Battling Perfectionism: Examining the Impact of a "Pencil Principle" Scaffold on Year 9 Girls' Confidence to Engage with Unfamiliar Problems in the Physics Curriculum.

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Abstract

Physics is an inherently problem-solving subject. The transition from modular to linear examinations in 2015 (first examined in 2017) changed the way that students must tackle unseen problems. In my experience, students are reluctant to dive into a problem without first clarifying whether they are correct, making their Physics study stressful and less effective. This "perfectionism" and reliance on the teacher is more prevalent in girls' learning. Girls are likely to make their grade and achieve well, but their confidence is low and internal stress is high. In this project, I investigated how a simple scaffold, dubbed "the pencil principle," would affect students' willingness to "have a go," rather than reverting to a passive attitude to learning with the expectation that I, as the teacher, would fill them with the knowledge they needed. I conducted the project over the course of ten lessons with my Year 9 class (girls aged 13-14 years-old) as they embarked upon their General Certificate of Secondary Education (GCSE) study. The pencil principle was, in essence, extremely simple: students were instructed to try a question first in pencil before asking for help in attempting it. They were also told that rather than leaving homework questions blank they should take a guess in pencil. Students were told that nothing in pencil would be judged, and that writing in pencil would be an indicator to me that they were not sure of what they were writing. In a mixed-methods research design, I observed student behaviour in lessons and collected data on the types of questions they asked in the classroom, monitoring the level of "helplessness" in their attitude to the problems they faced. I also quantitatively analysed the written engagement of students in their independent work, monitoring what proportion was left blank and how students adopted the principle in their own way. Analysis of the data indicated that students did engage with the pencil principle and that this increased their written engagement with unseen problems. Having a reminder to actively and independently engage with a problem first also prompted students to reflect more carefully on the questions they asked, which maximised the helpfulness of my answers and the efficiency of our lessons. The project also impacted my teaching practice in that it highlighted times when I too became complicit in the passive learning cycle.

Glossary

Fatigue in Physics: The increase in one's perception of the difficulty of the science being studied, and the consequent reduction in motivation to continue.

Learned Helplessness: A condition whereby a person is so used to an unpleasant sensation (for example, not understanding difficult content) that they inactively tolerate this rather than look for ways to escape it.

Passive Learning: The form of learning relying on information transmission from a teacher to a learner with little two-way interaction.

Polyangulation: "The process of relating or integrating two or more sources of data in order to establish their quality and accuracy" (Mertler, 2020, p.313)

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Every child in Britain studies Science from the age of four to at least the age of sixteen. No other communication platform allows a single subject to have such an extended and captive audience. And yet it is clear that pupils struggle to engage with the scientific curriculum. In a survey undertaken by the Oxford Cambridge and RSA (OCR) examination board and published by the BBC (2005), 51% of students found Science lessons difficult and boring, with only 7% of students thinking those with careers in the sciences were "cool." As the research suggests, girls' pursuit of Science, Technology, Engineering and Maths (STEM) careers is even lower than the general population due to numerous factors: lack of female role models, ingrained gender stereotypes, and lack of confidence, to name a few (Heaverlo et al., 2013).

My project focussed on girls' engagement in Physics lessons, which is a subject with a particularly poor uptake of girls in higher education. Homan et al. (2018) looked at 115 STEM disciplines and analysed the percentage of female versus male authors of papers, before extrapolating based on percentage change each year, the time it would take for gender parity to be achieved. It was found that on average across the sciences, gender parity would be achieved in around 16 years, but in Physics, it would take over 250.

As a keen Physicist and passionate teacher, I take a great amount of pride in educating girls in my subject. However, I am disheartened when I see real life examples of bright and driven young women who are turned off from the idea of pursuing a future in Physics or other STEM subjects. This usually happens when girls transition from Key Stage 3 Science to GCSE study, where their wonder with the scientific world is dulled by difficult work and under-confidence in their ability. It was for this reason that I chose to work with Year 9 girls beginning their Physics GCSE, and decided to investigate the question: *How does a "pencil principle" strengthen Year 9 girls' confidence to engage with unfamiliar problems in Physics?*

Action research was a most fitting way to investigate my research question as it enabled me to gain real-time feedback from the students, both directly and indirectly through observation in the classroom. As put forth by Stringer (2007), education is one of, if not, *the* most prolific source of action research resources and this enabled me to create a robust model upon which to investigate my question and incorporate the curriculum and classroom into the project. Having run many in-class interventions with the aim of increasing student confidence in my subject, I relished the opportunity to be actively involved in a structured project and adapt my practice to better the experience of my students.

Literature Review

From personal experience of encounters where people unashamedly detail their poor ability or dislike of Physics, it strikes me that there is something fundamentally lacking in the way we communicate the subject to our young and impressionable students. Students are being “filled” with knowledge, applying it to questions, passing their examinations and promptly forgetting the majority of it. There is little or no empowerment or inspiration in educating children in this way and the negative repercussions of creating such passive receivers of knowledge extend well beyond the classroom and into adult life. Indeed, “fatigue in Physics” as noted first by Hoffman and Lehrke (1986) and later by Broome (2001) causes diminishing willingness to put effort into understanding difficult content and leads to a learned helplessness, which remains a problem in this subject to this day. It may even be worsening.

Science education has not adapted well to today’s culture of immediate gratification. Children are constantly stimulated with hours of on-demand content, with over three hundred hours of content uploaded to YouTube every minute (Donchev, 2021) and multiple streaming sites, such as Netflix and Spotify among others. Beyond supplying on-demand content, Netflix has released information that, since its introduction five years ago, the “skip intro” button is pressed an average of 136 million times per day (Johnson, 2022). What else so succinctly sums up our lack of patience as a society than that figure? Consequently, children can instantly communicate with one another, access instant content or find the answer to whatever question they wish with a quick “ok google ….”

Ironically, Science education remains an old-fashioned practice. To grasp a new and difficult scientific concept requires work, and I often see children begin to try, but then reach a point where they struggle and give up. Even more alarmingly, once this has happened a few times, a student is more likely to immediately resign their efforts and ask for assistance, their confidence shattered. This is a much more common phenomenon in girls’ education, with Broome (2001), building on the work of Henderson and Dweck (1990), noting that:

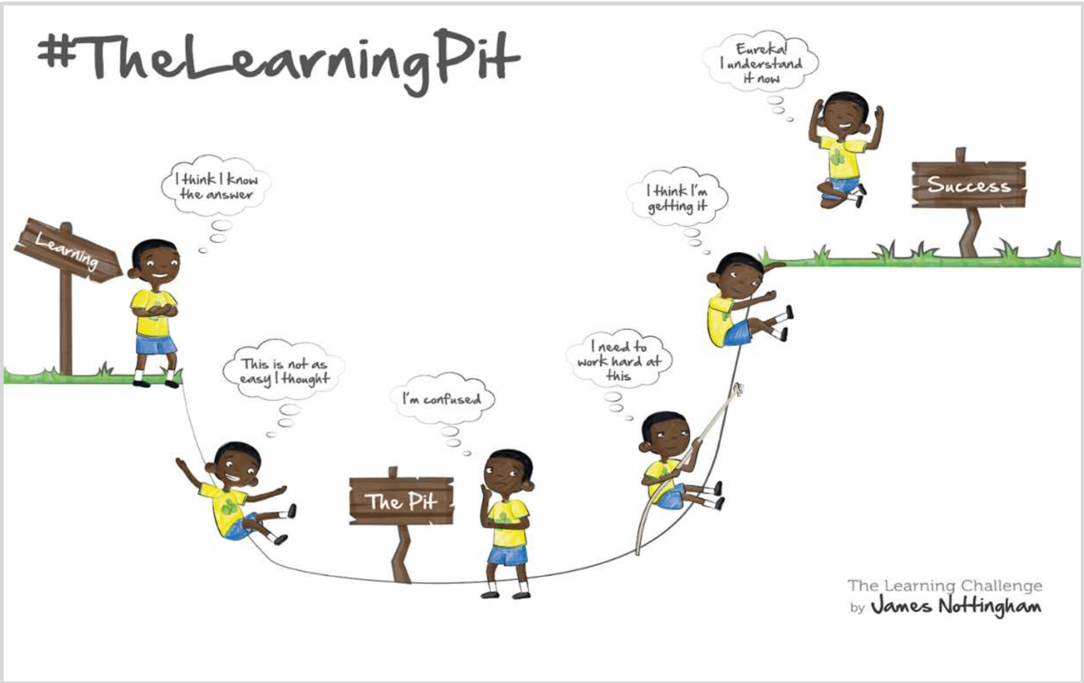
> On the one hand there are moderately gifted boys with favourable motivational sets who can be identified by persistence, knowledge of efficient learning and coping strategies and a positive attitude towards scientific demands …. On the other hand, we observe girls again and again with brilliant scientific and mathematical performance abilities who receive poor grades ... due to poor persistence, application of ineffective learning strategies or a negative set of attitudes towards physical and technical problems. (p. 103)

This phenomenon was further explained by Pomerantz et al. (2002) who state that, “Girls are more prone than boys are to internal distress. Specifically, they are more likely to evaluate themselves negatively and to experience internalising symptoms, such as anxiety and depression” (p. 396). The recent pandemic has only exaggerated this learned helplessness in students, with lack of engagement increasing for students who were subjected to long periods of online learning (Garcia et al., 2021).

I focussed my research on effective learning strategies to combat the girls' learned helplessness. One example of such a strategy is James Nottingham's (2018) "Learning Pit" as illustrated in Figure 1.

Figure 1

The Learning Pit: A Visual Representation of the Cognitive Conflict Students Face in Lessons and How to Manage That. (Nottingham, J., 2018, p. 18).



Many students find themselves stuck in "the pit" in an uncomfortable state of cognitive conflict and are not equipped with the skills to extricate themselves. If educators simply pull students out of the pit, they reinforce their students' learned helplessness. This situation is similar to that of the peasants in Paulo Freire's (1974) *Education: The Practice of Freedom* where they were so "influenced by the myth of their own ignorance" that they preferred to "keep quiet and listen to you who know" (p. 119).

In my project, I aimed to provide students with a simple scaffold to help them find their own way out of the pit, hoping that they could independently build their own understanding and, as a consequence, develop belief in their knowledge and ability to learn.

Ideally, as set out by Freire (1974), in a world of infinite time and resources, education would adopt a dialogical approach to allow students to fully engage. Students should be able to make scientific discoveries for themselves, thereby taking ownership of their scientific education. By "scientific discovery," I would not be expecting every student in England to make a significant breakthrough in science. Rather, there should be the opportunity for students to discover even well-established scientific principles for themselves. It is an illusion of discovery but, in this way, students can develop a deeper connection with the subject.

I aimed to take a small step with this project to hand ownership of learning back to the students. The simple act of allowing students a safety net helped to break through some learned helplessness and allowed the students to build effective problem-solving strategies that might apply beyond the subject of Physics, again, in an ideal world.

Research Context

Putney High School is an independent all-girls' school in Southwest London, United Kingdom. With a junior school attached, students can attend from age four to eighteen years old. The school has 1055 pupils and is also part of the Girls' Day School Trust, which comprises 25 schools across the UK, with 19500 students in total. The central theme of the school is that all students should leave with solid skills and key characteristics. Putney girls should be innovative, intrepid, intellectual, and inclusive. All students study Physics as a subject from Year 7 (age 11) up to GCSE level (age 16).

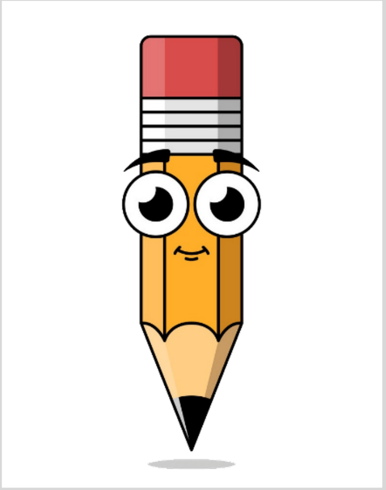
My research was undertaken with a class of Year 9 pupils, aged 13-14 years old. The research took place right at the start of our academic year in September and ran across the course of one term until December. I did not know any of the pupils prior to my project, but I chose them as they were at the very beginning of their GCSE Physics course and so they provided me with the opportunity to apply my research to students without a preconceived notion of how to go about their Physics studies.

The Action

My action in this project spanned ten Physics lessons with my class of 22 Year 9 pupils. I introduced the "pencil principle" as a guide for both their in-class work and written work, whether that took the form of an assessment, homework, or experiment write-up. The instruction to students was, in itself, very simple: "If you are not sure, try in pencil first before giving up." I amended my lesson resources to include a visual reminder of the principle (see Figure 2) and encouraged students to take ownership of their participation in the project by consistently reminding them to "consult with the pencil" first.

Figure 2

The pencil that students affectionately named "Sketchy"



By using this light-hearted approach, my aim was to allow students to adopt the pencil principle in any manner they wished, so that I might gain insight into how they approached their work and how, over the course of the project, I might adapt my own delivery of lessons to encourage their engagement and nurture their confidence in Physics, moving forwards.

Data Collection

To measure student engagement, I firstly made it clear to the students and to myself that I would not be looking at attainment. The students' ingrained perfectionism was a barrier I was looking to overcome, and this project was a small step towards that. To increase their confidence to engage with problems, however, I felt it was best to side-step this and to reassure them that their work would not be conventionally "marked" for this purpose. Since engagement in my context is reflected in both students' willingness to contribute to lessons and in their written work, I adopted a mixed methods approach to data collection (Mertler, 2020, p.197), focussing on the following five methods:

1. In-class written recording and coding of the type of questions students were asking
2. Observations to record in more depth what students were asking and discussing
3. Student voice at either end of the project through semi-structured questionnaires and follow-up focus groups
4. Homework and test analysis
5. A non-curriculum-based problems "quiz" at the start and end of the initial research phase. These used scientific questions from previous study, not currently taught material which would bias results.

Aside from methods three and five above, the other data collection methods ran continuously throughout my project. Student voice collected through questionnaires was an extremely important part of my data collection as it provided authentic and varied information. I chose questionnaires to gather such varied information quickly (Johnson, 2008).

I included quantitative data in two different forms. One was an analysis of the research quizzes, (see data collection point 5 above) homework, and assessments, which looked chiefly at the proportion of questions not attempted. The other was my coding of questions in lessons, in the following categories of questions from students:

- Helpless
- Partially Helpless
- Reflective
- Validation
- Extension
- Clarification

Due to challenges in obtaining parental permissions from all students, I was unable to video record my lessons and so deeper qualitative analysis of students' discussion and engagement in lessons was carried out using observations, both my own that I recorded using field notes, and observations by another member of staff. I believe the quantitative data were important as they allowed me to objectively assess trends over time and run this in parallel with my, and the students', subjective observations of their engagement. The variety of data collection processes enabled me to polyangulate my results (Mertler, 2020, p. 13), increasing my confidence in the trustworthiness of my findings, and having some outside observation was invaluable as I was able to cross-reference my observations with a colleague.

Data Analysis

To alleviate pressure at the end of the project, some analysis happened "in the field." As I observed students' questioning, I devised the categories described above, which evolved throughout the first few lessons of my project. My quantitative analysis of written work, through the necessity of returning this to students, also happened throughout the whole research phase.

I coded the student voice data at the end of the project once I had both sets of responses submitted. This helped me to condense and organise the volume of data using similar codes, allowing for direct comparisons between the students' feelings and reflections at the start and the end of the project (Parsons & Brown, 2002). I also ensured I discussed my decision of categories with my in-school mentor, to remain objective regarding student opinion.

Discussion of Results

After analysing the data generated by my research, it emerged that students' engagement with problem-solving was multifaceted: rooted in their confidence, their fear of judgement, and also in their ability to reflect on their learning.

Students engaged with written problem-solving more readily

Over the course of ten lessons, I collected five pieces of work from the students, and noted exactly what percentage of the work they had not attempted by leaving blank. I also noted how much of the students' work was written in pencil, rather than being left blank. My findings are represented graphically in Figures 3 and 4.

After the launch of my project the students initially overcommitted to the pencil principle in two ways. The first was a massive upswing in students writing everything, or more than they should, in pencil (see Homework 2 in Figure 4 for reference). When I asked why that was, Student H said, "I started off doing one question in pencil because I wasn't sure and then I just ended up doing everything else in pencil because I was too lazy to change,'' and Student G added, "I liked writing in pencil because it meant that if I was wrong, I could rub it out."

Figure 3

Graph Showing the Five Significant Pieces of Work Undertaken by Students Across the Term and the Percentage of Marks That Were Unanswered in Each Piece.

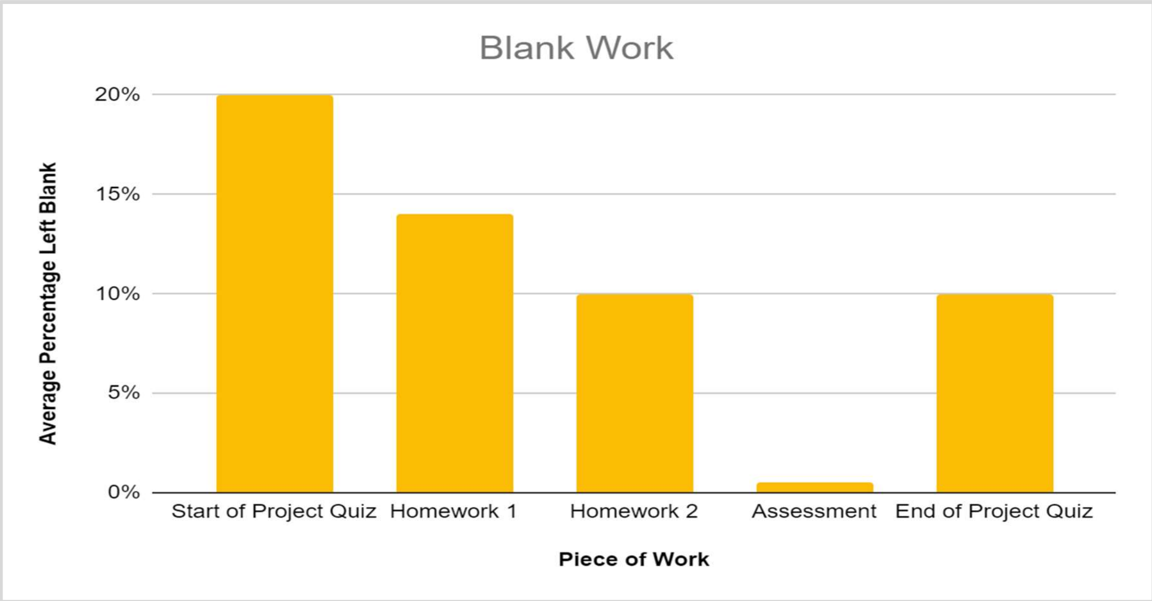
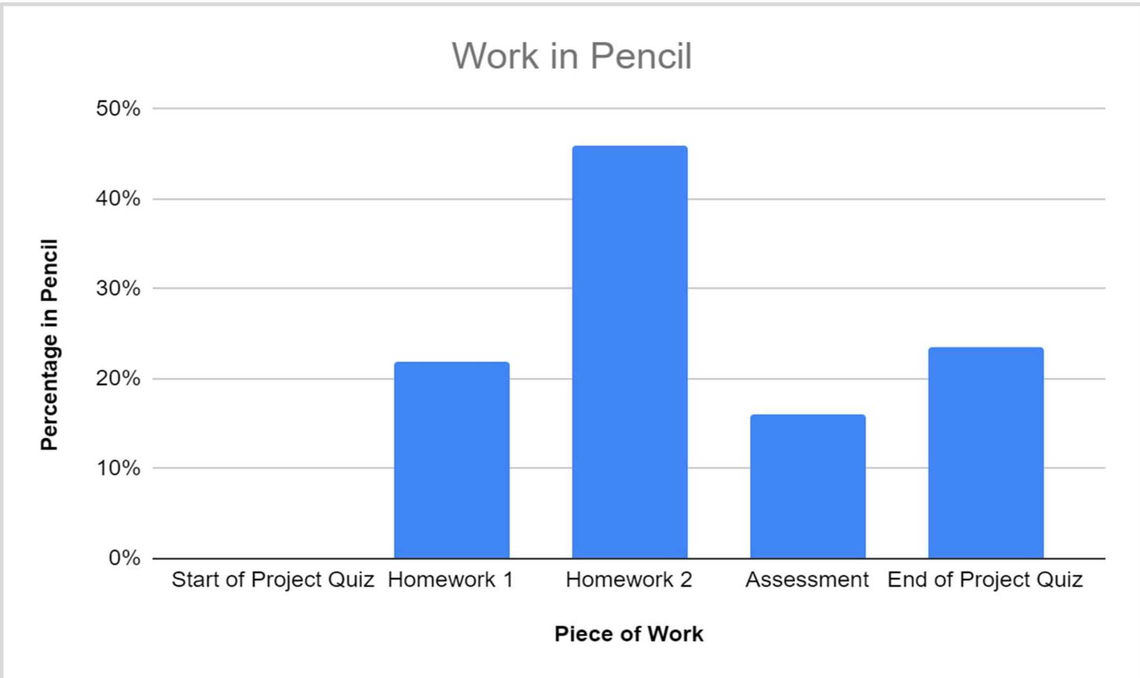


Figure 4

Graph Showing the Five Large Pieces of Work Undertaken by Students Across the Term and the Percentage of Marks That Were Answered in Pencil in Each Piece.



The majority of students left smaller amounts of written work blank as the project progressed. This was clearest when comparing the start and end of project quizzes; both were on material the students studied in their first two years of school but not during the project, and students were not given forewarning that they would be taking either quiz. This shows, at least on a surface level, higher initial engagement in problem- solving over the course of the project.

Confidence to Try Increased

Initially when asked about their confidence in tackling questions, students gave answers along the lines of "very confident," "somewhat," or "quite," with the majority being in the latter two categories.

Of the twelve students in my three focus groups, eleven immediately agreed they did not like having an incorrect answer on their page, and that they found it more embarrassing to get something wrong than to leave it blank. The most common answer to a survey question, "What would stop you guessing a question if you did not know?" was, "not having a good guess." This ties in with the idea of perfectionism that the students unanimously agreed they have when it comes to their academic work.

Focus group data supported that scaffolding written work with the pencil principle was beneficial when it came to students' confidence to engage with a problem. Student C said:

> I don't want to look like I know it, but then get it wrong.... If I write in pencil, since you know that pencil is unsure ... it signals that I'm not confident in the answer. And if I get the answer right and it's a pure guess it still lets you know that I wasn't sure why to put that.

Sentiments similar to that quoted above were a common thread throughout all of my focus group data, however the outlying student, Student J, answered: "I didn't like the pencil, so I never used it. I feel like I should probably stick to what I think, and if it's a guess it's still my answer."

Students Asked More Questions to Problem-Solve for Themselves

The second overcommitment to the pencil principle was that students stopped asking as many questions in the early lessons of the project: five to nine questions per lesson compared to 20 to 22 on average at other times (see Appendix for a breakdown). I observed in my field notes that students were becoming aware of their passivity; however, I recorded in my lesson observation notes that rather than reflecting well and asking questions that would aid their learning they did not ask anything at all. The students were responding emotionally to their learning (Pomerantz et al., 2002). This corrected itself over the course of the project: the number of questions in Lesson Ten was similar to the number asked in Lesson One, although it is worth noting that this only addressed the number of questions students asked of me as their teacher, not the dialogue I observed them to be having with one another, which increased over the course of the project.

I also looked at the type of questions students were asking in lessons, to see if they were attempting problems first themselves, before reverting to passive learning. Figure 5 shows the spread of questions asked in the first lesson of the project and Figure 6 shows the final lesson. A lesson-by-lesson breakdown can be found in the Appendix.

Figure 5

Breakdown of Questions Asked in Lesson 1 of the Project.

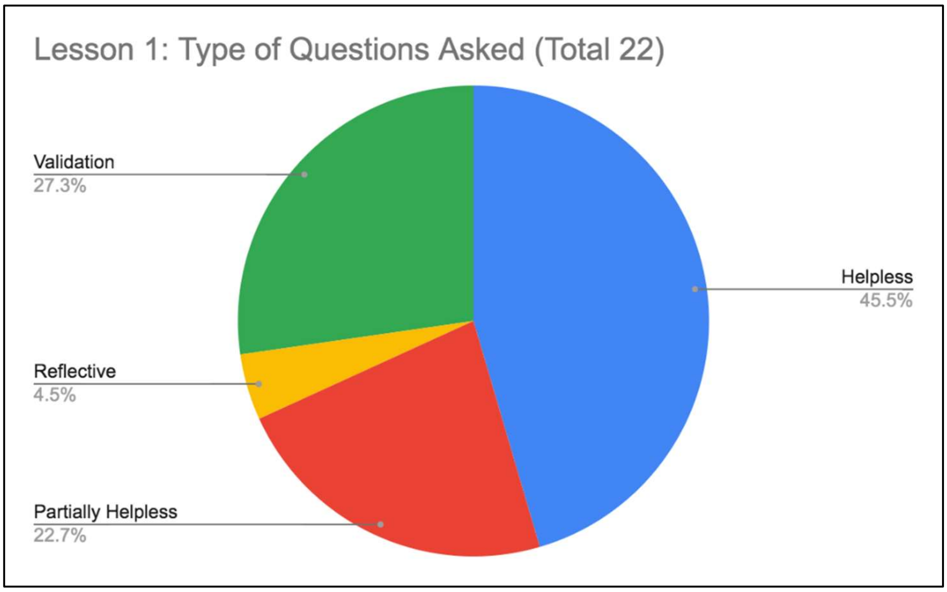
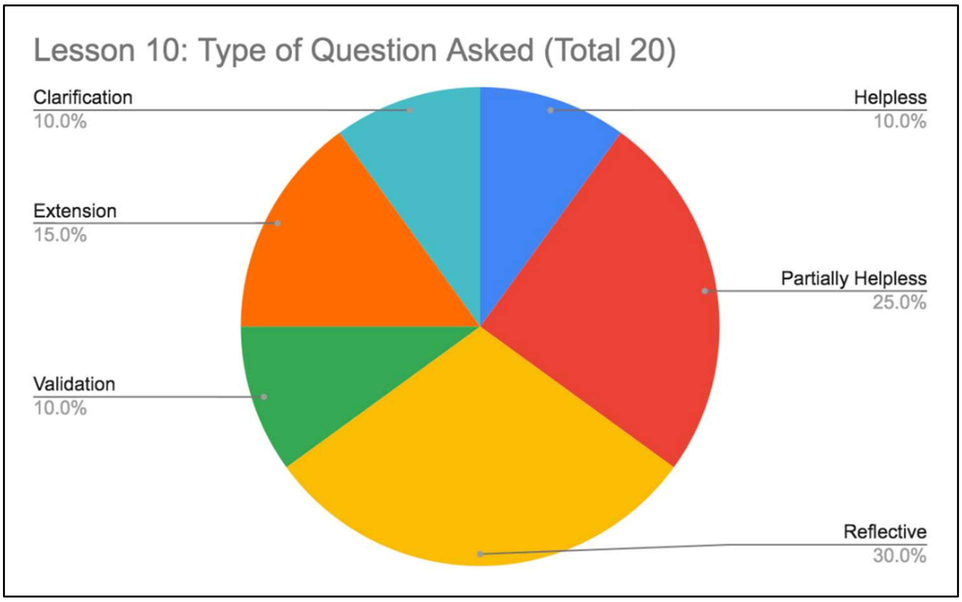


Figure 6

A Breakdown of Questions Asked by Students in Lesson 10 of the Project.



The two most notable outcomes were the decrease in the total number of either helpless or partially helpless questions students asked, and an upswing in the number of reflective questions. Two such examples from my in-lesson observations were, “If particles are cooler, does that mean they are denser?” and, “So do you need heat for evaporation?” Both questions show a small misunderstanding of the physics, but the clarity of the questions allows for more focussed discussion than student statements at the start of the project, which I recorded predominantly as “I’m confused” or “I don’t understand.” In fact, I observed my students going on a journey from those phrases to more rounded questions (deemed partially helpless), such as “I don’t understand how the sun radiates heat to us,” and finally to questions that did not start with reference to not understanding at all.

It is worth noting that, although the relative percentage of partially helpless questions is larger in Lesson 10 than in Lesson 1, this still reflected the transition of students away from purely helpless questions. I am aware that one limitation of my data collection was that it was simply not feasible to code which student was asking which type of question during a typical lesson, but the drop in helpless questions from 45.5% to 10% of questions shows a significant shift in the mindset of the majority of students.

Reflecting on Learning Increased, as did Metacognition

The students also became more reflective on what they wrote in pencil as the project progressed. In my in-class observations I noted that students readily swapped implements more often than early in the project. This shows a higher level of reflecting on what they did and did not feel confidently able to answer, rather than overcompensating. Importantly, the students were able to reflect without evaluating themselves negatively, an important step in battling their perfectionism and avoiding internal distress (Broome, 2001; Pomerantz et al., 2002).

Students also reported that they became more self-aware of how they were learning. All students in my focus groups were unaware of the terms “learned helplessness” or “passive learning,” but once I had explained these to them all twelve girls agreed that this applied to them, and that they had become more aware of it throughout the project, which forced them to actively focus on the type of questions they were about to ask. This made them aware of their “fatigue” when it came to problem solving (Hoffman & Lehrke, 1986).

Conclusions

The “pencil principle” did improve students’ written and verbal engagement measurably over the course of the project. A significant portion of work, once left blank, was filled with answers and intelligent guesswork. This is key to a subject like Physics where a large portion of examination questions present students with unknown situations to problem-solve.

Less easy to measure was the confidence of the students, so I relied heavily on student voice and observation in lessons to assess the efficacy of the principle in this regard. The majority of students, when interviewed, said they had found the implementation of the principle to be helpful when they were unsure of the answer in written work. Students also said the visual reminder made them reflect on the questions they were asking and to amend them to be more helpful to their learning. Whilst they, and I, agreed that they were not infinitely more confident and engaged with problem-solving in the Physics curriculum, they all agreed that they have been made more aware of their passivity and the moments where they tend towards helplessness. As a teacher, I have also caught myself falling into the habit of coddling the students at times, but upon catching the eye of the sometimes irritatingly happy "Sketchy," I have reminded myself to create the space for the students to develop the problem-solving skills they need independently.

As mentioned, this project did not provide a total fix to the problem of girls' confidence and engagement when faced with new concepts in the classroom. The impact of the project for their long-term approach to learning is limited in that it required a consistent reminder for both myself and the students, and since the students only had this in my lessons, a small fraction of the school week, it hardly became ingrained in their everyday practice. It was however, as intended from the outset, a small step to give ownership of their learning back to the students and has made an impact on my practice, which I will carry forward with this class and future Physics students.

Reflection Statement

This action research programme, with its theme, "Building Problem-Solving Capacity, Confidence and Skills in Girls" was a serendipitous encounter for me, and I must thank my line manager Dr Will Dixon for encouraging me to apply and carry out my research project and for his support in school throughout. In my practice I have consistently aimed to increase my students' resilience around this very theme. At times over the course of my teaching career it has felt a very Sisyphean task, and so I have enjoyed this opportunity to research educational literature with a solid aim and to carry out a small and structured intervention.

I have been rewarded with a clarity on this topic I did not possess previously, and with a renewed vigour to continue my encouragement of students' STEM futures on a daily basis. Truthfully, I was surprised at how the project made me reflect, as well as the students, on my levels of teacher intervention. I have only been teaching for six years but I caught myself pre-empting the students' questions and answering before the students themselves had really formed a rounded question and a proper idea about where they did not understand. Since in the project I was recording and coding the types of questions the students asked, however, I found myself asking, "can you rephrase that as a question?" rather a lot and found value in this itself. I would like to carry this forward, perhaps as a future project.

I must thank my research advisor, the tireless and ever patient Debbie Hill, without whom this report, and my project, would be a garbled mess, and the whole of my peer research group who have provided such a strong sounding board over the last two years. Thanks to Natalie Demers for running the programme and to Margot Long for her advice and guidance in the world of action research. Finally, I would like to thank my Headmistress, Suzie Longstaff, for allowing me to participate in this research collaborative.

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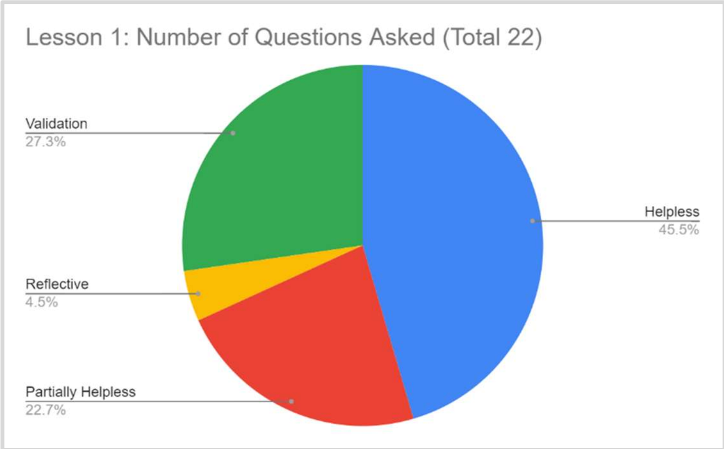
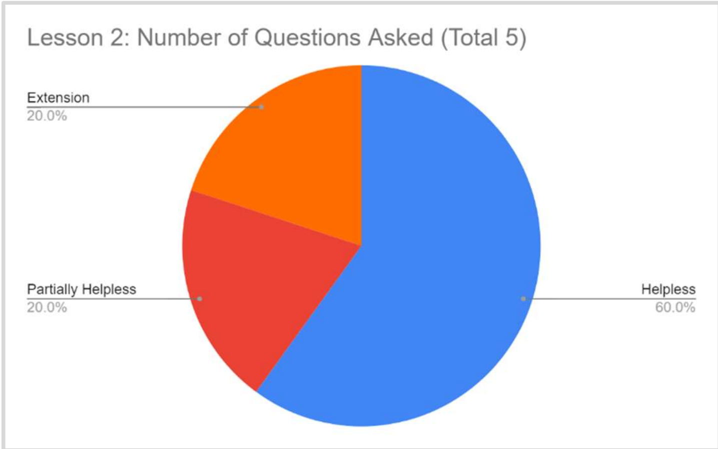
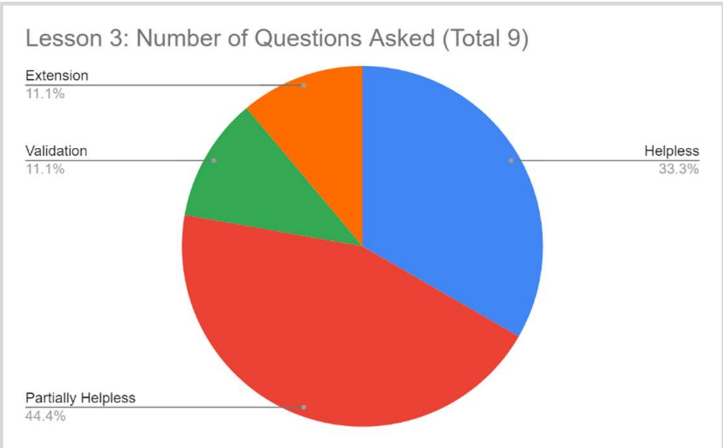
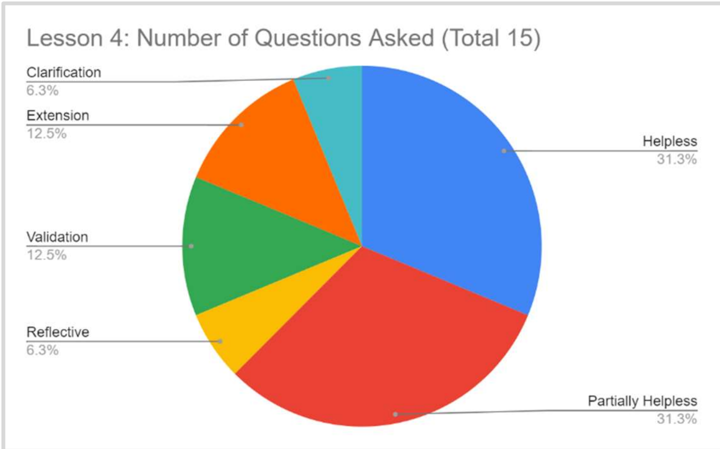
Appendix

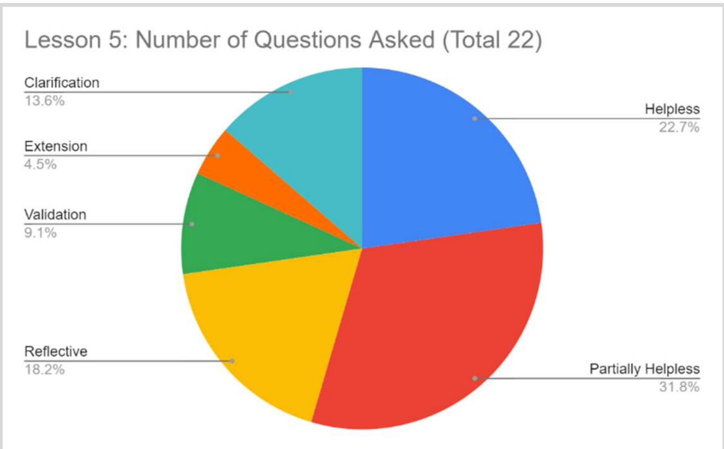
A Lesson-By-Lesson Breakdown of Type of Question Students Asked During the Project

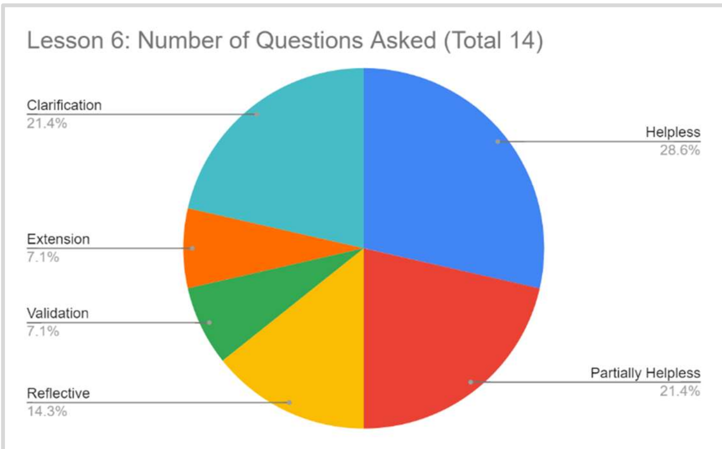


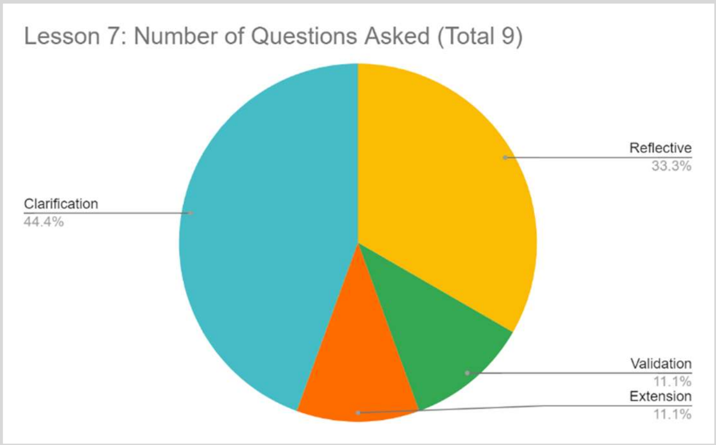


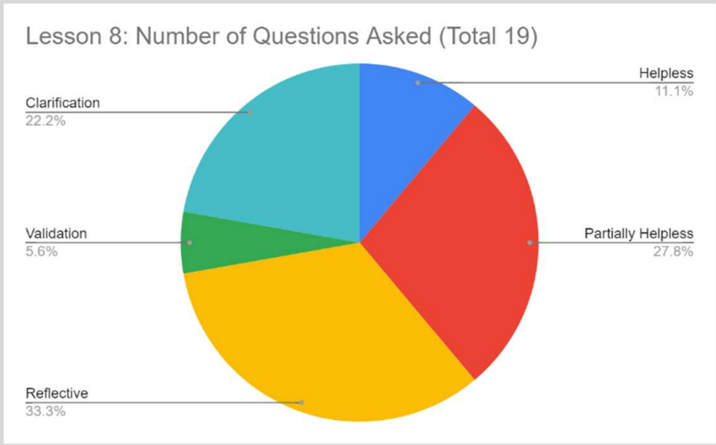


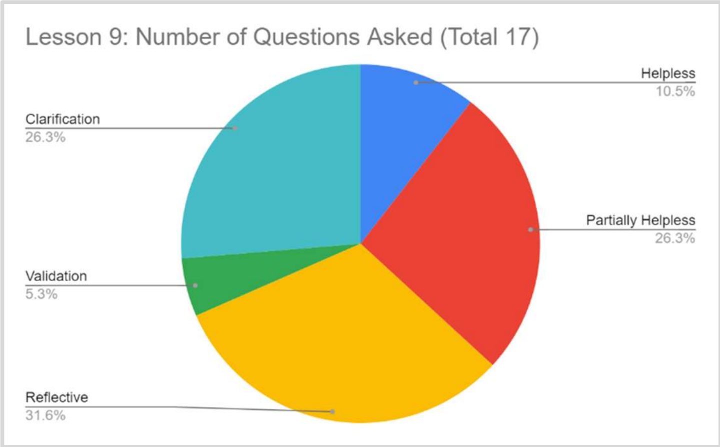


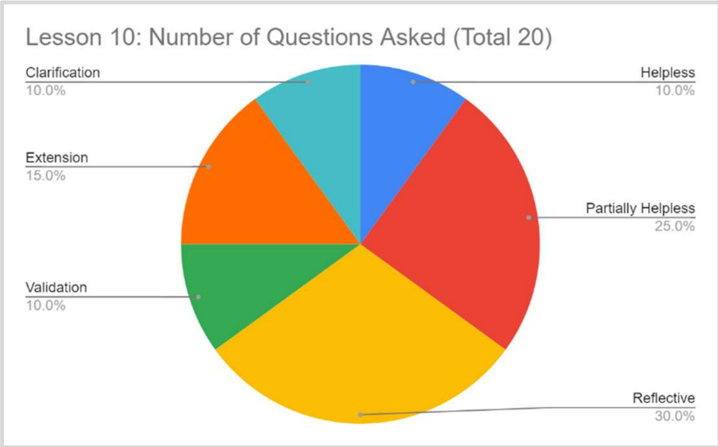





Lesson 7: Number of Questions Asked (Total 9)
Reflective
33.3%
Clarification
44.4%
Validation
11.1%
Extension
11.1%


Lesson 8: Number of Questions Asked (Total 19)
Helpless
11.1%
Clarification
22.2%
Validation
5.6%
Partially Helpless
27.8%
Reflective
33.3%


Lesson 9: Number of Questions Asked (Total 17)
Helpless
10.5%
Clarification
26.3%
Partially Helpless
26.3%
Validation
5.3%
Reflective
31.6%


Lesson 10: Number of Questions Asked (Total 20)
Clarification
10.0%
Helpless
10.0%
Extension
15.0%
Partially Helpless
25.0%
Validation
10.0%
Reflective
30.0%