What are the relationships between the design and use of teacher generated examples and learners' successes in the secondary mathematics classroom?

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Abstract

Learning in mathematics is guided by the examples used by teachers in lessons that they deliver. There is research evidence that suggests that the design and use of these examples can have an impact on learners' outcomes in mathematics. This study investigates the relationship between these variables to build a better understanding of how learning is influenced by the different approaches taken by teachers, aiming to answer the following research questions:

1. *What do teachers consider when designing examples to promote learner participation in the secondary mathematics classroom?*
2. *What considerations and adaptations of example delivery improve learners' opportunities to engage with mathematics most significantly and how can this be applied to other curriculum subjects?*

To answer these questions, a variety of different data collection methods have been used; lesson observations, teacher interviews and grouped learner interviews. The approach taken was purposeful in ensuring a focus on the learning experience and the outcomes that this can have upon learners' successes in mathematics, such as confidence and resilience to participate, in comparison with current research in this field that measures learners' outcomes by attainment. Data collection is completed pre and post-'intervention' to allow for a comparison of learners' successes both before and after the intervention stage.

It has been found that although learners are frequently invited to contribute their ideas during the delivery of examples, classroom dialogue is closely managed by teachers. Learners are also provided with minimal opportunities to contribute to the generation of examples. To improve learning experience in the secondary mathematics classroom, examples should be delivered in an interactive way. The findings suggest that by providing opportunities for learners to explain their justification for solutions, without interruptions, their ability to advance discussion through this participation significantly improves. Examples should be designed by teachers to promote discussion and unearth misconceptions held by learners, so that they can be clarified.

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1. INTRODUCTION

This small-scale study aims to explore the relationships between learners' progress and the development and use of teacher generated examples in the secondary mathematics classroom. Examples are the tools used in the mathematics classroom to demonstrate methods or concepts; they enable learners to understand how to solve problems and can be designed in such a way that they deepen learners' comprehension of a topic. Goldenberg & Mason (2008) explore how they can "be seen as cultural mediating tools between learners and mathematical concepts, theorems, and techniques" (p.184). As a part of prior research that I have conducted, I investigated the impact that learner generated examples can have upon learning outcomes. This encouraged me to explore how teachers may choose to incorporate these into the lessons that they deliver and what other factors may influence the creation of teacher generated examples that are shared in class.

In my experience, I have observed mathematics lessons to be typically comprised of four main stages. Namely a starter, an introduction to a concept which includes the teacher delivery of examples related to the concept, an independent study task for the learners where they practise the relevant skill, and finally a plenary that aims to extend learners' understanding or introduce the next topic of study. Within my school over the last 3 years, we have transitioned to using a digital platform that creates worksheets of questions for the 'practice stage', these are developed to improve learners' strength and depth of understanding. They complete these on a computer, where they are encouraged to note down all their workings and submit

their answers for instant feedback. They have 3 attempts to correctly solve the problem, before the teacher is notified that the learner requires assistance. As a result of this, I have observed an increase in learner confidence and resilience with problem solving, in addition to improved engagement. I believe that this is due to the incorporation of technology, which creates a blended learning environment. Blended learning can be defined as "a way of learning that combines traditional classroom lessons with lessons that use computer technology" and subsequently "a way of breaking down barriers to education" (Cambridge Dictionary, 2022). The digital platform also provides teachers with their own examples that link to the objectives of each lesson, that they can choose to explore with learners. Whilst this ensures that any content covered in independent practice seamlessly links with teacher generated examples, I am interested to understand to what extent teachers choose to use these already prepared resources and the considerations that they make when planning examples to illustrate concepts or methods in class. I aim to establish an understanding of any relationship that these choices can have with learner progress in mathematics and whether there are any additional considerations that could be made in the planning or delivery stage to improve learners' successes in mathematics.

The Department for Education (2011) outline in the Teachers' Standards that all teachers must "impart knowledge and develop understanding through effective use of lesson time" (DfE, 2011). Ensuring that the examples used promote progress is integral to the effective use of lesson time and so this study can play a significant role in improving learning by investigating example generation and use, and then

communicating any findings to provide teachers with evidence-based implications for planning and delivery. This notion of close attention to the teacher demonstrations in lesson is echoed in the 'learn that' statements that feature in the Core Content Framework (CCF) that outlines the minimum curriculum entitlement that a trainee teacher should study in their initial teacher training year. It discusses how "effective teachers introduce new material in steps, explicitly linking new ideas to what has been previously studied and learned" and that "modelling helps pupils understand new processes and ideas [and understand that] good models make abstract ideas concrete and accessible" (DfE, 2019). To be able to make judgements about the effectiveness of modelling through examples, it is important to consider the impacts that the examples have on individual learners' understanding of a concept. If they are accessible, then all learners should be able to benefit from their inclusion in lessons. However, there may also be occasions where teachers decide to include examples to scaffold or extend learning, to ensure that learners are sufficiently supported or challenged. I am interested to what extent that these factors influence a teacher's decisions when crafting questions to deliver as examples in lesson.

There is a significant amount of educational literature that explores the impacts that these decisions can have upon learners' outcomes in mathematics, this is because "examples and exemplification have had a significant role in the teaching and learning of mathematics throughout history" and "Researchers have asked questions about characteristics and features of chosen examples and questions about sequencing, in order to understand the optimal variation of such sets of examples to

best support students' learning of a particular mathematical concept or procedure" (O'Neil, 2018, p.1). I aim to explore the relevant literature surrounding my chosen line of enquiry and establish an investigation design that produces a valuable contribution to the existing wealth of literature by providing a new perspective, that is useful for the teachers and learners within my Multi-Academy Trust. In addition to my role as a Mathematics Teacher, I am the Initial Teacher Training Manager and Early Career Induction Tutor for my Multi-Academy Trust and so I am hopeful that I can interpret the findings of my research in mathematics and consider how my understanding of modelling in mathematics could be transferrable to other subjects taught across the school. This is so that I may support early career phase colleagues with their understanding of the considerations that may be helpful in the generation of examples for delivery in their lessons.

The specific areas of interest that I intend to explore through engagement with the relevant literature available include considerations in example design, the impacts that different example designs can have upon learners' ability to understand concepts and the pedagogical approaches to delivering examples to learners and the impacts that specific pedagogical approaches can have upon a learners' experience and engagement in the mathematics classroom.

2. A CRITICAL REVIEW OF THE LITERATURE

Examples are a crucial tool to guide learners' journeys to understanding mathematical concepts. Mathematics teachers have access to a wide range of pre-prepared resources that they can include within their lessons, these can be found in textbooks, as printable worksheets, viewable as online videos, and past examination question banks. In planning, teachers explore all these sources to find suitable examples to explain how to solve mathematical problems. Depending on the teacher's personal experience and education, they are also able to draw on their *example spaces*, Zaslavsky & Peled (1996) defined these as the collection of mathematical examples someone can mentally access. For teachers these would include a vast range of general and special cases, that they have previously encountered in their study or teaching of mathematics.

2.1 Considerations in example design and their impacts upon learners' understanding of mathematical concepts

Examples consume a large portion of the lesson time available to teachers. Essien (2021) recognises the importance of the this and explains how the example design chosen by teachers is pivotal in affecting what mathematics is taught and learned, ultimately determining what opportunities for learning are created. The following sub sections of this paper will navigate the existing educational literature, to evaluate some of the most significant elements for consideration in example design.

2.1.1 Spontaneous vs. Pre-Prepared

There are several decisions that a mathematics teacher makes in the preparation of their lessons, but ultimately it is important that they have the ability and confidence to adapt their lessons in the moment to ensure that all learners can access the material that they are studying. Mason and Spence (1999) deemed this as a necessary skill in a teachers' toolkit, terming it as *knowing to act in the moment.* Zodik and Zaslavsky (2008) acknowledged this in their study of the *Characteristics of teachers' choice of examples in and for the mathematics classroom*, looking closely at examples that were pre-planned and spontaneously delivered to respond to classroom situations. It was found that close to half of examples in lessons were developed in the moment, which is encouraging as it indicates that teachers are considering learners' responses to teaching materials and adjusting lesson plans accordingly to promote progress. Some of the most notable considerations uncovered by this study were as follows; the ambition to develop examples that recognise and attend to student errors, start with a simple or familiar case, draw attention to relevant features by minimising the inclusion of other topics within the examples and to convey generality by 'random' choice. A limitation of this study was the lack of accuracy of observation data collected, due to the difficulty in classifying examples with a specific theme in the fast-paced environment. Although, pre and post observation teacher interviews and lessons plans were used to help differentiate between examples that were spontaneous or pre-prepared and establish the justifications for their designs. The researchers concluded that there is an important place for randomly selected examples, spontaneously delivered in the mathematics

classroom; firstly “as a response to students’ utterances, such as falsifiable claim” and to respond to teachers’ “own recognition of certain limitations of a pre-planned example in the course of a lesson” (Zodik & Zaslavsky, 2008, p. 180). These conclusions lack evidence as to the wider implications that following this approach to example generation would have upon learners’ understanding of mathematical concepts and so there would need to be more investigations surrounding this. The discussion in the study also neglects to consider the importance of the characteristics of teacher generated examples, such as attending to learner errors, which makes it difficult to determine the most impactful considerations that can be made to ensure that learners can make the best progress.

2.1.2 Modelled vs. Worked Examples

Characteristics of teacher generated examples were explored more deeply by Huang and Cribbs (2017) who looked closely at the most favoured methods amongst teachers in developing examples for use in the secondary mathematics classroom. They argue that the consideration of teacher perception sets apart the research from other literature, and that it is “important to understand teachers’ perceptions on how [examples] could be integrated into their instruction and what constitutes advantages and disadvantages of using the various examples” (Huang & Cribbs, 2017, p. 387). Examples were categorised by 2 types; *Modelling Examples (MEs)* that allow learners to observe a demonstration of a solution, with the teacher verbalising the problem-solving process, and *Worked Examples (WEs)* which are presented to learners as a written step by step solution for a problem. *MEs* were then divided into 2

subcategories; *Coping MEs* where a learner either demonstrates the solution to a problem in front of the class or their work is shown on a visualiser and *Mastery MEs* that are flawlessly delivered by an expert (typically the teacher). *WEs* were also split into two types; typical textbook style examples termed *Standard WEs and Erroneous WEs* that are composed of an incorrect solution to a problem. The study found that teachers felt most comfortable modelling the process of solving a problem (*Mastery MEs)* and that they saw potential in planning for the inclusion of *Coping MEs* in lesson time, as observing a peer model may help learners to recognise mistakes and boost their confidence. *Standard WEs* were deemed insufficient in facilitating learning, this was because they lacked detailed explanations of steps in the solution process. It was concluded that "teachers felt less comfortable using examples that contain errors, partly because they felt that the errors presented may reinforce students' misconceptions" (Huang & Cribbs, 2017, p.386), this is supported by Star et. al (2015) who discuss the importance of displaying correct solutions parallel to any examples that demonstrate erroneous working. It is suggested that this makes it easier for learners to identify and analyse the error and through discussion with an expert about each step of the solution, any confusion as to which problem-solving strategies are correct and incorrect is reduced. Overall, Huang and Cribbs (2017) study of examples as an instructional tool for mathematical learning highlighted the importance of teacher-modelled examples, however it lacked significant perceptions and attitudes – those of the learners that the experience is designed for. It is acknowledged that the study was limited by the focus it had upon teachers' decisions and their justifications

for these, it lacked evidence to support the suggested impacts that the teachers' decisions had on learners' outcomes.

Although Huang and Cribbs (2017) favour modelled examples as a method to design and deliver examples, Renkl (2017) argues that worked examples also have an important role to play in mathematics education, particularly in fostering the initial acquisition of knowledge and problem-solving skills. The use of such examples is described as a successful method of preventing unproductive problem solving, by allowing learners time to understand the steps that must be taken to solve a problem, they can more easily comprehend a method. However, it is noted that once learners have secured their understanding of the solution steps, "further study of examples becomes redundant. Such students should proceed to solve problems so that other learning goals can be achieved" (Renkl, 2017, p. 573), this could include learning to perform and automate the solution procedures. These assertions are supported by a wide range of prior research and engagement with action research that investigates the impact that examples can have in the secondary mathematics classroom. Based on these findings, it would be appropriate to conclude that worked examples are effective in their use as a tool to introduce new concepts to learners. Although caution should be taken in planning to ensure that these worked examples are not perused by learners for longer than is necessary, as not to hamper their mathematical development. This would require the teacher to be confident in their assessment techniques and ability to determine each individual's learning outcomes.

2.1.3 Erroneous Worked Examples

As discussed, Star et. al (2015) recommend careful use of incorrect worked examples, to ensure that learners do not become confused, Pillai et al. (2020) also investigated the potential impacts of using such examples in teaching probability. Their study involved participants comparing incorrect and correct worked examples and rating their perceived correctness, as well as answering unseen and unstudied questions. It was found that there were no differences between the outcomes of learners who were asked to compare, or study correct and incorrect examples, or those that were only exposed to correct examples in their learning. Here, outcomes were measured by their ability to accurately identify correctness of examples in both studied and unstudied mathematical topics. They argue that this suggests that the results "provide preliminary evidence for educators that their worries about the negative effects of presenting incorrect worked examples may be unfounded" (Pillai et al., 2020, p. 529). In fact, the results of the investigation found that learners may have been more accurate with their judgement of incorrect and correct examples when exposed to both cases in lessons. This judgement is an important skill for learners to develop to contribute to their success in mathematical problem-solving, however it is rarely a skill assessed as part of examined content, which may influence teachers' decisions as to whether the inclusion of such tasks would be a suitable use of lesson time. The authors also describe how one result of the experiments conducted was that although in some cases individual learners became confused by incorrect examples and over time were inaccurate in identifying these when they were presented to them again, this was only recorded as an outcome when learners

had seen the incorrect worked example once. When comparing this with learners who were frequently shown the same incorrect examples that applied to the topic that they were learning, as time passed, they were much more successful in establishing a clear understanding of why some worked examples were incorrect. This suggests that when incorporating worked examples where solutions are inaccurate, teachers should revisit these same examples multiple times across a series of lessons to increase the accuracy of the recognition of incorrect and correct solutions. Whilst these conclusions are helpful to consider in practice when designing examples and planning for their use, this study focused predominantly on teaching the topic of probability and so it cannot necessarily be generalised that there would be the same findings across the teaching of all topics in mathematics.

Learning by reflecting upon the previous mistakes made by learners or their peers is something that Barbieri and Booth (2016) also explored. Their study tested the effect of this on both cognitive and motivational factors for secondary age learners, who were completing an Algebra course. Their findings also supported that of Pillai et al. (2020), contributing to the argument that incorrect worked examples have an important place in the mathematics classroom. They indicated that error reflection was equally beneficial for all learners, regardless of their prior knowledge of the topic being taught. The benefits were recorded as greater than for those learners who were limited to exposure to only correct worked examples. It was concluded that through developing learner understanding of the common errors made in problem solving, it would allow learners to encode the features of the

problem presented, as well as remedying any misconceptions that may arise as a learner is introduced to a new topic. When considering the limitations of the study, there was no access to the classroom environment and so any judgements about the effects across a course of study within a school setting may produce different results. Although there were many measures taken to mitigate the impacts of this, including a control group for comparison of results and there were discussions with practising teachers to attempt to ratify the findings. Ultimately the conclusions of this research highlight the value that error reflection, through use of incorrect worked examples, can provide in developing the understanding of learners who are less familiar with a topic when it is introduced in the secondary mathematics classroom. This approach may prove beneficial in supporting learners who find learning mathematics more challenging, as it normalises errors and explores how to avoid making the same mistakes.

2.1.4 Variation Theory

There are many aspects of examples that can be varied, I have discussed some ways in which they may vary due to the initial decisions made in the design process, but even in each of these categories they can differ from one another, by their features. Kullberg et al. (2017) explain how the variation theory of learning puts an emphasis on variation as critical in ensuring learners can discern new aspects of a learning objective. To provide context, a teacher may consider variation theory in their planning for teaching the addition of fractions. They would make decisions regarding whether to include examples that only feature proper fractions in the

questions and solution, or to also promote discussion about improper fractions and mixed numbers by designing questions that include these, it has been reported how "by using variation and invariance within and between examples, [teachers] can help learners to engage with mathematical structure" (Kullberg et al., 2017, p.559). By only including examples that deal with proper fractions, learners' example spaces can be limited and consequently this may also lead to a diminished understanding of how different fields of mathematics link. This notion is supported by a range of academics, including Sun (2018) who discusses how a major issue within mathematics education is the lack of connections made by educators to illustrate how different aspects of mathematics depend on one another and therefore how it is important to avoid presenting mathematics as a body of isolated procedures and concepts. The comparison of two examples within one topic is powerful in providing learners with a contrast to illustrate that although problems can sometimes look different, the same method can be used to reach a solution. Kullberg et al. (2017) discuss how if exploring straight line graphs, if the object of learning was to understand the y-intercept, then the gradient should remain invariant in the first few cases that learners are exposed to. However, once learners have demonstrated that they have grasped this concept, they should be shown examples showing more dimensions of variations, for example those with different positive numerical gradients, then those with negative or fractional gradients. By following this variation theory approach to example planning "certain aspects of the content [become more] noticeable for the learner and thereby enhance learning" (Kullberg et al., 2017, p.561). One limitation of the research conducted by Kullberg et al. (2017) is the reliance on secondary data, the study also

did not include any analysis of teachers' or learners' perspectives. Although, the authors make a clear distinction between learning that is a direct consequence of teaching and learning that is *made possible* through teaching, they argue that variation theory provides tools for teachers to understand what can be made possible to learn in their lesson through careful craft of their examples. This is supported by Marton & Pang (2013) who assert that students are more likely to discern the object of learning and are therefore more successful when teachers place an aspect that is varied against an invariant background.

2.1.5 Teacher Reflection

To design examples with varying dimensions that promote learning, some academics argue that teachers must reflect on previous teaching experience. This is termed as *reflection-for-action*, which can be defined as "thinking about future actions with the intention of improving or changing practice" (Olteanu, 2017, p.350). It may be that the teacher chooses to vary an element of the problem where learners have typically developed misconceptions in the past. Olteanu (2017) conducted a study that investigated the impact that reflection-for-action had on teachers' abilities to design examples that improve learners' discernment of concepts. By collecting data across three academic years, they were able to evaluate the influence that this approach to example planning had across a significant time period. During the study, teachers were asked about their approaches to example design and then provided with a guide to methodically plan examples for delivery, informed by their prior experiences of learners' responses in lessons. It was discovered that teachers found it

challenging to design their own examples and often relied upon using textbook examples that presented limited variations. This was particularly interesting, as the teacher participants within the study each had more than twelve years' experience teaching in the mathematics classroom. The results from the study suggested that "for the teachers, reflection-for-action was another form of learning that grew out of experience and was connected to students' discernment of aspects of the object of learning" (Olteanu, 2017, p.365). This positive connection between teacher development and learners' outcomes illustrates the importance that professional learning can have. As previously discussed, variation theory is a vital consideration in example generation, but teachers must feel confident in their initial creation of problems to facilitate learning. By improving teacher understanding of how examples can be crafted to allow for learning opportunities, they will become more astute to which elements of these problems learners benefit from the most. It is important to acknowledge that this study was completed in Sweden, where the education model and environment could be different to that of the secondary mathematics classroom in the U.K. The researchers also describe the heavy reliance that reflection for action places upon the teacher's depth of subject knowledge. This may present significant challenges, especially considering the national shortage of mathematics teachers and "the growing numbers of non-specialist teachers … being directed to teach maths in both schools and colleges" (Burghes, 2020).

2.2 Pedagogical approaches for delivering examples to learners and their implications on learner experience and engagement

The ways in which teachers choose to deliver their examples are fundamental to the success of learners in their classrooms. Ingram (2021) discusses how interactions within the classroom setting can uncover opportunities to learn mathematical behaviours and enjoy their engagement with mathematical problems. They also discuss the potential that the delivery of examples can have to 'close down' learners' understanding of the meaning of mathematics. In this part of the paper, I will explore the different pedagogical approaches to delivery examples that feature in educational literature and the proposed implications associated with these.

2.2.1 Interactive and dialogic

To complement the careful design of mathematical examples, teachers must ensure that they introduce these to learners in ways that they feel comfortable to ask questions and that they can become involved in the process of delivery. Essien (2021) explains how there is a need for teachers to develop an awareness of their classroom context and adapt their instructional practices appropriately to accommodate needs of learners in that environment. They explore the benefits of developing classroom practice that aligns with an interactive and dialogic approach. By choosing language carefully so that classroom interaction invites participation, learners' construction of mathematical knowledge and thought is improved. This relies upon teachers' prompts to encourage learners to justify their responses to problems in mathematics. Instead of initiating responses through a series of closed questions, learners are asked to

explain their mathematical reasoning. The teacher can facilitate discussion in the classroom by asking other learners whether they agree with their peer's answer and why. It is argued that when this is coupled with variation theory, it can be extremely powerful. This strategy was observed in Essien's (2021) study of a class of teachers learning probability and was found to be beneficial to the development of their knowledge. However, this does not mean that the same impact would be seen in learners of a school age. Nonetheless, this technique is frequently used in classrooms across subjects to promote discussion and is generally observed as being successful in increasing the number of participants and engaging learners in problem solving processes.

2.2.2 Person-presentation

Person presentation refers to the approach used by some teachers, where when delivering an example that they have designed they situate it in a context that involves a learner in the classroom. This can also be seen in some textbooks, where worked examples are presented as being generated by fictitious learners. Loehr et al. (2020) evaluated the costs and benefits of such an approach to example delivery, by analysing results from a study conducted within the classroom environment. The results were sourced from 2 schools with 6 teachers and their 168 learners. A pre-test and post-test were used to determine the academic progress of learners, where some were exposed to person-presentation and others were not, to allow for a direct comparison of their outcomes. It was found that person-presentation did not have any significant negative or positive impact on learner outcomes in assessments when

compared with the learners who did not learn through this approach. Although, the authors highlighted that this does not mean that no impact was had upon learner engagement with the concept, including factors such as motivation, interest in the topic and self-efficacy. It was recommended that further research be conducted in the impacts that this pedagogical approach can have upon these factors. It is also important to note that some SEND learners benefit from strategies such as this, with recommendations for this approach on their individualised support plans. It may be that this pedagogical approach is successful in improving academic outcomes for a specific learner in a class where all others are not disadvantaged by its feature. In this case, of course it would be a beneficial interactional process.

2.2.3 Flipped classroom (Inverted classroom)

The Flipped Classroom can be defined as a "technology-supported pedagogical innovation" (Lo & Hew, 2017, p.222) that consists of two major components. These include computer based individual instruction outside of the classroom environment and interactive learning within groups inside of the classroom. When using this method, learners would typically watch videos of examples modelled by their teacher before attending the lesson, which then provides more time for practice of mathematical problem solving with peers and opportunities to seek help from the teacher in lesson time. Lo and Hew (2017) investigated the impacts that this style of learning has upon learners who were either underperforming academically compared to their peers or those learners that were identified in the study as high ability. This study measured learners' and teachers' experiences by using questionnaires to gauge

their opinions on this structure of learning. It was found that both groups of learners made good progress and enjoyed the design of their learning journey. However, high ability learners were more confident in answering advanced questions in the collaborative problem-solving sessions, whereas underperforming learners were keen to continue practising simple problems. Teachers described how this model of learning allowed for the possibility of more time in lessons to be dedicated to learner questions and misconception remediation. Overall, the authors of this study recommend that the Flipped Classroom can be beneficial for learners' outcomes. Because of a lack of control group in this study, it makes it difficult to determine whether the learners' progress is more significant through the teacher's decision to adopt the flipped classroom approach, or whether the learners would have made the same progress or more by traditional teaching methods. In addition to this, by choosing to use this method, it could be argued that teachers' workload is increased as they are preparing additional resources to be used, as well as the learning tools to facilitate learning in the collaborative problem-solving sessions.

2.2.4 Classroom displays

Classroom displays can be found in mathematics classroom across secondary schools, in my context, they are often used to remind learners of key definitions, formulas or concepts. However, in my experience they are rarely used to facilitate the delivery of examples. Flynn (2018) investigated learners' opinions on the influence that they can have upon their experiences and outcomes in mathematics. This was achieved by interviewing 28 learners, both before and after displays were updated in

a college setting. As a part of the creation of the displays, learner generated examples were also presented. Learners were overwhelmingly positive about the role that displays can play in their learning journey. All learners regarded displays as a helpful tool that supplemented their ability to understand concepts. Although, this investigation did not consider the feature of carefully planned teacher examples to illustrate concepts, it aligned more closely with the typical use of displays discussed, whereby learners are reminded of key formulae etc. The positive engagement with this resource could be used as a vehicle to improve learners' interaction with examples in lessons, it could be advantageous to explore this in further research. However, it is important to be mindful of the distracting nature of some classroom displays. Fisher et al. (2014) conducted a study that aimed to explore the impact that classroom decoration can have upon learners' focus in lessons. They compared the behaviours of learners in a classroom that was heavily decorated with displays and in a 'sparser' environment. It was found that learners became more distracted by the physical environment in the classroom with displays, but in the white-walled classroom learners were much more likely to become distracted by their peers. Overall, the impact of the displays was considered to have encouraged more unproductive behaviours when compared with the alternative. Therefore, it is suggested that displays may have a negative impact on learning when not crafted carefully.

2.3 Research questions

Considering the breadth of research available that investigates the impacts of teacher generated examples design and use upon learner outcomes in the mathematics classroom, there appears to be a lack of account of learners' perspectives. Outcomes are generally measured by attainment, with many studies using pre and post-tests to determine whether learners' outcomes are more successful by prescribed examples design or teaching methods. Informed by my literature review as well as my own teaching experience, I have learned that discussion in class helps to promote justification of mathematical thinking. I am interested to learn more about the opportunities that we provide learners to participate in class, so that outcomes are measured by more than just academic outcome but also by the development of key skills such as speaking, listening, problem solving and teamwork. I would like to understand how teachers can design examples that foster this and deliver examples in a way that learners feel responsibility for their learning and that it is a tailored experience for them as individuals.

Taking this into consideration, I intend to learn more about what the relationships between the design and use of teacher generated examples and learners' successes in the secondary mathematics classroom, by posing the following research questions:

RQ1. What do teachers consider when designing examples to promote learner participation in the secondary mathematics classroom?

RQ2. What considerations and adaptations of example delivery improve learners' opportunities to engage with mathematics most significantly and how can this be applied to other curriculum subjects?

3. ***METHODOLOGY***

In the secondary mathematics classroom, learners are often told that it is essential that they copy down their teacher's examples, to enable them to succeed in problem solving independently. In most cases, teachers have these expectations to ensure that their learners can revise steps in methods and rehearse procedures until their understanding reaches the point where they can solve a problem without support. However, in my experience of teaching and observing mathematics lessons, I often find that learners can develop a very shallow depth of knowledge when example design is not carefully planned, or teachers do not adapt the learning journey to explore learners' questions. As examples are integral to the learning of mathematics, usually featuring as a significant proportion of lesson time, investigating the impacts that these can have on learners' outcomes could be extremely powerful in informing teacher practice to promote progress and an interest in mathematics.

To establish the nature of the relationship between teacher generated examples and learners' successes, the literature available in this field highlighted two important aspects for consideration. Firstly, how teachers generate their examples and the decisions made in the design process, and secondly how the teacher's delivery of these examples influence the progress of learners. Due to the nature of my inquiry, qualitative research was necessary to enable me to answer the research questions, by exploring the individual perspectives of teachers and learners and gain an understanding of their personal feelings and experiences. An interpretivist approach

was taken, with inductive reasoning used to develop an understanding of learning experiences and explore ways in which teachers can encourage progress.

3.1 Selection of participants

In this section, I will describe the methods involved in the selection of participants to represent these perspectives, as well as the ethical considerations that were made for their involvement.

3.1.1 Teachers

I recruited teacher participants by communicating information about the study with the Mathematics Department across the secondary phase in my Multi-Academy Trust, seeking volunteers to take part. I then had initial meetings with those that had volunteered to explain next steps. This was when the logistics were explored surrounding which classes it would be possible for me to observe. This resulted in the study involving 3 mathematics teachers in 2 coastal secondary schools. The Future Leaders Trust (2015) described their geographical location as a limiting factor to learner progression, due to their isolation. I had chosen to approach colleagues across the two schools rather than just one, as all opportunities to engage in research or implementation of initiatives is done so in a collaborative cross-phase approach, which aims to strengthen the network of support in the department.

3.1.2 Learners

Once I had identified 3 teachers who were willing to take part, I began to investigate the possible observations that I would be able to conduct outside of my own teaching commitments. I was able to involve 3 classes within the study, each taught by one of the teacher participants. I met with these teachers and shared relevant documentations that they could provide the learners and their parents/guardians with, so that they could make the decision to opt-out of the study. It was made very clear to the learners that should they wish to find out more information that I was contactable both in school, but also via email. Out of the 3 classes, 95 learners chose to be involved in the study, this provided me with a sample from which to collect data about learner's experience and perspectives. This would assist me in developing a deeper understanding of the influence that examples can have in the mathematics classroom. It is worth noting that the classes observed in the study were all high ability, this was not due to me specifically selecting these, rather that the classes that I had opportunity to visit without the need for me to seek cover of my own timetabled lessons to complete data collection. I acknowledge that this may result in any relationships discovered between design and development of teacher example and learner success may therefore only be applicable to high ability learners, but this is a consideration that I will need to make in my discussion of limitations of the study later in my findings and analysis.

3.1.3 Ethical considerations

In addition to providing participants with information regarding the proposed study, I also informed them that they could withdraw consent from the study at any stage and that no harm or favour would occur in line with ethical guidance outlined by the British Educational Research Association [BERA] (2018). I was also guided by the educational research policies detailed by the University of Oxford CUREC processes, from which I received approval for this study.

Another important ethical consideration was to ensure that learners in my own classes were not disadvantaged due to me conducting my research. My engagement with research did not impact my commitment to the planning of my own lessons and I was not absent from any of the lessons on my timetable to conduct any research activities. I was originally intending on involving my own classes within my study, but throughout my research I began to identify approaches to example design and delivery that were having clear positive impacts on learning. This led to these becoming integrated in my own teaching so that learners were provided with best opportunities for successful outcomes. This meant that comparison between data collected pre/post-intervention would not have been possible, as I was continuously adapting my teaching in response to the successful learner outcomes observed in other lessons. Ethical considerations surrounding concerns of power dynamics are explored within the next section of this report.

3.2 Data collection, procedures and instruments

The data collection was completed in two phases; one before any intervention was conducted and then a repeat of the same collection methods post-intervention. The intervention here refers to the collaborative meeting that I arranged with colleagues to share findings from my research and explore the relationships that observed between the design and delivery of a teacher's examples and learners' successes. By collecting before and after the intervention took place, it is hoped that the effects of any changes in teachers' planning and delivery of examples on learner successes were measured. It was important to me that teachers involved in the study felt that their ideas were valued and that any recommendations to improve learner successes were seen as such and not a directive to follow exactly what I had prescribed. This approach has the potential to have a more significant impact on the decision made by teachers to implement any suggestions made to develop their practice in securing more successful outcomes for learners. Wong (2015) explores how this can be achieved by empowering teachers and inviting them to consider how best these recommendations for adaptations to their pedagogy may apply in the context of their own classroom. A breakdown of both data collection processes is in appendix A. Considering each of these stages, I will now explore the approaches taken and the justifications for why these methods were chosen.

3.2.1 Teacher Interviews

Gaining insight into teachers' reasoning for their design and use of examples was extremely important to formulate responses to both research questions. These

teacher interviews were semi-structured to ensure that I could probe their answers to the questions asked. This approach was selected due to how “the versatility and strength [a] semi-structured interview can allow for an exploration of specific dimensions of the research question. The interview is instrumental in creating openings for a narrative to unfold, while also including questions informed by theory.” (Galletta et al., 2013, p.191)

The questions used in the teacher interviews can be found as appendix B. These were carefully considered to ensure that they were open ended in nature. By asking the teachers involved to identify 3 considerations for the design of examples, it would be possible to establish their perception of what was most important to ensure learner successes in understanding concepts that were taught in their classroom. These interviews were conducted face to face privately, one-to-one with each teacher participant. This provided them with a safe space to be open about their thoughts, I was explicit in explaining that this was not a judgement of their teaching or criticism of their decision making, but an opportunity for me to develop understanding of their planning process. I share the same role in the mathematics department as all the teacher participants involved and so I do not believe that their responses would have been impacted by any form of power relationships that could have existed, had I been their line manager or Head of Department for example. It was ensured that the date and time of teacher interviews was specified by the participant and that I would work around this, so that they were not inconvenienced or provided with additional workload on days that their demands were already high.

By completing pre and post intervention interviews with teachers, it would be possible to understand if exposure to the information provided in the intervention would inform their future pedagogy and in which way. I could establish if it caused any significant increase in teacher workload and the plausibility of recommending approaches more widely across the department and possibly the wider school.

3.2.2 Learner Interviews

An important element of this study is its focus on learner experiences and developing an understanding of how teachers could improve learners' successes by considering their design and use of examples. It was identified in the review of current literature in this field, that pupil voice could have a greater presence. It was vital that the study incorporated a platform for learners to be heard. As with the teacher interviews, a semi-structured interview style was selected due to the flexibility it provides the interviewer to probe responses and learn more about the participants' thought process. Here, interviews were selected over questionnaires as from my prior experiences as a teacher researcher I have found that learners often like to seek clarity of what the questions are asking them. In previous research, where I have distributed questionnaires to learners, responses are often limited, or the question ignored completely. To be able to draw appropriate conclusions on the nature of the relationship between the design and use of teacher generated examples and learner successes, a wealth of detailed data would need to be collected on their perspectives of the dynamics of the classroom and how they believed teachers could ensure that

they had the highest likelihood of success. Examples of the questions used in the interviews can be found as appendix C.

Darbyshire et al. (2005) discuss the necessary acknowledgement and mitigation of the effects of teacher-learner power dynamics, as this may limit the learners' opportunities to fully express themselves in the interview situation. Without consideration of these effects, and incorporation of tools to reduce them, authenticity of responses from learners may be questionable. In this study, it was decided that one way that learners may be encouraged to speak honestly and feel comfortable in a forum for discussion, would be to have focus groups of 3 learners. This meant that they would feel more comfortable in the interview situation as their peers would be present. This would also enable the participants to develop on their peer's contribution to the interview. In addition to this, at the beginning of each learner interview, it would be made explicit that they could speak openly and that no judgements would be made of them or their teachers because of their responses. The learners involved in each interview were selected randomly from the group of learners who had provided assent, and their parents had provided consent. They were provided with information forms that explained the study and that at any point they had the right to withdraw. All information forms were adapted so that they were in terms that the learners would understand, these can be seen in the appendices.

3.2.3 Observations

To gather the data from lesson observations, I devised a spreadsheet that recorded the following; the number of participations in a lesson, whether the participant volunteered their ideas, the nature of the participation (e.g. hand up to answer a question, hand up to answer a questions, 'calling out' a question, 'calling out' an answer), as well as scoring the participator's contribution to the learning journey. This score was informed by considering the following rubric (Table 1), adapted from the Bean & Peterson's (1998) 'Hollistic Rubric for Scoring Class Participation' in their article *Grading Classroom Participation*:

Participation Score	**Participation behaviours exhibited**
1	Only gives minimal answers when called upon Contributions are not developed or cogent Dominate discussions in an unproductive way
2	When called upon they talk too much, make rambling or tangential contributions Contributions are less developed and cogent
3	Makes thoughtful comments when called upon Contributions are more developed and cogent
4	Makes thoughtful contributions that advance the conversation Contributions are well developed and cogent Shows interest and consideration for others' views

Table 1

Whilst examining the frequency of participations aligns more frequently with a positivist approach due to quantitative nature of this data, the richness of the qualitative data collected through the rubric used illustrated a clearer picture of learner success in the classroom through the relevance and cogency of the

contribution of their ideas. It was important to differentiate between participations that were invited by the teacher and those that were volunteered by learners. In discussion about learner participation, Weimer (2013) asked "who decides when students will participate, recognize volunteers, or calls on those students who don't volunteer?" (p.89) and continued to explore how if students are encouraged by being made to speak when they haven't volunteered, they will come to realise they can contribute which will motivate them to volunteer. This is an important consideration for the development of this research and the intervention created to discuss with teacher participants, as from this it can be inferred that there can be a positive impact on learners' success rates when participation stems from their volunteering rather than being directed to provide a contribution. It would have been interesting to be able to collect data that would have allowed me to establish whether individuals contributed more frequently than others, but due to the pace and frequency of interactions between learners and teachers, this proved too difficult to record as an independent teacher researcher.

3.3 Data Analysis

Due to the vast volume of qualitative data collected in this study, a large part of the data analysis will involve me immersing myself in the data and establishing key themes across observations and responses in both learner and teacher interviews. In this section, I aim to outline the methods that intend to use to analyse the data collected, as well as my justification for doing so.

3.3.1 Teacher Interviews

It will be important to analyse the main considerations that teachers make in the design and use of examples and the reasons for why this is. Common themes between responses will be drawn to provide an insight into what example designs and uses teachers believe are the most significant in promoting learner success. It will also be interesting to compare how these align or differ with the example design considerations that were explored in my review of relevant literature.

As a part of this data analysis, I will also establish and evaluate the impacts that the intervention had on teacher's decision making and beliefs surrounding example use in the mathematics classroom. This may involve direct quotations and recognition of any opinions that are similar across the different teachers who were observed.

3.3.2 Learner Interviews

Learner's contributions will be analysed in a similar manner, and to provide a voice to learners from this study, key quotations will also be used to illustrate the importance of the consideration of their perspectives and experiences when teachers design and plan to use examples in the classroom.

3.3.3 Observations

By the nature of the rubric used to grade learner's participation in the classroom, I have introduced a coding system. This will enable me to calculate the

percentage of interactions in each class that align with grade 1-4 participation scores. Key statistics, such as frequency of participations and the percentages of these that are awarded each participation grade will be calculated. I will then be able to produce a direct comparison between this data pre-intervention and post-intervention, which will be a key indicator of whether any adaptations to teaching due to recommendations, had improved the quality of participations and therefore learner success in the mathematics lessons that I observe.

3.4 Reliability and validity

When commenting on the reliability and validity of these methods, it is important to recognise that I am only conducting this study of 3 different teachers and 3 of their classes, within one Multi-Academy Trust. Some researchers may argue that this reduces the validity of the study, as it will make findings and recommendations specific to the context in which I have investigated. However, Gwendolyn (2021) explores the idea that there is no specified method to identify an appropriate sample size for qualitative data collection techniques. This is because a vast quantity of data can be collected from a small number of participants. They also assert that a decision can be made on whether an appropriate sample size has been selected by being considerate of a phenomenon coined *'data saturation'*. Which is defined as the point where despite the involvement of more participants, the themes that arise from the data collected from them becomes exhausted. In this study, even with 3 teacher participants, interviews involving 9 learners and observations of 3 classes, I was provided with a wealth of data. There were significant overlaps in the

themes identified and I would therefore argue that the methods used here were suitable and appropriate for the nature of my inquiry. Gwendolyn (2021) also emphasises the importance of data collection and analysis being relative to the context of the study. The purpose of this study was to develop my understanding of the design and uses of teacher generated examples in the mathematics classroom and how these relate to learner successes. These findings would then be communicated with colleagues in my department, so that in collaboration we could develop and adopt strategies or approaches that have been shown to improve the outcomes for learners in our classrooms. In this sense, I believe that the involvement of 3 teacher participants in my study is appropriate in achieving this aim.

3.5 Intervention

Often when teachers are invited to become involved with professional development, there is a level of skepticism about whether it will be applicable to their practice and if the time invested will translate to success in the classroom. Because of this, I was ambitious in developing an intervention that would be short but meaningful, with a clear summary of initial data analysis and what the implications could therefore be on their pedagogy. A short presentation would be prepared and delivered, with suggestions for how adaptations could be made to how they planned and used their examples to promote learner successes in the secondary mathematics classroom. It was vital that the intervention did not present itself as a means of feedback on their teaching but provide some easy-to-use strategies that I had discovered may be useful to enabling learners to be more successful.

This intervention also provided an opportunity to establish a forum where ideas could be shared between the 3 teacher participants on methods that had worked in improving learners' successes. When delivering the intervention session, it was useful to include anecdotal evidence from each of their contexts, so that it would be easier for them to relate to how they may implement any new routines in planning or delivery. Childress (2019) found in a similar study, that when she established this forum where teachers engaged in action research to increase learner agency, teachers began working collaboratively instead of in isolation. This would be extremely powerful in ensuring that teacher workload is not massively increased in generating examples in new ways to promote learner participation and subsequently success. If a class is seen to have engaged well in a particular example, then this teacher could share this with the network of teachers created and it would have a greater effect on a larger number of learners.

3.6 Sharing of Findings

To ensure that the findings of this study allow for impact on the learning in my setting, it is vital that once all data has been collected and analysed and the nature of the relationship between the design and use of teacher generated examples and learners' success has been determined, that this is communicated department wide. This will enable all secondary mathematics teachers in my Trust to consider incorporating recommended practices into both their planning and delivery.

If my intervention is successful, whereby learners are deemed to have demonstrated greater success in the mathematics lessons in my post-intervention observations, I plan to deliver the findings of my research in a department meeting. This would be in addition to the intervention presentation I had previously shared with the teacher participants in the study.

3.7 Considerations of Wider Implications

In my role as the Initial Teacher Training Manager and ECT Induction Tutor in my trust, I am passionate about promoting engagement with research and the benefits that applying theory to practice can have upon teachers' professional development and subsequently learner outcomes. I would be excited to invite teachers of all subject disciplines to consider how the findings of my research may translate to the use and design of examples in their field. Initially, I expect it would naturally incorporate into pedagogies in the science classroom very well, due to the similarities in how knowledge is cascaded from teachers to learners using examples. Harding (2006) explores in '*Best practices for teacher leadership : what award-winning teachers do for their professional learning communities*' how "collaboration is the key to success for all students. It is an essential ingredient in an educational environment that demands nothing less than that every student can and will learn in our classrooms" and that "we must build communities that are conducive to sharing ideas, knowledge, theories, and data collection. Only within these communities will our students be able to achieve at an optimum level in all instances" (p.18). It would be extremely rewarding to be able to establish a community where action research is

valued in determining how we as teachers can best support the learning of our learners.

Another wider implication could be that learners are regularly invited to provide feedback on their experiences within the classroom. This would help to raise the profile of the importance of considering learners' perspectives in planning of examples and lessons more widely and ultimately result in more tailored learning journeys that provide regular opportunities for learner input, through the sharing of their ideas and approaches.

3.8 Possible Limitations

The sample selected in this study only featured 3 teachers who had volunteered to become a part of the research project. It could not be guaranteed that if I had observed and spoken with the learners of all mathematics teachers across my Trust that I would have reached the same conclusions or recommendations. Although there was a great range in style of the teacher participants that I was able to observe and so I am reassured that despite variation in pedagogies and therefore learner experiences, my recommendations for improving learner successes would have been similar.

On reflection, I acknowledge that the reliability of my findings would have improved had more participants been involved in the study, however I believe that I collected an appropriate amount of data and there was plenty to analyse and make

suggestions for adaptations to teaching from. The time taken to collect the data must also be considered, with the participants that I had, it was already very difficult to arrange the observations and teacher/learner interviews, due to clashes of schedules and school closures due to the COVID-19 pandemic. I was able to reschedule all of these to ensure that I had collected my data, however had more participants been involved then this would be significantly more challenging.

It was very challenging to ensure that all data collected in lesson observations was recorded accurately, due to the rapid nature of human interaction. I also needed to become familiar with the framework used to grade participants in lessons. I was able to practice with the use of these in observations that were not included in the study, to ensure that I had developed a routine for recording data in lesson observations. This massively improved my effectiveness as an observer. As forementioned, I would have liked to have been able to analyse frequency of individual learner's contributions to lessons, to establish whether some learners are provided greater opportunities to achieve success. This was not feasible due to the demanding nature of observation record keeping described.

The use of the semi-structured face-to-face interviews with both learners and teachers had many advantages in allowing the collection of a vast amount of data, although it is important that the validity of responses is considered, as with face-to-face interviews visual indicators such as body language and facial expressions can impact participant's responses. I also found that in some cases I could begin to ask

tangential questions regarding aspects of their answers I found interesting, despite their relevance to the research questions that this study aims to answer. Learner interviews can also be impacted by the power relationships existing between learners and teachers, which makes it challenging to assess the validity of any answers provided.

4. FINDINGS AND DISCUSSION

This section will explore and discuss the findings of the study outlined in the methodology. It is important to consider how the data collected contributes to the understanding of the relationships between teachers' choices in designing and delivering examples and the impact that this has on outcomes for learners. First, I will explain the key themes that emerged from my different data collection methods in the pre-intervention, followed by discussions had in the intervention and then explore the data collected from post-intervention interviews and observations.

4.1 Pre-intervention

4.1.1 Teacher Interviews

By conducting semi-structured interviews, I was able to ask questions to learn more from the initial responses of the teachers involved. When asked about example design, all teacher participants explained how when planning, they considered learners prior understanding of topics and that they tried to build on this to make productive use of lesson time. Their responses also aligned in describing how learners' ability must inform the design of new examples.

It became clear in each teacher interview that it was difficult for them to decide on a third consideration. The most experienced participant spoke of how they might sometimes adapt the example designs used to propel their lessons, to react to observed changes in learners' physical and emotional responses. For example, they may choose to change the delivery method of an example when unproductive

behaviours emerge. They also explained how with some classes they may avoid certain types of example design, such as the worked examples explored by Huang and Cribbs (2017). This teacher explored how delivering these using textbooks seemed to resemble a punishment for the learners, they had communicated this with the teacher when they had learned this way before. Using blended learning to present examples had been successful with classes, this notion is supported by Cambridge Dictionary's (2022) definition of blended learning as a tool to remove barriers to learning. The teacher expanded further to explain that where learners are engaged, "willingness to participate should be capitalised on". They believed that participation was key to a learner's success in developing mathematical thinking.

Another teacher participant discussed the importance of considering prior misconceptions before designing examples. However, this differed from the generic erroneous worked examples that Star et al. (2015) investigated. This teacher was passionate about remedying the misconceptions that learners had shown in prior lessons and deliberately designing examples to assess whether they still misunderstood, or if they would recognise the mistake and offer a correction. They believe that this method is the most influential in ensuring that learning is committed to long term memory rather than remaining in their working or short-term memory.

Rarely in mathematics do we hear teachers stating the importance of literacy, but one participant explained how when designing and delivering examples, the accuracy and the suitability of the vocabulary used, is a significant consideration.

Firstly, to ensure that no misconceptions are fostered and secondly to promote participation. Learning of key terms may be supported by productive use of display spaces to remind learners of vocabulary, an approach to promoting progress celebrated by Flynn (2018). In addition to this, carefully selecting language when using examples, the teacher participant argued that learners' engagement through participation could be welcomed, for example by asking questions such as "who agrees that this is the correct answer?" and then encouraging justification as for why.

As can be seen in appendix B, once establishing the main considerations for the design of examples, I was keen to include questions that would allow me to develop a greater understanding of teachers' willingness to adapt lessons in the moment. All teachers spoke of how it is vital that planning must be built with flexibility to be changed within the lesson, to react to learners' needs. However, they explained how this can sometimes result in an initial decline in learner engagement. They hypothesised that this may be since at this point in the learning journey, learners begin to become cognitively overloaded as they are not comprehending the concept that they are being taught. All teachers explained how in this instance, the careful design of their examples may have been ineffective in supporting the needs of all learners, which results in a fast adjustment to the lesson and the discard of pre-prepared materials. In this case, spontaneous generation of examples would be necessary to support the learning journey. An appropriate reaction supported by Mason and Spence's (1999) *'knowing to act in the moment'*. One teacher participant explained how in this eventuality, it is powerful to use learner generated examples to

reenergise lessons and reduce the teacher talk that may be contributing to the cognitive overload experienced by learners.

An emerging theme was that although generally examples would be teacher generated, they should be presented using the voice of learners. Facilitating learning, rather than directing it. It was argued that this ensured that learners develop a well-rounded skillset, including resilience, problem-solving and teamwork – all aspects that are extremely valuable in achieving success in mathematics.

4.1.2 Learner Interviews

An integral element of this study was voice that it provided learners, to explain their experience and relationship with their learning journeys. Initially, the interview questions explored how useful they believed examples were in guiding their learning. One learner described how they found it difficult to use examples to access understanding and that they preferred to make their own connections to prior knowledge. It would be interesting to explore this learner's learning strategies in more detail to better understand their approach to problem solving and learning of new concepts.

A common response explained how writing teacher's examples down into their books meant that they could revisit these when they needed a reminder of how to solve problems, or how when they are working through practice exercises it is helpful for examples to remain visible on the board so that these can be referred to

with ease. It was also interesting to hear how they valued the way that being shown different examples meant that it was easier to understand that there a variety of ways to reach the same answer. Learners felt that this was important, as often in mathematics they would avoid answering questions because they believed "there was only one right answer" and that they had forgotten a method shown. Renkl (2017) also supported the use of worked examples, and so their importance in the classroom context is becoming even more apparent through the findings discussed.

To enable me to establish a response to RQ1, it was important to discover more about learners' participation in lessons and what might influence their decision to become involved in dialogue in the classroom. Learners communicated that they felt that classroom discussion was dominated and controlled by their teachers, they felt comfortable to participate when invited to by the teacher but otherwise it would be unlikely that they would contribute to discourse in lessons. They also described how if they had shared one of their ideas in a lesson, they believed that they would be less likely to be called upon. All learners explained how this encouraged them to contribute earlier in the lesson so that they would be 'exempt' from more difficult questions as the lesson progressed. This linked with responses that explained how they avoided answering more difficult questions due to the possibility of them getting an answer incorrect in front of their peers and a teacher's response being negative.

When asked their opinion of what the 'best' examples looked like, learners described those that were presented in a fun way, typically through use of a game or

interactive resources. One focus group remembered how sweets had been used to illustrate a probability problem and that the class has enjoyed this approach. A common theme identified in the responses to this question was that often the best examples were those that involved a learner's assistance in generating. They articulated how they value the involvement in the planning process, because they understand and relate to the context of the problem and are therefore keen to reach a solution.

Learners explained that examples are used very differently in mathematics when compared with how new concepts are presented to them in other subjects. One learner expressed that the structure of mathematics lessons meant that often teacher input would be followed by a large amount of independent practice, which could feel daunting if they had not understood the content. They suggested that it may be beneficial to break independent study activities into shorter intervals so that learners felt less anxiety to problem solve independent of the teacher.

4.1.3 Observations

I will begin analysing the findings of my observations by exploring the example design and delivery methods observed, followed by the quantitative analysis of pupil participations in the lessons.

In the lesson observations of all 3 teacher participants, there was a heavy focus on teacher modelling. Which the DfE (2019) feature as an essential skill in the

Teachers' Standards. A problem would be posed to the learners and the teacher would ask them to write this down into their books and follow along. Classroom discussion regarding the concepts being learned was mainly controlled by the class teacher in the room and learners were encouraged to raise their hands if they had any questions. Images 1 and 2 illustrate the style of modelled example observed in one of the lessons.

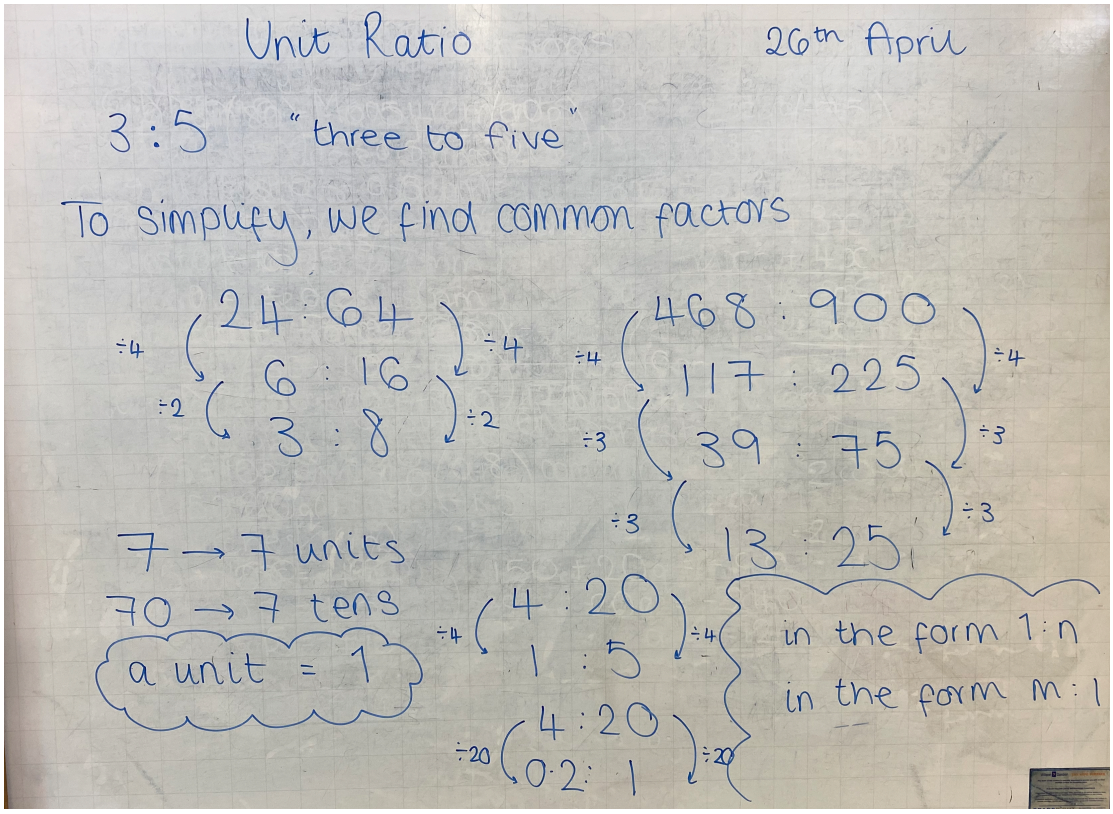

Image 1

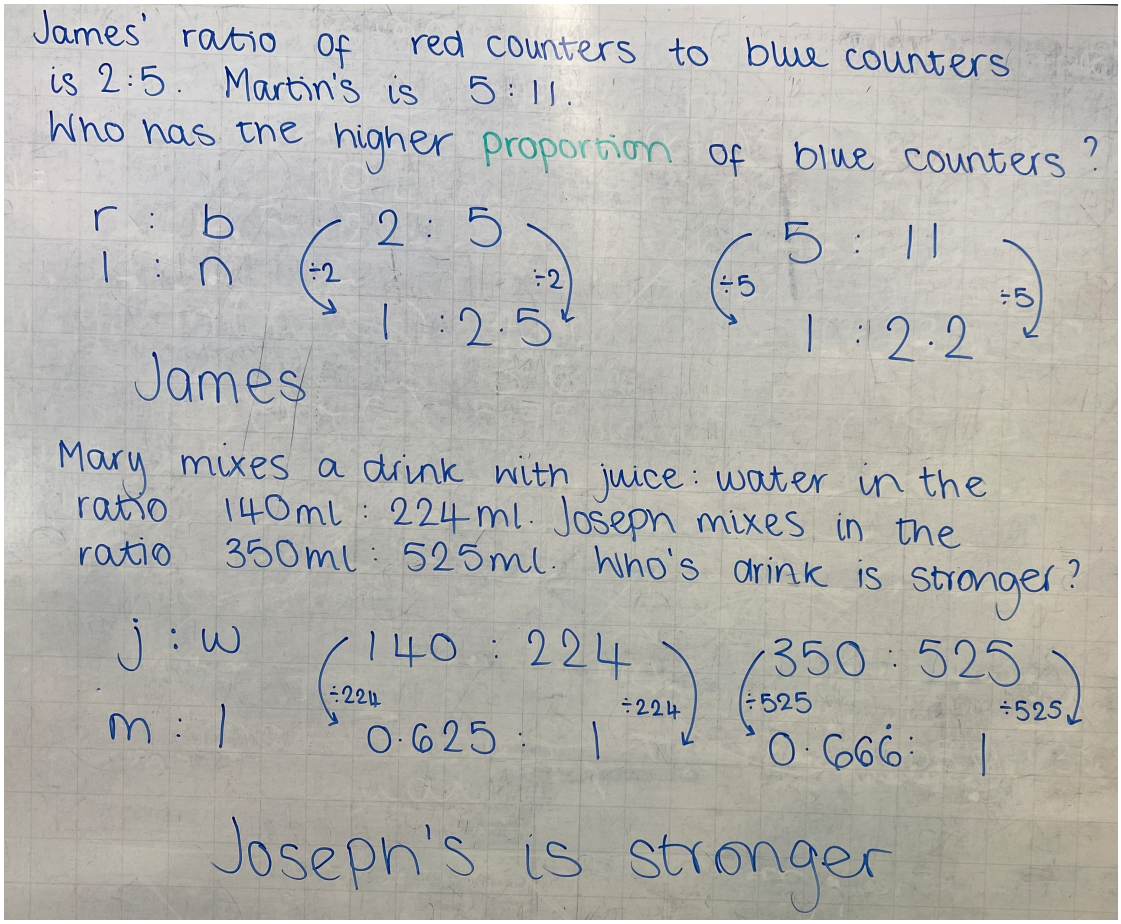

Image 2

The teacher explained the importance of presentation when showing workings and ensured that learners had mirrored the examples shown to them. The use of names within the questions to provide a context aligns with the approach identified as *person-presentation* by Loehr et al. (2020). By situating the numerical information in context, learners appeared to be able to develop an understanding of unit ratio and its relevance more easily than when being shown it as an abstract concept. This practitioner also delivered the examples in a way that invited contributions from learners, with learner participation promoting the progression of mathematical thinking, until a correct solution was found.

When observing another lesson there was a different approach to the delivery, instead of using the whiteboard to present examples, the teacher used an exercise book and a visualiser. This meant that as the teacher introduced the examples, they were also illustrating the expectations of bookwork. Learners were extremely engaged and copied the problems and solutions as the teacher completed these. This lesson also featured use of a spontaneous example, included to attend to the misconceptions of several learners, realised by the teacher as the circulated the classroom. An approach previously found to be successful by Barbieri and Booth (2016). A hybrid delivery of planned and spontaneous examples can be necessary in some lessons to ensure that misconceptions developed by learners are addressed as soon as possible.

The data presented in chart 1 illustrates that a large percentage of learner participations that were granted a grade 1. These percentages are of the 116 participations recorded in the lessons observed pre-intervention. There is a clear picture painted that most learners' responses in the lessons observed were of a low level, when graded by the framework. This meant that discussions were very rarely advanced by a learners' contribution, many answers to teacher questions were tangential and lacked accurate justification.

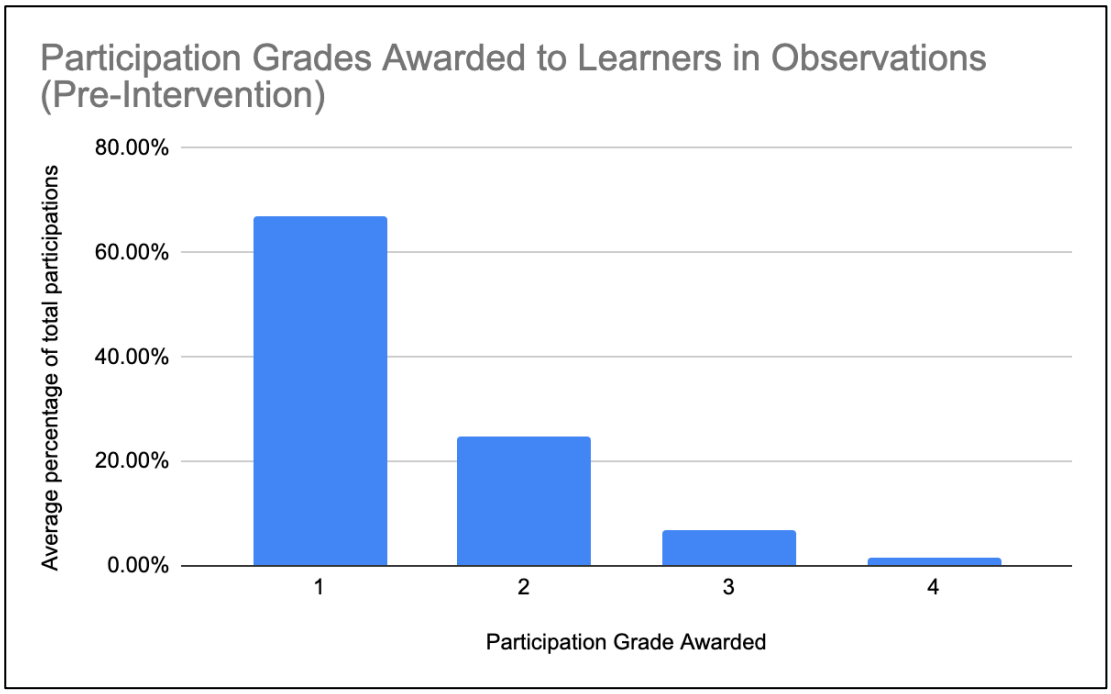

Chart 1

It is important to note that leaners may have been limited in their ability to achieve a high participation score due to the small number of opportunities presented to them by the teachers in the study. The average (mean) number of participations in each lesson stood at 39 per observation. This included any contributions that may have been unproductive and were therefore classified as a grade 1 contribution. The range of participations was only 7. This showed that there was not a great disparity in the contributions made in different teacher's lessons. As discussed, in each lesson observation learners tended to contribute after being granted permission to participate by the teacher.

4.2 *Intervention*

In providing an intervention, the aim was not only for recommendations to be made regarding individual teaching, but also to develop a collaborative community

whereby teachers could discuss research and the potential impacts that it could have on their classroom practice and subsequently learners' successes. To establish an environment that fostered this, the intervention was held with all 3 teachers together. The recommendations outlined to teachers were informed by the literature review conducted and the data collected to this point. The slides used to deliver the intervention session are included as appendix D.

The teacher participants were keen to discuss the findings of the pre-intervention data collection and were surprised to hear the honesty of learners and their awareness of what methods of example delivery and design were beneficial to their learning. There were elements of instructional coaching included in this intervention session, where the use of model questions was rehearsed, so that the teachers involved felt comfortable to employ these strategies. Recommendations were well received by the teachers, who discussed the importance of involving learners in the creation and facilitation of their learning experiences. They explained how by being presented with key strategies that are informed by research, made it more time effective than engaging with the research themselves.

4.3 Post-intervention

4.3.1 Teacher Interviews

In post-intervention interviews, teacher participants explained how the recommendations for teaching were easily implementable and that it had positive outcomes on the outcomes observed in their lessons.

All teacher participants expressed that they would be focusing more heavily on the use of learner generated examples to inspire their own examples. They described how this deepened their knowledge of learners' example spaces, as explored by Zaslavsky & Peled (1996). They explained how the intervention provided had provided them with insight into the perspective of learners in their classroom, especially through sharing of key quotations. Within one interview, a teacher participant shared that they had felt that using learner generated examples may cause them to appear disorganised and unprepared in front of the class or any visitors. I invited them to read through the literature that supported the use of such an approach, which reassured them that when planned and managed carefully, learner generated examples can instigate thoughtful discussions.

Another consideration that they felt important in example design was the acknowledgement of misconceptions and incorporating these into examples when they arose in lesson, promoting discussion about these and explaining the corrections that would be necessary. One participant explained how they had trialled only using misconceptions that had been shared in the classroom, and not introducing possible errors that could confuse learners, a dilemma acknowledged by Star et al. (2015). This had resulted in learners asking questions about how it would be possible to answer a taught concept incorrectly, it is likely that due to the routine delivery of misconceptions in mathematics, they were keen to hear what frequently made mistakes were, in these problems.

Understandably, prior learning remained as a key informant of example creation, as it is important not to cause learners to become cognitively overloaded by introducing too many novel topics at one time. Due to the unprecedented times faced in education over the past couple of years, because of the Covid-19 pandemic, gaining an understanding of prior learning has never been more valuable. A significant number of learners in our schools were not able to engage with learning, as they would have done within the usual classroom context. Therefore, when introducing concepts, one teacher participant recognised that assessment of prior learning has become a more challenging task, as a wide range of fundamental understanding has not been founded by learners.

When delivering examples, teachers described how they had attempted to increase interactivity in lessons, by asking learners to help model solutions on the whiteboard and articulate their ideas verbally in class. The questioning used to probe understanding meant that learners participation added value to lessons by enriching both their own and their peers' experiences.

4.3.2 Learner Interviews

Learners were much more comfortable sharing ideas in post-intervention interviews, this is likely as I had become more familiar to them. One group of learners explained how they had noticed an increase in the number of peers that wanted to contribute to lessons, as they were not worried about answering incorrectly as there were "lots of ways to get to the right answer". In this class, a game had been used to

aid the learning of key words associated with a new concept. This was perceived extremely well by learners who expressed that they felt that they would be more likely to retain the knowledge learned, due to the fun memories that they had of this lesson.

Learners generally felt more in control of their learning experience as they felt that their teachers had asked both them and their peers to provide their own generated examples or explain the solution to a problem from start to finish. They also spoke of the importance that 'quiet' learners being recognised by teachers. They explained that they had seen their friends who would not normally participate enjoy the different, engaging ways in which examples were being delivered by their teacher.

The post-intervention learner interviews also allowed the learners another opportunity for their voices to be heard. The participants involved shared that their involvement in the study had made them feel that teachers "want to make sure that everyone in the class understands and is having fun". Throughout interviews it is important to note that learners are acutely aware of the techniques that teachers put in place in the classroom to encourage them to participate. They recognised that some teachers may ask them for answers randomly to "check that they are listening". It seemed that despite the positive comments made about the changes that they had seen in lessons and their excitement to be involved in this study, that they often felt as though participation was a 'chore' and was usually used by teachers to manage behaviour in the class. For example, when teachers ask learners to repeat the steps of a solution to an example.

4.3.3 Observations

The observation data collected in post-intervention observations showed that all teachers had made the decision to integrate recommendations from the session into their teaching practice. Examples were designed in a way that their delivery was fun and engaging, learners' names featured in the examples used and they were asked to contribute learner generated examples for problems that they were involved in. When the teacher asked questions, these focused on developing knowledge, as well as improving the teacher's understanding of learner's prior knowledge. They did this by providing more opportunities for learners to articulate their solutions to problems, without the teacher interrupting the dialogue with their own contributions. This resembled a facilitative learning environment where learners had developed a great sense of responsibility for their journey to understanding.

As with Chart 1, Chart 2 shows the average percentage of total participations for each grade, awarded in the post-intervention observations. The total number of participations across these observations was 90. The percentage of grade 1 participations has fallen by approximately half, learners have been provided with greater opportunities to access higher grade participation scores and discussions were advanced in lesson because of this. This highlights the importance of dialogue and interactivity in the delivery of examples, as explored by Essien (2021).

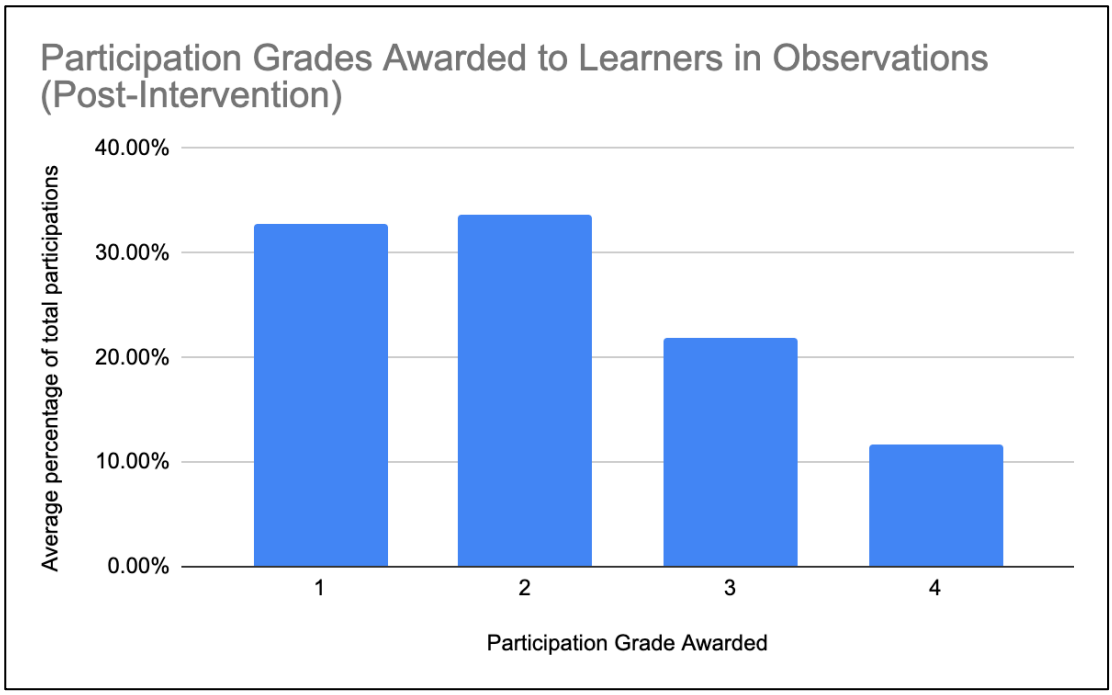

Chart 2

The average (mean) number of participations in each lesson was 30, this is a decrease from pre-intervention observations, but these contributions were more meaningful and thought provoking, and arguable therefore more valuable to the classroom environment. I also observed a noticeable increase in the number of learners who contributed to the lesson voluntarily, without the need for a prompt from the teacher. This was extremely encouraging as it showed that they had an increase in confidence.

4.4 Summary of key findings

To summarise the key findings from the study conducted, the designs of teacher examples were well thought through by the practitioners observed and the justification for their decision making was rooted in best practice approaches

communicated to them through their engagement with professional development. Teacher participants valued interactions with learners and recognised the importance of ensuring that both learning and teaching are reliant on developing a deep understanding of the individual characters in a classroom.

Learners demonstrated a good understanding of how best that they learn and are eager to take more responsibility for their learning and the paths that they take to securing knowledge. They spoke passionately about approaches that it would be best for their teachers to adopt when showing examples and the impacts that this could have upon their learning.

The intervention session created a network of teachers who could discuss and trial different approaches to example design and delivery, as well as providing the opportunity to ask questions about relevant research and how that this could inform practice. Teacher participants felt that the recommendations made would not increase workload but help to ensure that all learners have the best opportunity to succeed in lessons.

Chart 3 demonstrates the impact that the considerations and implementation of these recommendations could have upon the successes of learners in the secondary mathematics classroom. Learners' responses increased massively in value to the overall lesson, with a clear improvement in the proportion of contributions that promoted further discussions about concepts or methods.

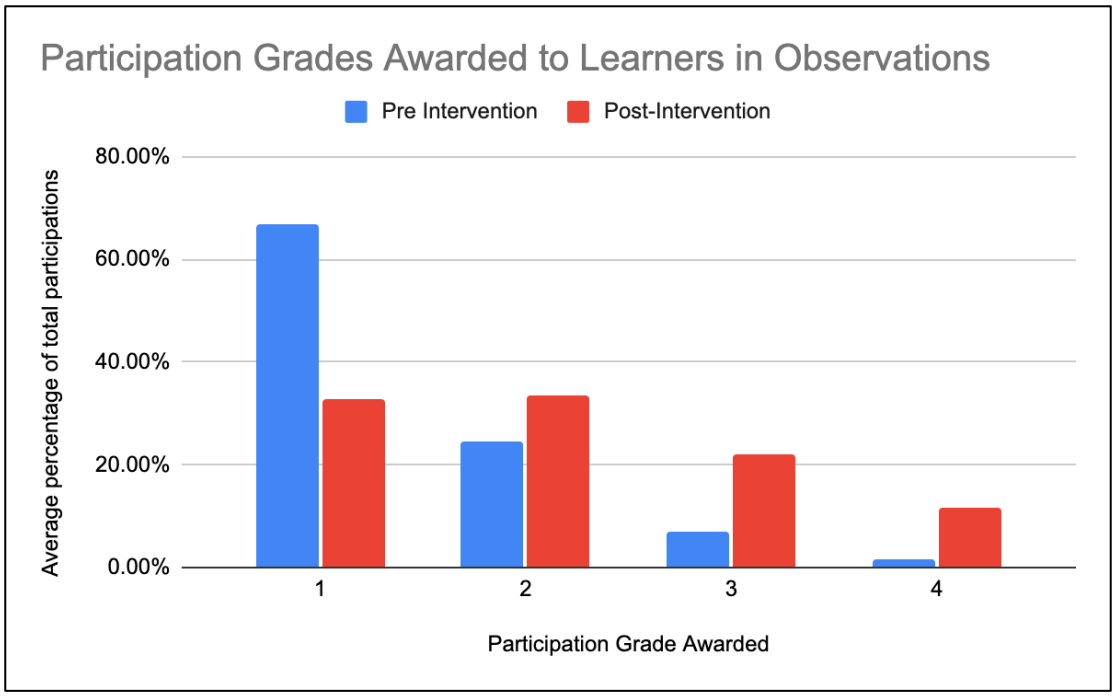

Chart 3

There was a decrease in the average frequency of participations following the intervention provided, from 38 to 30, but this is likely since learners were providing higher graded detailed responses, which in turn reduced the opportunity for multiple learners to contribute these ideas. However, the continuous description of the problem-solving process had a notable impact on learners' ability to understand their peers' approaches to find correct solutions.

Overall, teacher participants described how they felt that by considering the intervention and the data presented within this, they had developed a better understanding of how to address misconceptions in a productive way. They also explained that their delivery of examples had been adjusted to facilitate learning, rather than direct it. Ultimately having an overwhelmingly positive impact upon learners' experiences.

5. CONCLUSIONS AND IMPLICATIONS

To draw from conclusions from this study and begin to consider what implications it may have upon both my own and others' teaching practice, I must refer to the original research questions and explore what has been learned to answer these. Therefore, this section will begin by exploring the evidence to answer both research questions independently and then acknowledge any possible areas where further research would be helpful.

5.1 Research Question 1

RQ1. What do teachers consider when designing examples to promote learner participation in the secondary mathematics classroom?

There are a vast range of considerations that teachers make when designing examples, but the decisions made in their creation or selection do not always promote learner participation in lessons. From discussions with teacher participants and observations of their teaching, it appeared that the primary aim of an example was to explain a concept and not promote discussion about this concept. However, the considerations identified in my literature review all have the potential to have a significant impact upon learners' involvement in the learning process in the mathematics classroom. Teacher participants in this study initially explored the importance of choosing examples based upon prior learning experiences, which was also explored as an important aspect of 'Teacher Reflection', the research conducted

by Olteanu (2017) into this approach to example design was influential in the clarification of this study's focus on participation as a vehicle for success.

Across the study there appeared to be a major increase in teacher's design of examples to encourage learner participation, by exemplifying specific learners' work to illustrate to the class what a correct worked example should look like. Following the intervention, learner generated examples were tactfully used by teachers to assess how well they had understood a topic and inform any future planning of examples, targeting any misconceptions seen. It was also very interesting to see how impactful the involvement of learners in providing key details for teacher modelled examples could be, highlighting the benefits of spontaneously developed examples that relate to learners' contexts. This may also include featuring class members' names, aligning with the 'Person Presentation' approach explored by Loehr et al. (2020).

Learners explained that they felt that teachers designed examples so that they could be copied down into their books and referred to when they had become 'stuck'. This creates an interesting hybrid of the roles played by modelled and worked examples in the mathematics classroom, which challenges the opposing arguments of Huang and Cribbs (2017) and Renkl (2017). A modelled example only exists as such in the original learning episode, if learners' books and copied examples are to have a greater purpose it would be expected that they would revisit work to improve their retention of the knowledge. However, when revisited the learner only observes the

example as a worked solution. It could be argued that by exposing learners to worked examples more frequently, that we could improve their ability to revise topics independently and in light of the Covid-19 pandemic, learn new concepts through such an approach too.

It is clear from the data collected before and after the intervention, that the teacher participants have a good understanding of their thought processes when it comes to example design. This is likely due to the strong emphasis placed upon the careful planning of examples in the Teachers' Standards, where it is recognised as a vital skill for any teacher to learn and develop. Although, it is important to be mindful of ensuring that development continues beyond the minimum expectations of teachers and on reflection it leads me to question whether the true intent behind my first research question is for it to develop into: what *teachers should* consider in the design of their examples to promote learner participation.

The implications of this study are that within our practice, we must consider learners' experiences of the concepts that are being taught. Mathematics must be viewed as more than just the manipulation of numbers, it is a way to describe the world that we live in, and learners need to be involved in this realisation for engagement to increase in mathematics classrooms. It may be that participation remains low in some lessons as interaction with mathematics is not viewed favourably by learners' peers. Discussion of examples is commonplace in many classrooms across the curriculum, and in my leadership roles I often observe other subjects. Here,

learners are actively involved in dialogue with one another, attempting to solve problems without the fear of being wrong. By understanding learners' perspectives and the reasons for these in greater depth, I believe that it is possible to engineer examples that will improve participation, when measuring by both quality and quantity. One approach could be to develop examples that have multiple methods for a solution to be found, in addition to applying the concept to a real-world situation that learners can relate to.

5.2 Research Question 2

RQ2. What considerations and adaptations of example delivery improve learners' opportunities to engage with mathematics most significantly and how can this be applied to other curriculum subjects?

Through engagement with relevant research and my involvement in this study, I have been able to observe learning and teaching in the mathematics classroom through a lens that enables me to recognise missed opportunities for learner participation in lessons delivered by colleagues and myself. Therefore, where possible striving to take advantage of learners' contributions to encourage discussions about mathematical concepts and learn more about their thought processes so that I may capitalise on this to tailor my example delivery to the methods they will relate most closely to.

Learners indicated that the structure of mathematics lessons generally saw the delivery of examples followed by lengthy independent practice sessions and they spoke of how this made it daunting to complete tasks when they were not confident. This suggests that it would be beneficial for the learning experience to ensure that regular check ins are made throughout lessons, to introduce new examples that advance the learning or examples that remedy and misconceptions that have been observed throughout the independent practice session. This may result in an increased frequency or quality of participations, as learners could rehearse their method independently before sharing this with the class.

By adapting the language and approach used by the teacher in the delivery of examples, following recommendations made in the intervention, there was an extremely positive result. Learners enjoyed being a part of the delivery of examples, whether that be by providing answers to questions in the traditional classroom sense or by presenting their own worked example to the class, they were involved, and their mathematical thinking was presented in a more successful way. This not only improves confidence of learners, but also allows the teacher to understand how a learner has solved a problem, whether this be correct or incorrect. Meaning that it is easier to identify the next steps for a learner's journey to mastering a concept.

When imagining how findings of this research may inform the practices of teachers of subjects beyond mathematics, it would be important to reduce the successes observed to generic terms. The teacher must place themselves in the

position of a learner in their classroom and consider what opportunities are being presented for a contribution to be made. In the context of a physical education lesson, it may be that a learner models a drill-based task instead of this being done by the teacher. In a science lesson, the teacher may choose to explain a practical to a pair of learners who then demonstrate this to the class. Without these adapted deliveries, learners risk becoming isolated from the journey of their own learning and developing a shallow understanding of any concept being taught.

5.3 Considerations for future research

Future research in this field should focus on analysing teacher's examples and classifying them by their type and the intended outcome of the delivery. This was an element of my own research that I felt was lacking. This study relied heavily upon both teachers' and learners' opinion of their engagement with examples and the introduction of this additional level of analysis would have provided more evidence to establish considerations made in example design and use.

It would be encouraging to see similar studies to this one, conducted in different contexts nationally. This is because it would allow a picture to be created of the realities of secondary mathematics classrooms across the country and not just in the context of one Multi-Academy Trust. In addition to a national secondary context, it would be interesting to analyse example use and delivery in the primary mathematics classroom. Often these may not be crafted or delivered by a subject

specialist and so the intervention may be extremely useful in promoting learner successes.

5.4 Importance of collaboration

This study has relied upon significant collaboration efforts, which has enabled me to develop excellent relationships with colleagues, who volunteered as participants and those who asked questions about the key findings of my research. I have been extremely fortunate to be surrounded by a supportive team who show a willingness to engage with research informed practice, daily. I have been able to communicate results from my research both in department and more widely to the early career phase colleagues that I support and hope to inspire to remain engaged with research throughout their careers.

I am grateful for the advice provided to me by my supervisor and the questions asked of my study as part of the poster conference day at the University. This helped me to think carefully about my aims and how I would ensure that learners remain at the forefront of this study and in the generation of examples for delivery in the classroom.

The learners who participated in the research shared perspectives that have broadened my understandings of the experiences of the secondary school mathematics classroom, it was a pleasure to share their ideas, with the aim of improving their learning experiences and outcomes.

6. ***REFERENCE LIST***

Barbieri, C. & Booth, J.L. (2016) Support for struggling students in algebra: Contributions of incorrect worked examples. *Learning and individual differences*, 48, pp.36–44.

Baumert, Jürgen et al., (2010) Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American educational research journal*, 47(1), pp.133–180.

Bean, J.C. & Peterson, D. (1998) Grading Classroom Participation. New directions for teaching and learning, 1998(74), pp.33–40.

British Educational Research Association [BERA] (2018) *Ethical Guidelines for Educational Research*, fourth edition, London. https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018

Burghes, D. (2020) *Maths education in the UK: exploring the shortage of Maths Teachers* [Online] Available from: https://uat.ncfe.org.uk/core-maths/maths-education-in-the-uk-exploring-the-shortage-of-maths-teachers/ (Accessed 5th September 2022)

Cambridge Dictionary (2022) *Blended Learning* [Online] Available from: https://dictionary.cambridge.org/dictionary/english/blended-learning (Accessed 16th August 2022)

Childress, D.M. (2019) Teachers Engaging in Action Research to Increase Learner Agency, University of Arkansas.

Darbyshire, P., Schiller, W. & MacDougall, C. (2005) Extending new paradigm childhood research: meeting the challenges of including younger children. Early child development and care, 175(6), pp.467–472.

Davidson, A., Herbert, S. & Bragg, L.A. (2018) Supporting Elementary Teachers' Planning and Assessing of Mathematical Reasoning. *International journal of science and mathematics education*, 17(6), pp.1151–1171.

Department for Education (2011) *Teachers' Standards: Guidance for school leaders, school staff and governing bodies* [Online] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1040274/Teachers_Standards_Dec_2021.pdf (Accessed 16th August 2022)

Department for Education (2019) *ITT Core Content Framework* [Online] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974307/ITT_core_content_framework_.pdf (Accessed 16th August 2022)

Department of Pedagogical, Curricular Professional Studies et al., (2017) What is made possible to learn when using the variation theory of learning in teaching mathematics? *ZDM*, 49(4), pp.559–569.

Essien, A.A. (2021) Understanding the choice and use of examples in mathematics teacher education multilingual classrooms. *ZDM*, 53(2), pp.475–488.

Fisher, A.V., Godwin, K.E. & Seltman, H. (2014) Visual Environment, Attention Allocation, and Learning in Young Children: When Too Much of a Good Thing May Be Bad. *Psychological science*, 25(7), pp.1362–1370.

Flynn, K. (2018) 'The influence of implementing classroom displays on student learning in mathematics', MSc Submission, University of Oxford, Oxford

Galletta, A., & Cross, W.E. (2013) Mastering the Semi-Structured Interview and Beyond, New York: NYU Press.

Goldenberg, P.& Mason, J. (2008) Shedding Light on and with Example Spaces. *Educational studies in mathematics*, 69(2), pp.183–194.

Huang, X. & Cribbs, J. (2017) Examples as an instructional tool in mathematics and science classrooms: teachers' perceptions and attitudes. *Pedagogies (Mahwah, N.J.)*, 12(4), pp.374–390.

Ingram, J. (2021) *Patterns in Mathematics Classroom Interaction*, Oxford: Oxford University Press, Incorporated.

Lawrie, G. (2021) Considerations of sample size in chemistry education research: numbers do count but context matters more. C*HEMISTRY EDUCATION RESEARCH AND PRACTICE*, 22(4), pp.89–812.

Lo, C.K. & Hew, K.F. (2017) Using “First Principles of Instruction” to Design Secondary School Mathematics Flipped Classroom. *Educational technology & society*, 20(1), pp.222–236.

Loehr, A. et al., (2020) Does calling it “Morgan's way” reduce student learning? Evaluating the effect of person-presentation during comparison and discussion of worked examples in mathematics classrooms. *Applied cognitive psychology*, 34(4), pp.825–836.

Marton, F., & Pang, M.F. (2013) Meanings are acquired from experiencing differences against a background of sameness, rather than from experiencing sameness against a background of difference: Putting a conjecture to test by embedding it into a pedagogical tool. *Frontline Learning Research*, 1(1), 24–41.

Mason, J., & Spence, M. (1999) Beyond mere knowledge of mathematics: The importance of knowing-to act in the moment. *Educational Studies in Mathematics, 38*, 135–161. DOI 10.1023/A:1003622804002.

O'Neil, A.H. (2018) *Middle Grades Mathematics Teachers' Learning through Designing Structured Exercises and Learner Generated Examples*.

Olteanu, C. (2017) Reflection-for-action and the choice or design of examples in the teaching of mathematics. *Mathematics education research journal*, 29(3), pp.349–367.

Pillai, R.M. et al., (2020) Are There Costs to Using Incorrect Worked Examples in Mathematics Education? *Journal of applied research in memory and cognition*, 9(4), pp.519–531.

Renkl, A. (2017) Learning from worked-examples in mathematics: students relate procedures to principles. *ZDM*, 49(4), pp.571–584.

Roddick, C.D. et al., (2010) *Succeeding at teaching secondary mathematics : your first year*, Thousand Oaks, California.

Sanders, A. (2018) Generative tools enhance creative and ethical research with children. *Qualitative research journal*, 18(1), pp.33–44.

Star, J. R., Caronongan, P., Foegen, A., Furgeson, J., Keating, B., Larson, M. R., . . . Zbiek, R. M. (2015) *Teaching strategies for improving algebra knowledge in middle and high school students* (NCEE 2014-4333). Washington, DC: National Center for Education Evaluation and Regional Assistance (NCEE), Institute of Education Sciences (IES), U.S. Department of Education

Stone, R., Cuper, P.H. & Dubowe, M. (2006) *Best practices for teacher leadership : what award-winning teachers do for their professional learning communities*, Thousand Oaks, California.

Sun, X.H. (2018) Bridging whole numbers and fractions: problem variations in Chinese mathematics textbook examples. *ZDM*, 51(1), pp.109–123.

The Future Leaders Trust (2015) *Combatting Isolation* [Online] Available from: https://s3.eu-west-2.amazonaws.com/ambition-institute/documents/Combatting_Coastal_Isolation_-_Future_Leaders_Trust.pdf (Accessed 1st June 2022)

Weimer, M. (2013) Learner-Centered Teaching : Five Key Changes to Practice. 2nd ed., Somerset.

Wong, J.L.N. (2013) How Do Teachers Learn Through Engaging in School-Based Teacher Learning Activities? Applying a Knowledge Conversion Perspective. *The Asia-Pacific education researcher*, 24(1), pp.45–55.

Zaslavsky, O. & Peled, I. (1996) Inhibiting factors in generating examples by mathematics teachers and student-teachers: the case of binary operation. *Journal for Research in Mathematics Education*, 27(1), 67–78.

Zhu, Y. & Kaiser, G. (2022) Impacts of classroom teaching practices on students' mathematics learning interest, mathematics self-efficacy and mathematics test achievements: a secondary analysis of Shanghai data from the international video study Global Teaching InSights. *ZDM*, 54(3), pp.581–593.

Zodik, I. & Zaslavsky, O. (2008) Characteristics of Teachers' Choice of Examples in and for the Mathematics Classroom. *Educational studies in mathematics*, 69(2), pp.165–182.

7. APPENDICES

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7.1 Appendix A – Research Design Process

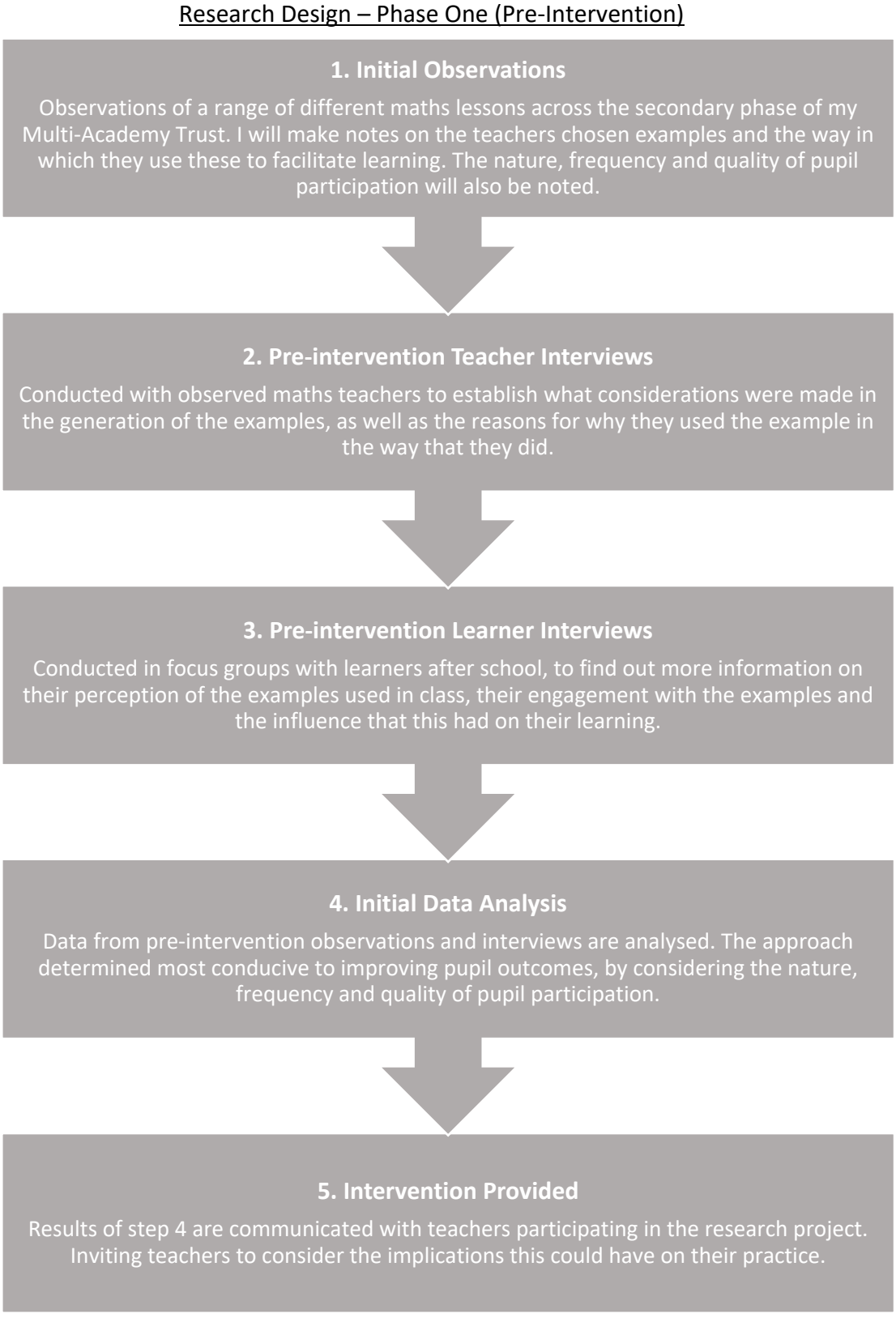


Diagram 1 – Research Design Phase One

Research Design – Phase Two (Post-Intervention)

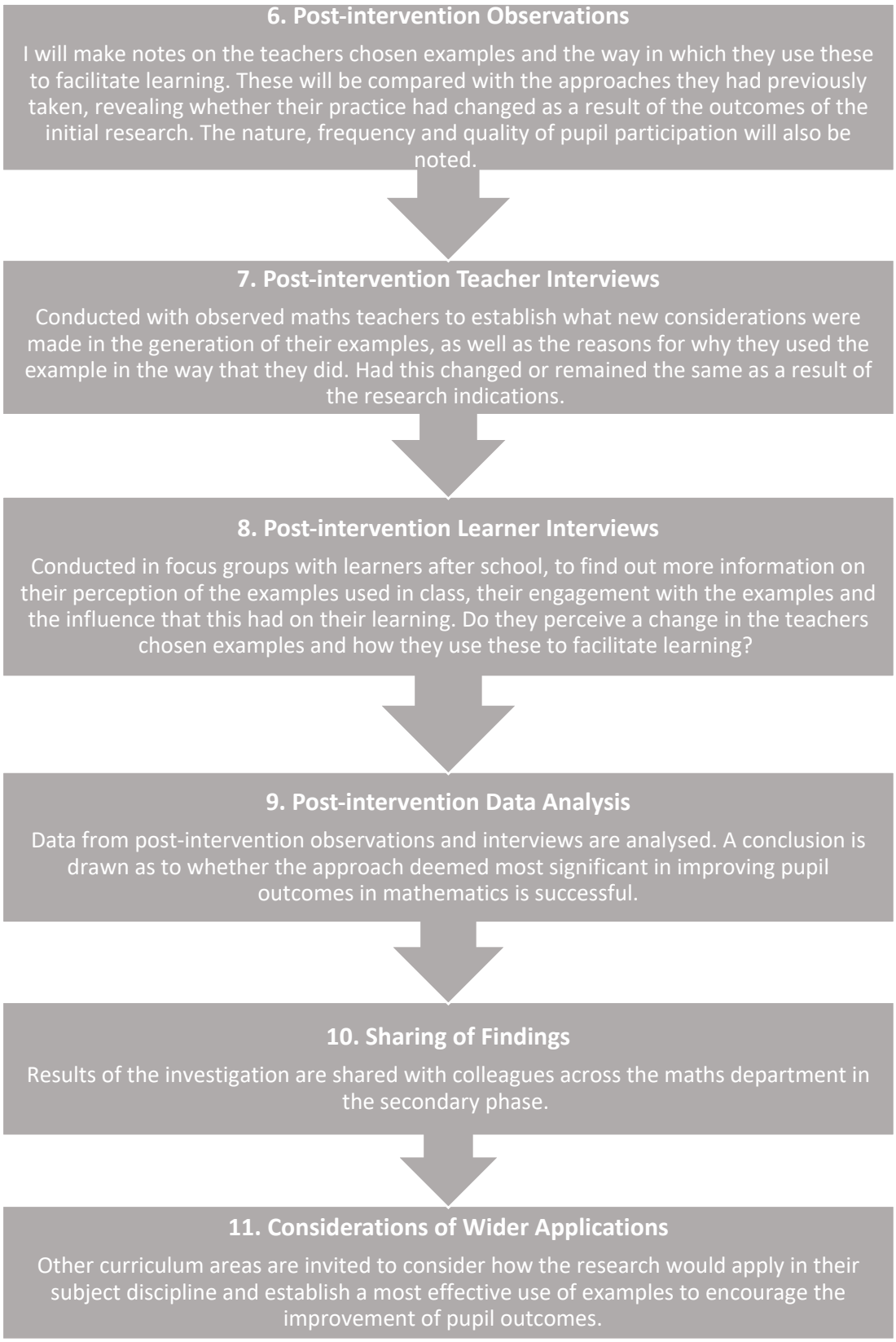


Diagram 2 – Research Design Phase Two

7.2 Appendix B – Teacher Interview Questions

Pre-Intervention Interview

- What are the 3 things you may consider in order to facilitate student learning in your lessons?
- Can you tell me more about why you feel these considerations are important?
- Can you explain the nature of the impact that adapting lessons when learners are not understanding can have upon these considerations?
- Could you give an example of how you choose examples to use in your lessons?
- What is your approach for delivering these examples in class?
- Why do you choose to use examples in this way?
- What evidence would you use to support your opinion on this?

Post-Intervention Interview

- Considering the findings of the research explained, what 3 things do you think that you will consider when planning to facilitate student learning in your classroom?
- What impacts do you think that this will have on student learning?
- How could these considerations be impacted by having to adapt lessons to react to student responses?
- Considering the findings of the research, can you describe the nature of the influence it will have upon your future selection of examples?

- Can you explain why you think this is important?
- Considering the findings of the research, can you describe the nature of the influence it will have upon your future delivery of examples?
- Can you explain why you think this is important?
- What evidence do you believe would indicate improved student progress as a result of this intervention?

7.3 Appendix C – Learner Interview Questions

Pre-Intervention Interview

- When your teacher shows you examples of new topics in maths, how does this help you learn?
- Can you tell me about your participation in class?
- Are there some lessons where this is different to others?
- What do you think the reasons for this are?
- If you don't understand an example in class, what can you do?
- Do you think that there is a "best way" to show examples?

Post-Intervention Interview

- Considering your learning in recent lessons, how has the way your teacher shows you examples changed, if at all?
- Does this change how likely you are to participate in class?
- What do you think the reasons for this are?
- Can you explain how you think that this has impacted your learning?
- Why do you think that it has had this effect?

7.4 Appendix D – Intervention Session Slides

Design and Delivery of Teacher Examples in Secondary Mathematics

Intervention Session

Key objectives

- To provide an insight into the data gathered from observations & teacher/learner interviews
- To share initial data analysis
- To provide recommendations for adaptations to practice in light of findings
- Establish a forum for sharing of ideas linked to the design and delivery of teacher examples

Initial Findings & Data Analysis

Lesson Observation Pupil Participation Grading Framework

Participation Score 1

- Only gives minimal answers when called upon
- Contributions are not developed or cogent
- Dominate discussions in an unproductive way

Participation Score 2

- When called upon they talk too much, make rambling or tangential contributions
- Contributions are less developed and cogent

Participation Score 3

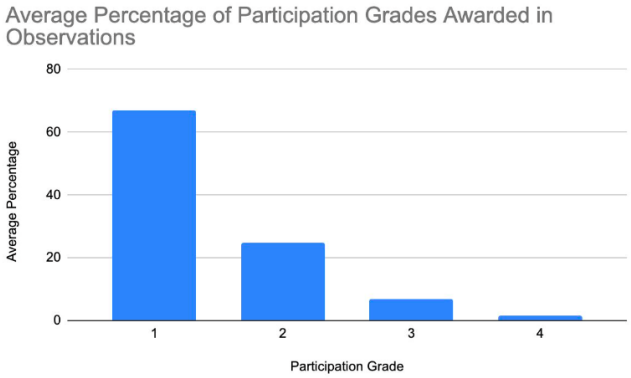
- Makes thoughtful comments when called upon
- Contributions are more developed and cogent

Participation Score 4

- Makes thoughtful contributions that advance the conversation
- Contributions are well developed and cogent
- Shows interest and consideration for others' views

Observations of Teaching

Participation Grade	Average Percentage
1	66.81
2	24.62
3	6.95
4	1.62



Observations of Teaching

- Learners provided with opportunity to ask questions
- Learners asked to explain key steps in solutions to problems
- Very clear modelling
- Applications to real world scenarios
- Learners provided with very few opportunities to explain solutions fully
- Examples delivered usually included a clear misconception illustrated to the learners
- Learners participate in a step-by-step approach
- Learners contribute as a result of permission to participate given by the teacher

Teacher Interviews

Considerations for design:

- Prior learning
- Ability
- Misconceptions previously observed

Considerations for delivery:

- To show clear expectations of solutions
- To promote depth of understanding e.g. concrete/pictorial representations
- Timings of delivery

Learner Interviews

When your teacher shows you examples of new topics in maths, how does this help you learn?

1. Can you tell me about your participation in class?
2. Are there some lessons where this is different to others?
3. What do you think the reasons for this are?

If you don't understand an example in class, what can you do?

Do you think that there is a "best way" to show examples?

Headlines

[participation] depends on class and teacher. If i get answer wrong "you're not listening" don't want to go wrong in front of peers

Answer questions by putting hand up - dad tells him to. Every lesson

only answers when sure she is right. Still contribute if there was significant evidence to support

Maths is very different to other subjects - you get a couple of examples then work independently for 30 mins - it can be quite difficult

How does the teacher know that the quiet pupils are listening and understanding?

Recommendations

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Ensure:

- Examples encourage the discussion of misconceptions by their design, but not deliberate mistakes that learners may be confused by
- The structure of your lesson is staged to include short sessions of examples throughout
- Example delivery involves learners as much as possible to promote engagement - encourage Learner Generated Examples (LGEs)
- Learners are provided with more opportunities to explore their ideas by enabling learners to explain their entire solution and not limit them to individual steps (allow your learners to be a Grade 4 participant)

When delivering examples, approaches could be...

- Today we are learning about _____, has anyone learned about this before? Could you give me an example?
- Who could provide me the full solution, explaining their steps along the way?
- Now that I have shown one example, who would feel confident to show their own and bring a friend to help?
- Promote an environment where productive participation is rewarded despite the accuracy of the answer
- Make learners aware of the Grade 1 -4 Participant scale and link positive rewards to those that make progress along it