An examination of an effective mathematics classroom – searching for the secret ingredients

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Genevieve Colston
Canterbury Christ Church University

Abstract
This research set out to establish the key features of a mathematics teaching practice, which was deemed highly effective. This was demonstrated by a class of children who were eager to learn and confident in the subject, whilst at the same time making rapid progress. In order to examine this successful classroom, a set of unstructured observations; unstructured conversations with the children and a semi-structured conversation with the class teacher were all undertaken over a two week period. The results highlighted six common themes that seemed to occur across all three data collection methods. Such features included: significant opportunities for problem solving; exposure to multiple representations; the facilitation of talk; the teacher's enthusiasm for mathematics; the teacher's in depth subject knowledge and a teacher's drive to ensure children felt they could 'do *maths'.*

Introduction

For a long period of time, mathematics education in the United Kingdom has been high on the agendas of government officials, and arguably more so now than ever before. Practice has often been widely criticised, especially in the primary phase, where often teachers are not educated in the subject past GCSE level (Vorderman et al., 2011). A review of mathematics education in 2012, undertaken by Ofsted (2012), also raised concerns about the varying quality of teaching that was being received by pupils, even between those within the same school. As schools are now judged significantly on the mathematics performance of their pupils, it has become increasingly important for those working in educational settings to strive for a type of practice that will achieve results that can compete with government expectations. However, alternative views have questioned an approach that works to ensure high grades in school exams, suggesting that this may be hampering opportunities to acquire deep levels of understanding (NCETM, 2008; Askew, 2012).
Whilst on a final teacher training practice, I had the honour of discovering mathematics teaching that, in my opinion, was highly effective. This was arguably demonstrated by children who were confident, resilient and seemed to consistently achieve whilst also making rapid progress. Perhaps what signalled exemplary practice was the enthusiasm that all children within the class displayed for the subject. What was this teacher doing in order to achieve such a successful mathematics classroom? The aim of this study was to examine the practice of this teacher, specifically in mathematics lessons, in pursuit of identifying the 'secret' ingredients that achieved such desirable results.

Methodology

Ethical Considerations

Before undertaking this research, an ethical clearance form and research proposal were viewed and signed by the appropriate Canterbury Christ Church University tutor and headteacher of the school in which the research took place. The identity of the school remained confidential and names of participants have been changed to fictitious ones. Verbal assent was also gained from all participants

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that took part in observations and conversations that supported this study. (See Appendix 1 for signed Ethical Approval Form).

Purpose and sample

The research was undertaken in a small village school. The study focused on a mixed year five and six class, consisting of fifteen children (eight boys and seven girls). The teacher had been teaching at the school for roughly eight years and was also designated mathematics leader. The aim of the research was to examine the class teacher's practice in mathematics lessons in order to identify common features that may explain her effective mathematics classroom. For the purpose of this study the class teacher has been referred to as Anna Jones.

Approach

The data collection was based on an interpretive paradigm in order to gain an in depth understanding of the social setting (Thomas, 2009) that I planned to examine. Qualitative data was collected to allow for a range of responses (Holliday, 2008) and to avoid data being manipulated to conform to any preconceived ideas, about 'effective practice', that I may already have had. With this goal in mind, I further chose to undertake a literature review *after* data collection rather than before, again to avoid data being shifted towers expectations or perhaps even subconsciously disregarding data that may not have matched expectations. Despite this, it has been contested that qualitative data is not without subjectivity (Holliday, 2008; Thomas, 2009; Cohen, Manion and Morrison, 2011); previous experiences, social background, gender, political views have all been suggested possible influences upon the way data is collected, recorded and analysed by an individual (Thomas, 2009). With this in mind, I have tried to recognise my social position during the research process and consider the impact of this throughout. Methodical triangulation was used to obtain a range of perspectives held about the social setting which I planned to understand, therefore limiting researcher assumptions (Bell and Waters, 2014). In order to use data analysis to construct a hypothesis about the characteristics of this effective mathematics classroom, I have also implemented *elements* of a 'grounded theory approach' (Glaser and Strauss, 1967) throughout my research.

Methods of data collection

Observations

During the first week of data collection, I undertook five one hour observations of Maths lessons. As previously highlighted above, I was cautious of the impact of my own ideologies on data, thus, undertook unstructured observations with the aim of recording as much detail of the lesson as possible, without the guidance of a list of pre-determined categories. Simpson and Tunson (2008, p.11) argue that 'if you set out categories beforehand you have already decided what the situation is all about'. After having spent nine weeks working with the children and class teacher, I became quite familiar with the usual behaviours of all that participated in this social setting. During the first observation, it seemed that my presence in the classroom as a 'researcher' was perhaps slightly altering their behaviours. Therefore, during the remaining four observations I chose at times, to adopt the role of 'classroom assistant' whilst also recording data observed. It seemed that becoming a participant within the setting that I observed was less intrusive (Simpson and Tunson, 2008), consequently allowing me to gain an insight that was closer to reality (Holliday, 2008).

Conversations with the children

In addition to observations, I carried out unstructured conversations with all of the children, which I recorded and transcribed. I chose to group the children in threes, resulting in five conversations altogether. The choice to conduct group, rather than individual conversations, allowed for the dialogue to be led by the children (Thomas, 2009), rather than myself. As a result, topics raised were

less likely to be initiated by my own perspectives, which, as previously highlighted, was an important characteristic of my approach. It has also been suggested that the use of focus groups to collect qualitative data, may result in riskier and more detailed responses, as more opportunity for discussion often occurs (Thomas, 2009). Whilst I intended for the majority of dialogue to be controlled by the children, it was important that I provided prompts to facilitate conversation that would effectively explore the social setting I set out to examine. I started all group conversations by asking the children to describe themselves, others and the sorts of activities that occurred within their daily Maths lessons. In consideration of a 'grounded theory' approach, Starks and Trinidad (2007, p. 1737) suggest that in order to develop theories about a social setting studied, interviews must allow interviewees to 'describe their experiences' within that setting. Whilst I did not avoid new, unforeseen comments made, I directed participants towards themes that had been highlighted in the data recorded from the observations, when dialogue irrelevant to the study occurred and to also gain another perspective. Again, with reference to a grounded theory approach, Bryant and Charmaz (2007) highlight that data collection and analysis must occur simultaneously, using later data collection to test theories developed through previous analysis.

Conversations with the class teacher

Finally, I undertook a semi- structured conversation with the class teacher. I wanted to gain an in depth understanding of the teacher's perspectives, therefore planned a range of open- ended questions that allowed opportunity for detailed responses. As the interview was conducted after observations and conversations with the children, previous data analysis, had started to identify common themes. In order to increase reliability of results, I wanted to gain the teacher's perspectives on these common themes that had been highlighted. This resulted in a semi – structured conversation to ensure this happened.

Literature Review

Effective teaching in mathematics – the current situation

It has been suggested by research that it is not possible to identify a single 'best practice' in the teaching of mathematics (Cockcroft, 1982; Askew et al., 1997; NCETM, 2008). The 'adaptive challenge' of teaching mathematics, described by Askew (2012), implies that teaching mathematics in preparation for a future we cannot yet define presents difficulties; a solution is required that has not yet been found. Instead, Askew (2012) suggests that knowledge of teaching should be treated as 'conditional'; 'working with the best of our knowledge within the current conditions of teaching' (Askew, 2012, p.xvi).

A government requested review of England's mathematics education in 2011 (Vorderman et al.), raised significant issues about the quality of mathematics education, claiming that nearly half of all students were failing mathematics at GCSE (i.e. not achieving a C grade or above). The review found that, amongst many other issues, primary school teachers' mathematics subject knowledge required urgent improvement; most teachers were spending two terms of the academic year teaching to the test due to league table pressures and mathematics was not being encouraged within other areas of the curriculum and children often had little opportunity to apply Mathematics. In response to the findings of Vorderman et al., and in pursuit of identifying 'best practice', projects have been undertaken to identify common practice within the world's highest performing jurisdictions, (NCTL, 2014) ,with a planned aim of implementing such approaches by 2016 (MathsHub, 2015). Such policy borrowing approaches may suggest that (in opposition to the views of Askew), government perspectives find that a descriptive list of 'best practice' exits and can be effective for all.

This perhaps raises questions about how effective teaching should be measured. Who should be identified as 'doing well'? Jurisdictions perceived as successful by current government officials are

those ranked highest in international comparison assessments such as PISA and TIMMS. However, a review of mathematics education taking place in the 'highest performing' countries, highlights that many of these countries benefit from curricula which may be more in line with such international comparison tests (Askew et al., 2010). For example, there is an emphasis on traditional algebraic manipulation within TIMMS items – such concepts are significantly more evident in Pacific Rim curricula than that that exists in English curricula (Askew et al., 2010). Furthermore, significant findings from the review implied that attainment may be much more closely linked to cultural values, than particular methods of mathematics teaching (Askew et al., 2010). Lew (2008) proposes that strong links between economic status and success in examinations in Japan provide extrinsic motivation for pupils to perform in mathematics. Perhaps, in order to achieve 'best practice', we should be focusing on ways to improve attitudes towards mathematics or even educational success in general, rather than adopting specific teaching methods? (This will be discussed later in the review).

Alternative views of effective teaching in mathematics

Making connections

Whilst, as outlined previously, research implies that a single best practice is unidentifiable, common themes have occurred. Studies undertaken (Askew et al., 1997; NECTM, 2008) found that effective practice was often characterised by an approach that encouraged learners to form 'connections'. More specifically, Askew et al. (1997) highlighted effective teachers as having a 'connectionist orientation' towards teaching mathematics. Practitioners identified paid particular attention to connections between aspects of mathematics (for example, between fractions, decimals and percentages) and connections between representations of mathematics (moving between symbols; words; diagrams and objects). These findings are arguably supported by the model constructed by Hiebert and Carpenter (1992, cited in Barmby et al., 2009; Thompson, 2010), that suggests that mathematical understanding is achieved by a network of mathematical knowledge connected by rich links. It has been contested that such connections allow learners to transfer understanding across multiple contexts in order to solve a range of problems (Hiebert and Carpenter, 1992).

Subject knowledge

Rowland et al. (2009) also acknowledge that a move towards teaching for understanding in mathematics requires teachers to make connections between mathematical concepts and representations of a given concept. However, they argue that teachers themselves must have a deep subject knowledge of these connections in order to make them explicit. This view is arguably supported by a study undertaken by the NCETM (2008) that implied that a lack of teacher subject knowledge in mathematics often prevented practitioners from providing effective teaching for learners. They suggested that the recruitment of more mathematics specialists in education could increase standards of teaching in the subject, inferring that a teacher's level of mathematics qualification has an impact on their practice. Conversely, research undertaken by Askew (1997), found that teachers identified as 'effective' were in no way differentiated from other practitioners by their level of subject relevant qualifications. However, it is perhaps important to consider both methods undertaken to gather data. Whilst Askew's study first identified 'effective mathematics teaching' and then sought to find common characteristics amongst those teachers, the data collected by the NCETM (2008) was compiled by the *views* of those working within the mathematics community. It could be argued that although those in education believe advanced subject knowledge in mathematics enhances teaching in the subject, perhaps in reality this is not the case.

Talk

Facilitating 'talk' has also been suggested by research and literature (Mercer and Sams, 2006; NCETM, 2008; Monaghan, 2010; Askew, 2012) as a feature of effective classroom practice in

mathematics. Talk can occur between peers or between teacher and learner. It has been contested that allowing for talk in mathematics lessons provokes mathematical reasoning by allowing pupils to articulate and demonstrate connections by making predictions, generalisations and forming justifications (Barmby et al., 2009; Haylock, 2010; Monaghan, 2010). In consideration of the ideas highlighted by Hiebert and Carpenter (1992), Barmby et al. (2009) contend that a process of *reasoning* is necessary in order to form links between different mathematical concepts and representations of the same concept. However, a review of mathematics undertaken in 2008 (Williams) outlined concerns for the productivity of talk in primary schools. The review found that often talk was 'off task' and sometimes even disruptive (Williams, 2008). This could suggest that 'talk' needs to be carefully implemented in lessons; teachers must model effective talk and also provide opportunities for children to practice appropriate forms of discussion (Mercer and Sams, 2006) that will result in a process of reasoning to enhance understanding.

Is effective teaching the only determinant of success?

Attitudes

As previously identified, a review of the mathematics education taking place in high performing jurisdictions (Askew et al., 2012) suggests that their impressive performances may be significantly due to the cultural attitudes towards education; in particular, towards mathematics. This perhaps poses questions about the relevance of children's attitudes towards mathematics. Can learning be effective if, despite the existence of the 'effective' teaching methods, learners hold negative attitudes about the subject? Studies undertaken in the United Kingdom (Ashby, 2009; Dowker et al., 2012) investigating the impact of children's attitudes on mathematics attainment, found strong correlations between the two variables. The findings of Ashby (2009) not only suggested that negative attitudes towards mathematics had a damaging impact on mathematical achievement, results also implied that the cause of such negative attitudes was often the result of a perceived lack of purpose for studying the subject. This seems to oppose the general beliefs about the importance of mathematics of those living in countries that 'do well' in international ranking tests (Lew, 2008), implying attitudes may hold some significance.

To what extent it is possible for a teacher to alter the attitudes and beliefs of the children in their class? A study undertaken by Boaler (2009) identified practice where teachers consciously made way for opportunities to consistently praise their learners and identify their strengths. It was suggested that this approach gave children confidence in their abilities, having a direct impact on the achievement. In support of these findings, research undertaken by Dowker et al. (2012) found that children with a positive 'self-rating' performed significantly better in mathematics than those with a negative 'self-rating' of their ability. However, whilst these studies may hold some significance, it is important to acknowledge that the study undertaken by Boaler did not assess the attitudes of children before partaking in this particular form of education and therefore it is difficult to identify to what extent the *teacher's approaches* had an impact on the attitudes of learners.

Results and Analysis

Due to the qualitative nature of all data collected, multiple results were found, highlighting elements of the effective mathematics classroom described. However, particular 'themes' were common, appearing frequently from data across all three methods of collection. The 'themes' have been split into six categories and discussed below.

Problem Solving

Data collected by all three methods suggested that activities described by both the teacher and children as, 'problem solving' played a significant part in many of the mathematics lessons. Observations highlighted that such activities required pupils to draw upon a range of mathematical

knowledge and recognise 'connections' between concepts in order to find solutions to given problems. Whilst some lessons started with the introduction of a particular mathematical procedure, activities were soon altered to allow pupils the opportunity to draw upon that procedure, alongside previously learnt concepts in order to solve problems. However, comparison of both the teacher's and the children's responses provided two reasons for its positive impact upon the learning. During conversations with the children, many claimed that the existence of problem solving in mathematics made the subject fun. On the other hand, Anna justifies her approach differently, *"…things have to be presented inside out and back to front and they have got to see it all from the word go... It is very rare that I am getting children to just follow a procedure".* The teacher's lack of activities that required children to just follow procedures perhaps suggested that she felt they were unproductive. This is supported by an opinion that implies a deep level of understanding cannot be achieved by simply learning and carrying out prescriptive techniques (Askew, 2012). Understanding of a given concept is perhaps truly demonstrated by the ability to *apply* the concept to different problems (Askew, 2012). Additionally, the element of 'fun', described by many of the children, is perhaps significant to these findings. A similar study undertaken by Boaler (2009), investigating a particularly effective mathematics classroom identified an approach that focused heavily on problem solving to acquire understanding. It was suggested that the approach was significantly effective due to its 'enjoyable' nature, allowing pupils to become engaged in the learning (Boaler, 2009).

Multiple Representations

Whilst not significantly identified in the children's responses, both observations and responses from the class teacher highlighted that multiple representations were used to express different concepts. For example, pictures, objects, verbal explanations and mathematical symbols were also used to demonstrate fractions. Even in a year 5/6 class manipulative aids were valued by Anna in supporting understanding. Although, the teacher did not justify her approach, the use of multiple representations *is* justified by a range of research and literature, again advocating 'connections' (Askew et al., 1997; NCETM, 2008).

The Facilitation of Talk

The use of 'talk' seemed to be a prominent characteristic of the mathematics lessons. Observations identified that talk between peers was used throughout the lesson to discuss problems, share ideas and question one another's answers by providing justifications for why an answer may be incorrect. The children seemed to be able to use talk effectively to develop one another's understanding and talk was rarely, if ever 'off task'. The use of talk in mathematics has been described by many (Mercer and Sams, 2006; Haylock, 2010; Askew, 2012) as a vital characteristic of effective practice, some linking the approach again closely to the development of 'connections' (Barmby et al., 2009; Monaghan, 2010). Unlike many of the findings of the Williams review (2008), the class teacher explained that she felt she could trust the children to use their talk opportunities productively in the lessons. However, Anna felt that it was important to acknowledge the smaller than average size of the class. She explained, "*I know that I could spot if anyone wasn't working…I mean if I had a class of thirty- two, it would be much harder to spot whether someone wasn't getting on*". Previous experiences of my own have suggested that using dialogue in a larger class can sometimes seem a lot more 'hectic' and perhaps prove more difficult to identify children off-task. Although, comparison of results with alternative research examples suggests that the use of talk contributed distinctly to the success of this class, it could also be argued that the class size may also have had an impact.

An Enthusiasm for Mathematics

Throughout the conversations with Anna, it was notably implied that she had a passion for teaching mathematics. She described the subject as her "*favourite*'' and explained that she "*preferred teaching it over any other area of the curriculum*". She also suggested that she spent more time

planning for this subject than any of the others. Whilst it is arguable that Anna's increased planning time assigned to the subject (as a result of her liking for mathematics) could provide some explanation for the effective classroom practice observed, conversations with the children also implied that they were aware of their class teacher's enthusiasm for mathematics. For example, one child said, "*You can tell Mrs Jones is a real maths person!*"

Subject Knowledge

With primary school teacher's mathematics subject knowledge seeming to be a current contentious topic within education, it seemed important to gain an idea of the class teacher's mathematics background. Anna highlighted that she had completed mathematics up to A level and although she had not achieved a degree in the subject, had recently completed the MaST (mathematics specialist teacher) course. Arguably, the teacher's qualification up to A-level could have an impact on her ability to effectively approach the teaching of mathematics, as perhaps her higher level understanding enhanced her ability to recognise connections between concepts and make these explicit (Rowland et al., 2009). With many high performing jurisdictions identifying a mathematics degree as a must for teachers, even at primary level, it could be argued that a correlation between subject knowledge and effective teaching may exist (NCTL, 2014). However, it is perhaps also important to note that Anna's choice to undertake the MaST course was fuelled by her own personal interest and enthusiasm for the subject. Therefore this could imply that subject qualifications in mathematics may also be an indirect demonstration of enthusiasm for the subject, which as discussed above, seems to have had an impact on practice.

You can do it!

When asked to describe effective practice Anna replied, *"I like to think it's something that the children think that they can do…I think a lot of children think that they can't do Maths, but effective practice allows children to think they can do it".* Although, it seemed that Anna (consciously or not) provided a mathematics education that to some extent mirrored many of the current views and theories advocated within the literature review, it seems that ultimately her practice was underpinned by a belief that in order to achieve, children must feel they *can do Maths*. Whilst it is important to consider the fairly small scale of Dowker et al.'s (2012) research, findings that indicate a learner's self-rating has a significant impact on ability very much support Anna's practice. Observations implied that this underpinning belief was characterised by constant praise and reassuring children of their abilities. Phrases such as, "*This is a real challenge this question, but I know that all of you are good enough to do it*", were a common example of dialogue used by Anna throughout mathematics lessons. Again, this perhaps highlights the importance of developing children's attitudes in mathematics. Unfortunately my research does not provide information about the attitudes of the children before exposure to this sort of practice, therefore it is not possible to guarantee that this teacher's approach had an impact on the children's results. However, recent studies undertaken by Dweck (2008) have suggested that ability is determined by mind set. She advocates that people who believe they are good at something are much more likely to achieve than those who feel they are not. Whilst these studies were not all mathematics specific, her findings perhaps further support my assumptions.

Conclusion and Implications for Practice

The aim of this study was to identify the features of a mathematics classroom that seemed highly effective. The most significant results suggested that the class teacher had a 'connectionist orientation' to teaching mathematics; taking every opportunity to make explicit links for learners between different mathematical concepts and also between different mathematical representations of the same concept. This was characterised by lessons focused around collaborative problem solving activities and multiple opportunities for children to use 'talk' to develop understanding and

undertake a process of reasoning. Overall, these findings seem to fall closely in line with research and literature surrounding the topic of 'effective mathematics teaching'. Findings also implied that the class teacher had a good level of subject knowledge. She had been educated up to A-level in the subject and had also recently been awarded a 'Mathematics Specialist Teacher' qualification. Whilst the results perhaps suggested that this had a positive impact on the practice of the teacher, diverse views regarding the significance of subject knowledge seem to exist within literature and research. Analysis of the results questioned whether her subject knowledge was in fact a demonstration of her enthusiasm for the subject and perhaps it was this enthusiasm that had the most significant impact. Additionally, results found that Anna put high importance on ensuring all of the children felt that they could 'do maths'. This seemed to also play a significant role in her overall practice, constituted by constant praise and the identification of children's strengths.

It is however important to acknowledge the limitations of my research. It was my personal judgements that identified this particular classroom as 'successful' and as highlighted in the methodology, both this assumption and further interpretations of data can never be without subjectivity. Furthermore, the study did not provide a comparative classroom. Perhaps the existence of a control variable may have provided further insight into the extent to which Anna's practice actually achieved such desirable results.

Looking forward, I have considered the impact that this study will have on my future practice. Based on these findings, I would aim to implement all of the themes highlighted. Most importantly, I would strive to approach mathematics lessons having a 'connectionist orientation' and aim to utilise engaging problem solving activities that create opportunities for learners to draw upon new and older mathematical knowledge to find solutions.

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