BERA, 2018). The 'principle of plain speaking' (Cohen et al., 2017) was used when explaining the research project to the interviewees to ensure informed consent could be achieved. Participants also had the right to withdraw from the interview at any stage as is necessary for ethical research (BERA, 2018). Students will also not be identifiable in the report of results to ensure privacy and anonymity (ibid.).

In executing the interviews themselves, I was careful to design the interview questions so that they would not encourage participants to reveal sensitive or potentially upsetting information. I also considered my role as the interviewer thoughtfully to ensure I could guide the group interview in both a productive and ethical way, where interviewees felt equally heard and comfortable throughout.

Group Interview Design

The pool of potential participants was girls in my Y10 mathematics class. The entire class was informed about the first group interview in advance and all girls from the class were invited. Of the 14 girls in the class, 10 attended the interviews. An interview guide approach was taken where topics to be covered were decided in advance, but flexibility was given to tailor to the personal experiences of interviewees and follow organic lines of conversation that arose. This particular interview design structure was chosen to allow a balance between providing answers to specific questions I had whilst still allowing a natural conversation to occur (Cohen et al., 2017).

Questions in the pre-intervention interview were focused around finding out the participants' feelings towards mathematics. They consisted around what the interviewees liked or did not like about certain aspects of mathematics, their mathematics classroom and mathematics teaching. These questions were accompanied by possible prompts to refocus the discussion.

Questions in the post-intervention interview were more focused on discussing particular aspects of the lessons to find out how the participants felt about them. There was also a broad question on whether interviewees felt any of their opinions on mathematics had changed during the lessons. Participants were also given the opportunity at the end of each interview to make any comments they wished about topics that they felt were important. A brief outline of questions and prompts from both interviews are given in Table 2 on the next page.

The pre-intervention interview was held the day before the lesson sequence began and the post-intervention interview was held the day after the sequence ended to ensure interviewees could still remember the lessons in detail. I also brought materials used in the lessons to refresh participants' memory.

Pre-Interview Questions	- How do you feel about maths? [What do you like or not like about maths?] - How do you feel in your maths class? [Are you comfortable asking questions? Making mistakes? Do things go at the right speed?] - What kind of maths lesson do you enjoy most? [Do you enjoy working on your own/ group work? Teacher led v discovery? Competition?]
Post-Interview Questions	- [Social tasks] Over the lessons, we had an activity working in pairs (Lesson 1), an activity working alone & discussing in pairs (Lesson 2), an activity where we taught the class (Lesson 3) and an activity working completely alone (Lesson 4). Which activity did you enjoy most? In which activity did you understand and learn best? Why? - [Learning for understanding] Over the lessons, we had an iPad activity to help understand vector multiplication (Lesson 1) a question with real life context (Lesson 2) and a flipped classroom activity (Lesson 3). Which activity did you enjoy most? In which activity did you understand and learn best? Why? - [Time for reflection] Over the lessons we had written exit tickets (Lesson 1 and 3) and time to improve our exit tickets (Lesson 4). Did you find the reflections helpful to deepen your understanding? - [Open problem solving] During the lessons, we answered several questions that had multiple answers and choice. Did you enjoy questions with multiple routes / choice? -Have any of your opinions on maths changed after the series of lessons?

Table 2: Pre- and post- intervention group interview questions

Reliability and Validity

Reliability and validity are important concerns when undertaking any qualitative research. There are several features of a reliable and valid interview suggested by the literature that were carefully considered when undertaking data collection. I as the interviewer was aware of the subject matter, the interviews were structured well and I gave all my attention to the interviewees (Cohen et al., 2017).

Validity is achieved in qualitative research by using an appropriate research instrument to answer the research questions (Carcary, 2009). Therefore, the selected instruments are valid in that they answer the research questions. The structure of the group interviews also aids in triangulating the data received from the students to create a narrative as a group (Cohen et al., 2017). To try to reduce bias in the research, triangulation of the literature was also undertaken throughout data collection to validate the data from previous results (ibid.). Bias can be created from the researcher in interpreting interview data so thick descriptions were used to reduce this (ibid.).

Reliability is mainly concerned with the repeatability of the research (Cohen et al., 2017). In the context of action research in such a specific context this is clearly not a sensible interpretation. Some argue that in action research, a lack of internal consistency, in both procedures and interpretation of data is a more measured concern (Coghlan & Brydon-Miller, 2014). Consistency in this study was ensured by having multiple accounts of the lessons (from researcher, external teacher and student perspective) to ensure consistency in interpretation of the lesson-generated data. Finally, in qualitative research it has been suggested that to improve reliability the researcher carefully document the procedures that lead to research findings (Cohen et al., 2017) which are detailed at various points in this section.

Data Analysis

First, the data collected had to be processed. The interviews took place in a classroom, with seats arranged in a circle. Both interviews took around fifteen minutes to conduct. The interviews were initially transcribed in full shortly after the interviews took place to reduce data loss by any incoherence in the recording. Initially, any irrelevant data was eliminated from the transcripts. Student work was also scanned and compiled. Lesson observations were gathered and sorted into a proforma that matched the feminist pedagogy themes.

Then a process of iterative coding was used on all collected written data to identify common themes. This coding was guided by the research question and literature but frequently returning to the data itself to reduce bias in interpretation (Cohen et al., 2017). Then the coded data was considered and re-examined and a higher-level of coding was completed resulting in more abstraction to create a framework of codes. This was repeated until the extraction of data was fully saturated.

Findings & Discussion

The girls' attitudes towards mathematics

The participants struggled to articulate what they did or did not like about mathematics. The predominant reason students gave for their feelings towards mathematics was their ability to complete work. Students that said they liked mathematics or a mathematical topic said they found it easy whilst those that said they did not like mathematics or a mathematical topic said they found it “hard and hard work”. One student humorously recounted that she liked that mathematics was straightforward but when a question asked for her opinion and thoughts, she always got it wrong. Although said in jest, this comment seemed to speak to the heart of the issue for many of the girls. They seemed to hold the idea that mathematics was intentionally confusing, and it was sometimes difficult to understand what exactly was expected of them. Several of the girls explained that they had liked mathematics when it was “just numbers” and did not like it “when the letters came in”. Another voiced that she did not like trigonometry because “you don’t know whether you should do sine or cos or tan and then Pythagoras!”. At the core of many of the participants issues with mathematics seemed to be a lack of understanding of what they were being asked to do and why. On the other hand, when they found it easy to understand they had much more positive views about mathematics.

These findings suggests that the biggest barrier these girls face to enjoying mathematics is understanding it deeply. This implies that feminist pedagogies can improve girls’ attitudes towards mathematics if they help students to understand mathematics, which almost all features of feminist pedagogies put a significant focus on. The emphasis the girls placed on wanting to understand mathematics in order to enjoy it agrees with much of literature on girls’ enjoyment of mathematics (e.g., Zohar, 2006).

Over such a short intervention, it was unlikely to see any drastic changes in the girls’ attitudes but there were some indications in their work that students’ attitudes were beginning to change. For example, students frequently chose to use algebra in their own explanations despite stating in pre interview that they did not like using letters (Figure 1, next page).

This might suggest that the students had an increased comfort using algebra because the task built up the generalisation slowly. However, it may also be the case that students use algebra because they think it is what the teacher wants to see. In future research, it would be interesting to see if a more prolonged focus on developing understanding can improve girls’ attitudes towards particular topics in mathematics (like algebra).

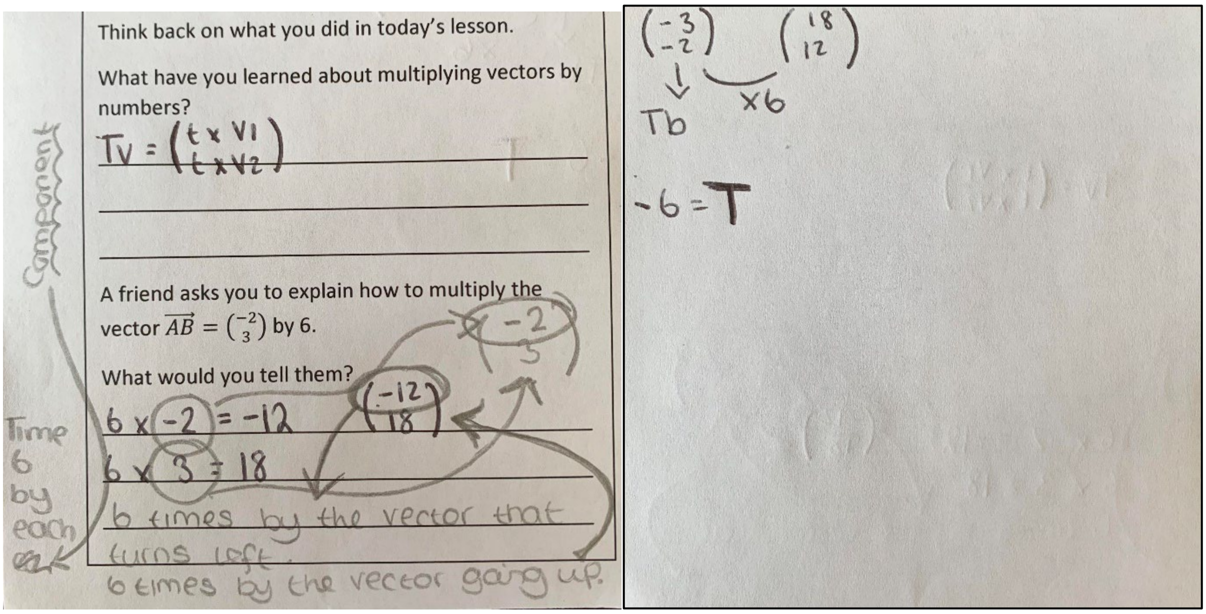

Figure 1: Exit Ticket using algebra to generalise multiplying vectors by a scalar, with post-reflection additions in pencil

Social Learning

Having opportunities to partake in social learning was consistently highlighted as important by the participants. In the pre intervention interview, one participant specified that class was more fun than other subjects because students speak and interact during teaching. Almost all of the students in the group said they preferred to work with other people on tasks and particularly with friends because "you understand each other". A small number of students said they preferred to work alone. These were some of the girls who were most confident with mathematics, and they also said they would rather not work with friends.

In the post intervention interview, many of these views were reiterated. Participants were quick to say that tasks where they we were working in pairs were the tasks they enjoyed most. One student, who had previously been more sceptical about group work, said that although she definitely found the groupwork more fun, she was not sure if she learned better than she would have working alone. This sentiment was reflected by the observing teacher who noted that students seemed to be having a good time but that not each student in the pair was working or that students were not always discussing the task. However, many students in the group emphasised social learning had helped deepen their understanding. One participant felt that she learned better in a pair because "there's not only one brain working on it, so there's more than one person, which can help you". Similarly, one student commented that she liked when "other people share their opinions" in the whole class discussion to which another replied, "and you can learn from that". The observing teacher also noticed how much students enjoyed coming up to the board to share their ideas.

These findings emphasise the importance girls place on social learning and therefore provide support for its ability to improve girls' attitudes towards mathematics. This is heavily corroborated by much research showing that girls value group work because it helps them access more tasks and understanding (e.g., Boaler, 1997). The findings also raise some concerns about how social learning should be implemented and whether students enjoy group work simply because it is easier to be off task. It was hoped to address some of the concerns around students maintaining ownership of their work within groups by having each student complete their own activity sheet. Within pair work, this did not seem to fully address the issue. However, within activities where students worked alone then shared as a group, social interaction was facilitated, and it could be more easily ensured that all students were engaged with their own work. It would be interesting to research further which formats of social learning assist in both interaction and agency for girls.

The other point these findings raise is that not all girls feel the same about social learning, or indeed any aspect of a mathematics lesson. Some of this may be due to differences which should be expected amongst individuals but may also be due to attitude differences within subsets of girls. In this case, the girls did not seem to want to work with their friends because they recognised that they were stronger in ability and were concerned about the effect on their friendships. Whilst there is research into the social difficulties experienced by high achieving girls (e.g., Skelton, Francis & Read, 2010) further research could be done to investigate whether this concern extends specifically to group work as it may create an additional barrier to girls engaging with activities which aid their understanding.

Connected Knowing

The only totally unanimous response in the pre-intervention group interview was when participants stated a strong preference for understanding why they did something in mathematics rather than just being told what to do. With this focus in mind, I targeted three different activities on trying to help students create a deep and connected understanding of the subject matter: an interactive activity on iPads, a question set in real-life context and a brief flipped classroom activity. In a flipped classroom activity, students encounter new knowledge before teaching rather than after. Students reacted to these activities in varying ways. The iPad activity was carried out in Lesson 1. The iPad activity was conducted using graphical software so students could explore the effect of multiplying a vector by a scalar visually. In the post-intervention interview, students said they enjoyed using the iPads, but some felt that it did not help their understanding. The observing teacher noted that students struggled to connect the visualisation on the iPad to the process of multiplying by a scalar. Despite this, after a class discussion aided in making this connection, students seemed to gain both a procedural knowledge and a deeper understanding of multiplying a vector by a scalar, as can be viewed in their exit tickets from the class (Figure 2). For example, students recognised from the iPad visualisation that, in general, vectors remain parallel to the original when multiplied by a scalar.

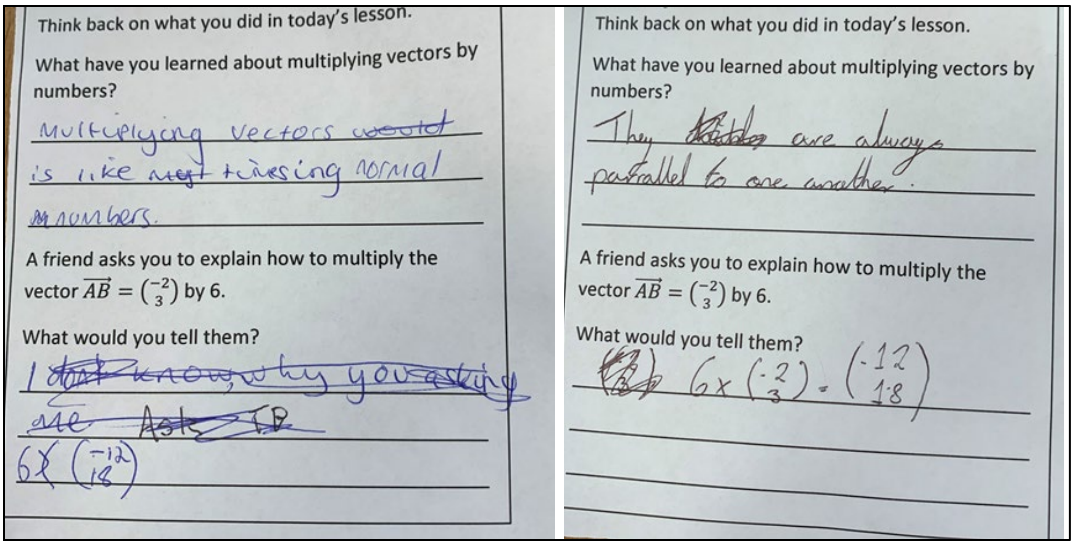

Figure 2: Student exit tickets demonstrating procedural knowledge and general understanding

The example set in a real-life context was a question about navigation of a boat in Lesson 2 and 3. In order to facilitate a meaningful context, the activity sheet ended up being very word dense, which the observing teacher noted was making it hard for some students to engage. In interview, students said that they felt the question was very difficult and confusing which meant they did not enjoy it. Some said that in general they did not like questions in context whilst others felt that it depended on what the context was. The teacher also suggested that using a context that was more real to the lives of the students, such as using locations they might actually go to, might have been better which reflects what much of the research says (e.g. Solar, 1995). I think in trying to come up with a context that felt mathematically natural, I failed to come up with a context that was relevant enough to the lives of the students to help add any understanding to the situation. With that in mind, it would be interesting to plan further research using examples that have both a mathematically natural and relevant context to the lives of students.

The mini flipped learning activity took place in Lesson 3. I gave students a small print out of an answered subtraction of vectors question with a diagram and gave them time to study it to work out what was happening before asking some students to explain their thoughts. The result of their own interrogation of the example can be viewed in their work (Figure 3).

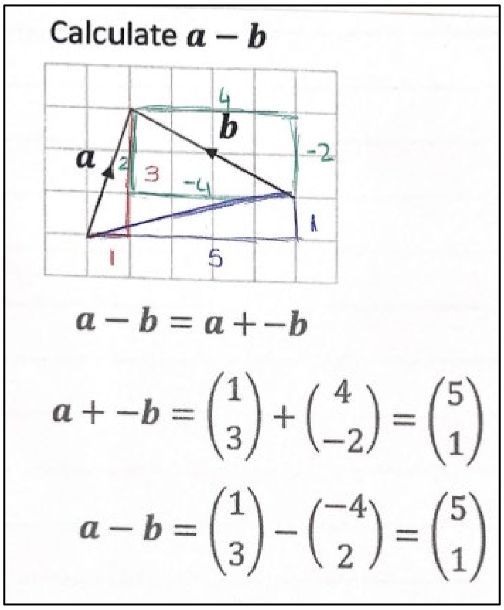

Figure 3: Flipped learning activity showing student annotations on vector subtraction

Students stated that they really like this activity and seemed empowered by it. They said they especially like the group discussion it encouraged after and did not feel unsupported in learning even though I was not doing expository teaching. There is an opportunity for more focused research into how effective the use of flipped learning is in empowering girls to enjoy and understand mathematics.

Finally, to encourage connected knowing in the classroom, I tried to link the new subject material to any previous knowledge students had throughout the lessons. The observing teacher commented that in Lesson 4, the connection to parallelograms and parallel lines allowed students to see a "bigger picture" and allowed them to incorporate new knowledge about parallel vectors with this established knowledge.

These findings suggest that there are many different paths to helping students to develop connected knowledge. Unlike some of the feminist pedagogical features in other sections, there is not a set strategy to facilitate the formation of connected knowledge, but many viable routes and activities. The most important thing is that they are planned with the students' existing knowledge in mind.

Reflective and low-pressure

The main source of reflection within the lesson sequence was through the use of written exit tickets. Many students in the post-intervention interview stated that they liked completing the exit tickets and specified that they preferred the tickets where there was space to draw and room for interpretation. Some pointed out that it helped them check their own understanding. We then spent time discussing the exit tickets in class after which students had the chance to improve their work, having seen some other examples. An example of the improved exit tickets can be viewed in Figure 1. Participants were insightful about how this helped them revaluate their work and improve their understanding. This suggests that this kind of reflection can be used to deepen and consolidate understanding, which agrees with the findings of similar research (Goldberg & Bush, 2003).

However, some students in the post-intervention reflection felt that the exit tickets were too high stakes. One participant said:

> *"All the work you've done in the lesson. You get them all right, and you've done really well. And then you could slip up or something on the [exit ticket]. And you got it wrong. Then you think, oh I don't know. It just brings you down, kind of."*

This comment shows how much of an issue perception and pressure continues to be for girls in the mathematics classroom. This was also reflected in their discussion of competition in the classroom. When asked about whether they enjoyed doing quizzes, some students thought they were fun and easy whilst others thought they would only enjoy it if they were good at the topic already. One student vocalised that she felt she would get left behind because it would "just be between the top two in class and then like everyone else". These findings show the barriers to enjoyment that perceived pressure can create in the classroom and highlights issues with competition previously raised by others (Cheng, 2020).

In contrast to this, students seemed to value the creation of a low-pressure environment. In the pre-intervention interview, students stressed the importance of feeling supported by their mathematics teacher and said they needed to feel they could ask for help. They also said they liked when their teacher did not mind when they got stuff wrong and that they felt comfortable making mistakes because of this. This reflects the findings of other researchers on the importance of a low-pressure environment to encourage girls (Garcia-Luis & Dancstep, 2019). At times, I found it difficult to maintain a low-pressure environment whilst also adhering to the heavy time constraints necessitated in secondary education. Further research needs to be continued into how to create low-pressure environments in classrooms within these confines.

Problem Solving with multiple routes

The main two tasks that incorporated problem solving with multiple routes were in Lesson 4. The first task was a problem that could be solved in many ways, which also helped to reinforce that order of addition does not matter. In the post-intervention interview, students specified that they liked when problems had more than one solution. A student suggested she found this easier because "then there are loads of different ways to do it. There's not one right specific way" and that this helped reduce pressure. The teacher also noted that having the students share that they all completed the task in different ways helped them reflect on the problem and involve them in their own learning. An example is shown in Figure 4.

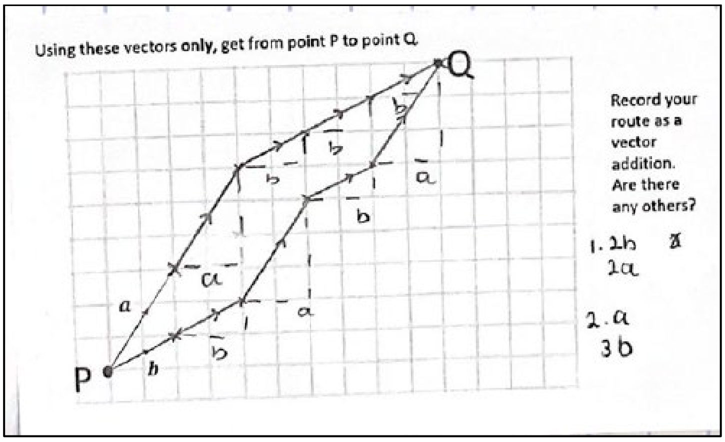

Figure 4: Problem solving activity with student demonstrating two different routes from P to Q

These findings suggest that incorporating problem solving with multiple routes can support students' understanding, encourage social interaction and aid in creating a low-pressure environment. That is, problem solving with multiple routes also helps facilitate other features of feminist pedagogies. It would be interesting to understand these interactions further, and whether problem-solving would still improve girls' attitudes towards mathematics if it did not incorporate these other features.

The second task still had multiple solutions as it did not matter what route students chose in their vector addition. As students completed this task, I circulated the room and helped those who asked. I made sure to question students carefully rather than give them the answer. In the pre-intervention interview, some students mentioned that they liked trying problems on their own before receiving any help. They said that this helped them understand the work better than if they asked for help straight away, whilst other students felt they sometimes needed help getting started in order to understand. Anderson (2005) also found that students enjoyed problem-solving in their own way, and they preferred if their teacher helped them without giving away the answer. There is some research into exactly what kind of teacher interactions aid problem-solving (Kojo, Laine & Näveri, 2018) but it would be interesting to discover specifically if asking more activating questions more frequently in mathematics classrooms could improve girls' attitudes towards mathematics.

Conclusion

The aim of this project was to investigate the impact of implementing feminist teaching pedagogies on Y10 girls' attitudes towards mathematics. This was explored via two research questions. First, (RQ1), can feminist teaching pedagogies improve Y10 girls' attitudes towards mathematics? Secondly, (RQ2), how did particular features of feminist teaching pedagogies impact Y10 girls' attitudes towards mathematics?

From this research, it appears that feminist teaching pedagogies can improve Y10 girls' attitudes towards mathematics. By interviewing the students, it was found that the most important factor affecting girls' enjoyment of mathematics was whether they could do and understand it. I then outlined how each feature of the feminist pedagogies either directly improved girls' enjoyment of mathematics or increased their understanding of mathematics in order to improve their attitude. Social learning through whole class discussion worked best at facilitating discussion to help the participants understand mathematics better. Helping students develop connected knowledge by making connections to their prior learning also helped deepen their understanding. Creating a reflective and low-pressure environment facilitated depth of knowledge and comfort in the classroom. Finally, problem-solving with multiple routes helped implement all the other features of feminist pedagogy to increase understanding. Throughout this discussion, it was reiterated that girls are still individuals, their responses varied in a number of areas, and a one-size-fits-all approach will not solve all issues with gender in mathematics.

The professional implications of this work will be far-reaching and long-lasting for me. I think in my future planning, I will be more conscious of whether my students will be able to gain enough understanding to enjoy their lesson. The importance of building understanding and links between topics was really emphasised in this experience and I think through recognising this I will be able to optimise my students' learning. I also came across much more difficulty than I expected when trying to set problem-solving activities with multiple routes and designing questions with both meaningful and natural context. In future, I will try to incorporate them as often as they organically appear as I do think they can benefit students. It remains extremely important to me that all students, and particularly girls, come into my class and enjoy mathematics and this study has given me more tools and experience to be able to do that.

In order to get more girls pursuing more mathematics, it is of a critical importance that we help them improve their attitudes towards mathematics. Teachers can do this by incorporating more social interaction in their classroom, through whole class discussion, student led activities or pair work. They can also carefully review students' prior knowledge to find links from new topics to what students already know and provide opportunities for students to deepen their understanding of both concepts and processes. Creating an environment where girls feel comfortable and have time to work and reflect is also important. Finally, giving students opportunities to solve problems in different ways and share their ideas about them will help girls enjoy mathematics more.

References

Adams, R. (2021). *Girls overtake boys in A-level and GCSE maths, so are they 'smarter'?* The Guardian. Retrieved 26 April 2022, from https://www.theguardian.com/education/2021/aug/13/girls-overtake-boys-in-a-level-and-gcse-maths-so-are-they-smarter

Anderson, D. L. (2005). A Portrait of a Feminist Mathematics Classroom: What Adolescent Girls Say About Mathematics, Themselves, and Their Experiences in a "Unique" Learning Environment. *Feminist Teacher, 15*(3), 175–194.

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., & Domet, M. (2011). Women in STEM: A gender gap to innovation. *U.S. Department of Commerce - Economics and Statistics Administration Issue Brief*, 4-11.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, body, and mind*. Basic Books.

British Educational Research Association [BERA]. (2018). *Ethical Guidelines for Educational Research* (fourth edition). BERA London.

Boaler, J. (1997). Reclaiming School Mathematics: The girls fight back. *Gender and Education*, 9(3), 285-305.

Boaler, J. & Sengupta-Irving, T. (2006). Nature, Neglect and Nuance: Changing Accounts of Sex, Gender and Mathematics. In *Sage Handbook of Gender and Education* (pp. 207-220). SAGE.

Cantley, I., Prendergast, M., & Schlindwein, F. (2017). Collaborative cognitive-activation strategies as an emancipatory force in promoting girls' interest in and enjoyment of mathematics: A cross-national case study. *International Journal of Educational Research,* 81, 38-51.

Carcary, M. (2009). The research audit trail – Enhancing trustworthiness in qualitative inquiry. *The Electronic Journal of Business Research Methods*, 7(1), 11–24.

Cheng, E. (2020). *x+y*. Profile Books Ltd.

Cohen, L., Manion, L., & Morrison, K. (2017). *Research methods in education* (8th ed.). Taylor & Francis Group.

Coghlan, D., & Brydon-Miller, M. (2014). *The SAGE encyclopedia of action research* (Vols. 1-2). SAGE.

Department for Education [DfE]. (2013). *Mathematics programmes of study: key stage 4*. National Curriculum in England. DfE.

Further Mathematics Support Programme [FMSP]. (2015). *Girls' participation in A level Mathematics and Further Mathematics*. MEI.

Fuchs, L. S., Gilbert, J. K., Powell, S. R., Cirino, P. T., Fuchs, D., Hamlett, C. L., Seethaler, P. M., & Tolar, T. D. (2016). The role of cognitive processes, foundational math skill, and calculation accuracy and fluency in word-problem solving versus prealgebraic knowledge. *Developmental Psychology, 52*(12), 2085-2098.

Garcia-Luis, V., & Dancstep, T. (2019). Straight from the girls: The importance of incorporating the EDGE Design Attributes at exhibits. *Curator, 62*(2), 195-221.

Goldberg, P. D., & Bush, W. S. (2003). Using metacognitive skills to improve 3rd graders' math problem solving. *Focus on Learning Problems in Mathematics, 25*(4), 36.

Guthrie, K. (2020). Qualitative Inquiry with Adolescents: Strategies for Fostering Rich Meaning Making in Group Interviews. *American Journal of Qualitative Research, 4*(3), 92-110.

Hahn, Y., Islam, A., Patacchini, E., & Zenou, Y. (2017). Do Friendship Networks Improve Female Education?, *IZA Discussion Papers*, 10674, Institute of Labor Economics (IZA), Bonn.

Institute of Mathematics and its Applications [IMA]. (2022). *Which Degree Courses need A-level Mathematics?* Maths Careers. Retrieved 12 May 2022, from https://www.mathscareers.org.uk/degree-courses-a-level-mathematics/.

Jacobs, G. M., & Ilola, L. M. (1991). A Brief Look at How Feminist Pedagogy Interrelates Learning. Paper presented at the *Annual Meeting of the American Educational Research Association* (Chicago, IL, April 3-7, 1991).

James, A. (2009). *Teaching the female brain: how girls learn math and science*. SAGE.

Karp, K., & Shakeshaft, C. (1997). Restructuring Schools To Be Math Friendly to Females. *NASSP Bulletin, 81*(586), 84–93.

Kellermeier, J. (1996). Feminist pedagogy in teaching general education mathematics: creating the riskable classroom. *Feminist Teacher, 10*(1), 8-11.

Kojo, A., Laine, A., & Näveri, L. (2018). How did you solve it? – Teachers' approaches to guiding mathematics problem solving. *LUMAT: International Journal on Math, Science and Technology Education, 6*(1), 22–40.

Lynch, K., & Star, J. R. (2014). Teachers' views about multiple strategies in middle and high school mathematics. *Mathematical Thinking and Learning, 16*(2), 85-108.

Marshall, E., Staddon, R., Wilson, D., & Mann, V. (2017). Addressing maths anxiety and engaging students with maths within the curriculum. *MSOR Connections*, 15(3), 1-8.

Miller, H., & Bichsel, J. (2004). Anxiety, working memory, gender, and math performance. *Personality and Individual Differences, 37*, 591–606.

Richardson, F. C., & Suinn, R. M. (1972). The Mathematics Anxiety Rating Scale: Psychometric data. *Journal of Counseling Psychology, 19*(6), 551–554.

Schettino, C. (2013). *Relational Problem-Based Learning: Adolescent Girls' Experiences with an Inclusive Pedagogy for Mathematics* [Research Report]. International Group for the Psychology of Mathematics Education.

Skelton, C., Francis, B., & Read, B. (2010). "Brains before 'beauty'?" High achieving girls, school and gender identities. *Educational Studies*, 36(2), 185-194.

Solar, C. (1995). An Inclusive Pedagogy in Mathematics Education. *Educational Studies in Mathematics, 28*(3), 311–333.

Smith, T., McKenna, C., & Hines, E. (2014). Association of group learning with mathematics achievement and mathematics attitude among eighth-grade students in the US. *Learning Environments Research*, 17, 229-241.

Spielman, L. J. (2008). Equity in mathematics education: unions and intersections of feminist and social justice literature. *ZDM, 40*(4), 647-657.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Webb, N. M. (1991). Task-Related Verbal Interaction and Mathematics Learning in Small Groups. *Journal for Research in Mathematics Education, 22*(5), 366–389.

Woodard, T. (2004). The Effects of Math Anxiety on Post-Secondary Developmental Students as Related to Achievement, Gender, and Age. *Inquiry: A Journal of Medical Care Organization, Provision and Financing, 9*(1), 1-5.

Zohar, A. (2006). Connected Knowledge in Science and Mathematics Education. *International Journal of Science Education, 28*(13), 1579-1599.

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