How can we improve mathematical vocabulary comprehension that will allow students to develop higher-order levels of learning?

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Abstract
The style of the mathematics GCSE examinations in England is changing under the new reform (Department for Education, 2013a), which promises to test in problem-solving and worded contexts to a greater degree. This will undoubtedly present a barrier for many students due to the increased need to understand and use mathematical vocabulary. During this enquiry, I aimed to find a teaching strategy that would help students to learn mathematical vocabulary, and so enabling them to access higher-order levels of learning in preparation for the new exams. The strategy used was the Frayer Model, implemented for a 6-week period with a class of 15 participants. Results from pre- and post-instruction testing were analysed, along with the results from a control class. The class who received the instruction showed clear improvements over the control class, however the model appeared to be less effective with those participants with a lower reading age. Also, the questionnaires highlighted that those who were more engaged with the model generally experienced greater improvements in their understanding of mathematical vocabulary in the test.

Introduction
One of the most significant reforms in the education system in England in recent times is the introduction of the new GCSE examinations (Department for Education, 2013a). The new mathematics summative assessments will be rolled out next year, and there is currently much anticipation and uncertainty regarding their style and complexity. However, we do know is that they will examine mathematics in a much more applied context with a much greater need for students to read and understand worded problems that will test not only their knowledge and skills, but also their ability to reason and present robust mathematical arguments (Department for Education, 2013a). Mathematical vocabulary has always been an important yet somewhat over-looked aspect of learning mathematics that perhaps has previously not always received the attention that it deserves (Adams, 2003). But now there can be no hiding from the fact that it can pose as a significant barrier to learning and achievement in the imminent reformed examinations. So how can we improve mathematical vocabulary comprehension that will allow students to develop these higher-order levels of learning?

Literature Review
There is known to be a strong correlation between vocabulary knowledge and reading comprehension ability (Stanovich, 2008), and it follows that reading comprehension is essential in learning how to problem solve effectively (Carter, 2006; Amen, 2006), a fundamental part of the new assessment strategy. Marzano (2004) specifically linked vocabulary knowledge to overall academic achievement, and precisely the same relationship

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has been found between mathematical vocabulary and mathematical performance (Riccomini *et al.*, 2015). For decades, it has been known that linguistic abilities have an impact on mathematical performance (Aiken, 1972), and more recently, Morgan (1999) and Schleppegrell (2007) emphasised how learning to understand and use mathematical language is a critical part of learning mathematics. These literacy skills are so heavily demanded in the new GCSE assessments, yet still do not seem to hold the weight that they deserve in Maths lessons, and it appears that without these literacy skills, students are ill-equipped to progress their learning to the standard required to achieve a pass grade.

Mathematics is deemed to be a language in itself, as it possesses all of the characteristics of any other spoken language (Wakefield, 2000). Yet unlike most other languages that we are familiar with, we do not read it merely from left to right, but also from right to left, top to bottom, bottom to top, or a combination of all four directions (Adams, 2003). It has a complex and precise structure, being composed of numerals and symbols as well as words. This use of symbols immediately causes turmoil in the minds of some students, as there is additional cognitive processing required to translate those symbols not only into words so the mathematical sentence can be read, but also into meaning so the mathematical sentence can be resolved.

Yet the mind cannot rest easy when reading mathematical words either; these are often words that are unfamiliar, multi-syllabic, difficult to read and spell, and carry with them a precise and sometimes highly abstract concept (Chinn, 2012); for example, the word 'isosceles' falls into this category. In addition to this, assessment questions are often complicated by implied meanings associated with this type of terminology; therefore, if a student is told that the shape in the question is a regular hexagon, they must instantly realise that they may be required to draw upon any of the shape's properties (such as number of sides, symmetry, angle facts or tessellation) without being explicitly told, in order to successfully find a solution (Thompson and Rubenstein, 2014).

There is a second set of mathematical words that students may be more familiar with and would have experienced in everyday conversations (Gough, 2007), and one may be fooled into thinking that this is a helpful circumstance. However, these words rarely transmit the same meaning when placed in a mathematical context; for example, the word 'volume' falls into this category. The original word meanings that have been formed and reinforced in the brain over the years must now be altered in order to accommodate a new path to a somewhat intangible meaning, potentially causing conceptual confusion.

Whether reading mathematical symbols or words, the route to success lies in the vocabulary comprehension (Fisher and Frey, 2014), and hence it is important to all ability levels. Bloom's model of taxonomy (1956) and the SOLO taxonomy of Biggs and Collis (1982) both indicate that learners must be able to identify, define and describe concepts (at the heart of which is the content vocabulary) before progressing on to higher-level thinking and reasoning. In addition to these learning classifications, the *Subject Content and Assessment Objectives for Mathematics* (Department for Education, 2013b) specifically states that students of all abilities will be tested on their vocabulary in particular content areas; for example, both foundation level and higher level paper will require examinees to:
use the concepts and vocabulary of prime numbers, factors (divisors), multiples, common factors, common multiples, highest common factor, lowest common multiple [and] prime factorisation (Department for Education, 2013b)

When it comes to worded problems in assessments, there is much research that considers that impact that mathematical vocabulary has on achievement. Ofqual (2015, p107) looked specifically at the expected and actual difficulty levels of the new GCSE mathematics papers from the various exam boards, and concluded that, beyond the maths involved, the way the questions were worded and the context had an effect on the difficulty level. They also noted that OCR[1] examination board had a slightly higher word count which correlated with a slightly higher level of difficulty. However, looking at word count alone is not a sophisticated enough method to assess the impact of language in the questions.

Kan and Bulut (2015) found that changing the language used in mathematics questions affected student performance in both directions: if numeric questions were converted into worded questions, students' performance worsened if the language became technical, but improved if the language became colloquial. Either way, they highlighted a bias towards those students who were more proficient readers, meaning that test scores could not be compared on the grounds of pure mathematical ability. This is an interesting discussion point – should we be testing pure mathematical ability, or is the language of mathematics an intrinsic part of the learning that should simultaneously be tested? I believe that the evidence here suggests that the language cannot be differentiated from the mathematics if more than surface level learning is to be achieved.

Aims and Purposes

Background

From my previous classroom observations, I identified that vocabulary comprehension was a particular weakness across all ability levels; in a middle ability set, the technical term 'congruent' caused confusion in one of the summative assessments, and in a top set class, even the word 'fully' in the expression 'fully factorise' caused perplexity for some students. As teachers, we may sometimes be inclined to frivolously hand over the definition in order that the students get to the mathematical skills needed, but in a GCSE examination, this lack of understanding could be the barrier that is the difference between a pass and a fail.

Aim

The aim of this enquiry was to find out if students were able to overcome a barrier to learning, which took the form of mathematical vocabulary comprehension, by introducing a focused teaching strategy.

Purposes

The purpose of the enquiry was to improve students' overall mathematical ability in the classroom and in assessments. I also carried out this enquiry to help to develop my own teaching practice, and that of other teachers by disseminating my findings.

Ethical Considerations

Ethical considerations were at the forefront of my enquiry at all times, although this did occasionally cause some conflict with my research objectives. My intention was to follow the guidelines set out by the British Educational Research Association (BERA, 2011), which first of all required that I inform and subsequently gain permission from the class teacher and head of department to proceed with the enquiry.

[1] http://www.ocr.org.uk/about-us/who-we-are/

Once permission was granted, the issue of consent from the participants arose. Cohen, Manion and Morrison (1993, pp77-81) comment extensively on the issue of informed consent of the participants, particularly of children, and that there are very few instances where consent would not be deemed to be as important as other conflicting ethical factors. This emerged as the main conflict to my research aims; my dilemma was whether to fully inform the participants of these aims and risk damaging the integrity of the data. Barker Bausell (2015, p66) writes about the Hawthorne Effect whereby participants may act out of character if they know they are being watched for a particular reason, and part of my study was to observe how the students involved themselves with the vocabulary model.

I had ownership of the class with whom I was intervening, and since the primary objective of any teacher is to improve the ability of their students, I did not perceive the strategy that I was using or my intentions to be deceiving the students in any way. However, there is a difference between a teacher who performs action research in their class as a part of their on-going aim to improve the learning of their students, and that of an action researcher who plans to more formally present and disseminate their work, the latter creating the impetus to abide by the formal ethical guidelines (Zeni, 1998). Therefore, to strike an acceptable balance, I informed the students of just the broad context at the start of the action research in order to allow them to give their informed consent to participate.

BERA (2011, section 16) states that children should be facilitated to give their fully informed consent where possible, so having studied the school's Record of Need, detailing SEN/D (Special Educational Needs/Disabilities) and any other support that the children require, I was confident that all participants in the study would be able to understand the simple details of my enquiry, which would be sufficient for them to decide if they wanted to participate. I gave all participants the opportunity to withdraw their work from the study if they did not wish to continue to participate at any point.

In an effort to protect the anonymity of all participants (BERA, 2011, section 25) I have removed all student and teacher names from the data collected, and will refer to students, teachers and the school with numeric suffixes, if it is necessary to distinguish particular participants. Similarly, I have made every effort to keep any personal information confidential by sharing it only with those deemed to be necessary to the purposes of the enquiry (BERA, 2011, section 25).

Methodology

Approach

The enquiry approach that I have used is that of action researcher. Bell and Waters (2014) describe this approach as "applied research, carried out by practitioners who have themselves identified a need for change or improvement". It is a strong form of enquiry as it allows the researcher to be part of the research, having the advantage that they know the full purpose and methodology of the study, helping to improve its integrity and ethical validity (Elton-Chalcraft, Hansen and Twiselton, 2008, p60).

Cohen, Manion and Morrison (1993, p7) discuss the two leading paradigms in the field of educational research, that of the positivist paradigm and the interpretivist paradigm. Their view on the most appropriate paradigm with regards to educational research is that of the interpretivist, since it accommodates for the "immense complexity of the human nature". I agree that it is not wise to look at educational research in a purely positivist way which can be cold and calculated, yet in relation to the nature of my particular research, it is the primary paradigm that I will follow. Since the aims of this enquiry are ultimately to improve mathematical ability, which is formally assessed by way of the summative GCSE examinations, I feel that taking a predominantly positivist approach to the research enquiry is most appropriate, with a secondary interpretivist element in order to triangulate my results (Bell and Waters, 2014, Part 2).

Setting and Participants

I conducted my action research in School A, a larger than average-sized secondary school. It accommodates the full range of abilities, with a special provision for those students with more complicated learning needs. The school has a lower than average proportion of pupil premium students, and less than a quarter of the participants involved in the research were identified as fulfilling the pupil premium indicator.

The participant selection process was given much thought and planning in order to make sure my study was feasible and that it would provide valid data. To begin, I made sure that I had sufficient access to the participants that were to be involved in the instruction and testing (Cohen, Manion and Morrison, 1993, p81-84). Being a large school, each year group was split into two populations which each had different timetables. Having studied the data of the classes to which I had already been assigned in School A, I searched for classes of the same age and ability in opposing populations. In one of these instances, the two populations had the same class teacher, and on speaking with the teacher, I established that their abilities were very similar and that they would be suitable classes to use in my enquiry. Throughout this enquiry, I have referred to Class A as the class who received the vocabulary instruction via the Frayer Model, and Class B acted as the control group.

There were 15 students in each class who participated in the study, all of whom were of low mathematical ability, and most of whom had a lower than average reading age, an indication of vocabulary comprehension. Abedi and Lord (2001) found that there is a relatively greater disadvantage for lower-ability students in answering questions that are composed of complex language; therefore, I felt that the effects of the vocabulary instruction would be highlighted to a greater extent with this low ability class, and they would potentially experience the greatest improvement.

Design

Explicitly teaching keywords at the start of a lesson is the most common form of vocabulary instruction that I have encountered. However, Monroe and Orme (2002) state that definition-only teaching of vocabulary is ineffective and leads to minimal understanding, and it is this surface level learning that I wanted to improve upon. Etymology is also a method used by some teaching, yet as Morgan (1999) points out, with students rarely learning Latin or Greek in today's secondary schools, they are unlikely to be able to make the connection with the word origins.

Some educationalists value learning through a vivid context that helps to motivate the student (Boaler, 1994; Chapman, 2006), yet Monroe and Orme (2002) suggest that this alone cannot provide the full depth of meaning. They conclude that a combined approach has seen much better results.

The use of graphic organisers has been deemed to successfully fulfill this combined approach of vocabulary instruction, if the teacher is able to facilitate their usage effectively. There are many forms of the graphic organiser, such as the Concept of Definition developed by Schwartz and Raphael (1985) that uses a semantic word map, and more recently, Rupley *et al.* (2012) discussed the advantages of the Concept Wheel. The Frayer Model (Frayer, Fredrick and Klausmeier, 1969) is a well-known example, yet not one that I have ever seen used in the classroom. It has been modified from 13 vocabulary attributes to just 4, making links between definitions, examples, non-examples and connections. These links are vitally important for vocabulary comprehension, particularly the link to 'connections', which brings in the background (existing) knowledge that provides the hooks allowing for retention and recall of new knowledge (Marzano, 2004).

Graphic organisers have proven to be much more effective if presented as an activity at the end of a period of direct instruction, context and utilisation (Moore and Readance, 1984); this aids the organisation of the new word and, more importantly, the associated concept in a way that best serves the retention and recall processes of the brain (Monroe and Orme, 2002).

Positive results are also seen if the graphic organisers are used as a discussion focus; Vygotsky (1978) wrote extensively on the connection between language and development, and a great deal has been written about the importance of discussion in learning new vocabulary and concepts (Furner, Yahya and Duffy, 2005; Gough, 2007; Thompson and Rubenstein, 2014).

However, Monroe and Pendergrass (1997) warned of using graphic organisers with low-ability students as they often had less rich background knowledge with which to make the conceptual connections. Conversely, Singleton and Filce (2015) have since noted that graphic organisers have indeed proven to be a valuable tool in helping secondary students who struggle to read and comprehend difficult texts. They make the critical distinction that teachers must teach students how to use the graphic organisers and model them effectively, harnessing whatever background knowledge they may have in order to build confidence, a crucial point to which Monroe and Pendergrass (1997) failed to make any reference.

In light of this evidence, I planned to use the Frayer Model of the graphic organiser for vocabulary instruction, rather than direct vocabulary instruction or instruction in context alone. I built this activity into the end of the lessons, after a period of usage, as a way to recapture the main elements of the new word. The activity was always completed as a class activity; the mathematical ability of the class was low and many of the students also lacked good literacy skills, so we discussed the elements of the model together and I combined the ideas of the class in order to come up with definitions, examples and connections to previous knowledge.

McConnell (2008) carried out similar action research that involved direct vocabulary instruction. He concluded that the vocabulary instruction was valuable as it raised that test scores of the participants. Yet the vocabulary test scores were compared with scores of the same class in previous tests. Without further investigation, I could not be sure that it was the vocabulary instruction alone that improved the scores; perhaps the topics being tested were not so challenging for those students. To avoid this area of uncertainty, I decided to conduct my research using two classes of very similar ability and in the same year group who were completing the same units of work in parallel; one class received the usual form of vocabulary teaching, while I would teach the other class using the Frayer Model, allowing me to compare the progress made with and without the new style of instruction. I continued with this instruction for a period of 6 weeks.

It was important that I first gained some baseline data in both classes that were to be involved in the research in order to be able to assess any improvements, so I assessed their current knowledge of the vocabulary in the forthcoming unit of work by way of a written test prior to any instruction commencing. Students were asked to write a definition or description of each word or give an example and non-example. Provided the students were able to convey the concept of the mathematical word, I marked the question as correct. I did not demand perfectly formed definitions at any stage due to the literacy abilities in the class; plus there is never a need to provide a dictionary definition of a mathematical word in a GCSE examination. I then re-assessed both classes at the end of the 6-week period using the same vocabulary test.

The interpretivist element of my research approach took the form of observations throughout the action research and results from a questionnaire. I briefly noted key observations of the way that the students involved themselves with the graphic organiser during the lessons, and then wrote the full details once each lesson had ended (Merriam, 2014, pp.128-131).

Participants who received the vocabulary instruction in the form of the Frayer Model were also asked to complete a questionnaire at the end of the 6-week period. Due to the below average literacy level of the class as a whole, I made sure that the language used in the questionnaire was simple and statements were kept concise. I used a Likert scale to create responses in the form of ‘Strongly agree’ to ‘Strongly disagree’ which I then coded in order to analyse the data; however, I did not allow the respondents to see the codes as they can be deemed as too confusing for children (Mellor and Moore, 2013). The questions were all framed in a positive manner towards the method of vocabulary instruction, and therefore the higher the score in the questionnaire, the more positively the participant engaged with it. I aimed to avoid bias in the design of the questionnaire by using a 5-point balanced scale with the same number of positive and negative options, and one neutral mid-point (Brace, 2008, pp. 67-73).

When collecting the data over the 6-week period, there were variables that were beyond my control that I did not foresee. These included the absence of some students during some of the lessons when I delivered the vocabulary instruction, which would have an impact of the post-instruction test results. I believe that these absences were minimal however, so I have not taken this into account when analysing the data, but have considered it a possible factor when interpreting the results. Other variables included the motivation of the students to engage with the model, and their ability to transfer their knowledge onto the test paper in writing, both of which could be significant factors affecting the results of the study, yet beyond the scope of this particular enquiry.

Data Analysis

I used Excel software in order to analyse the data from the test scores and the questionnaire. Initially I represented this information by way of a dual bar chart to highlight the differences between the two classes at a participant level.

The data from the vocabulary tests were then compared using averages (mean, mode and median) and measures of spread (range, interquartile range, standard deviation and variance) in relation to the change in scores; this allowed me to gain an understanding of the scale of improvement made by each class. I have presented these differences visually by way of box plots.

In order to help explain some of the differences in the test scores, I have analysed the students' reading ages compared to their improvement level in the vocabulary test using regression analysis to determine if there is any correlation between the two variables.

Finally, I used the results of the questionnaire to help determine if there are other factors that could affect the results of using the Frayer Model; for example, did those with low levels of improvement record that they did not engage well this type of vocabulary instruction?

Findings
At participant level, students in Class A made significantly greater gains, although some students in both classes made no improvement at all.

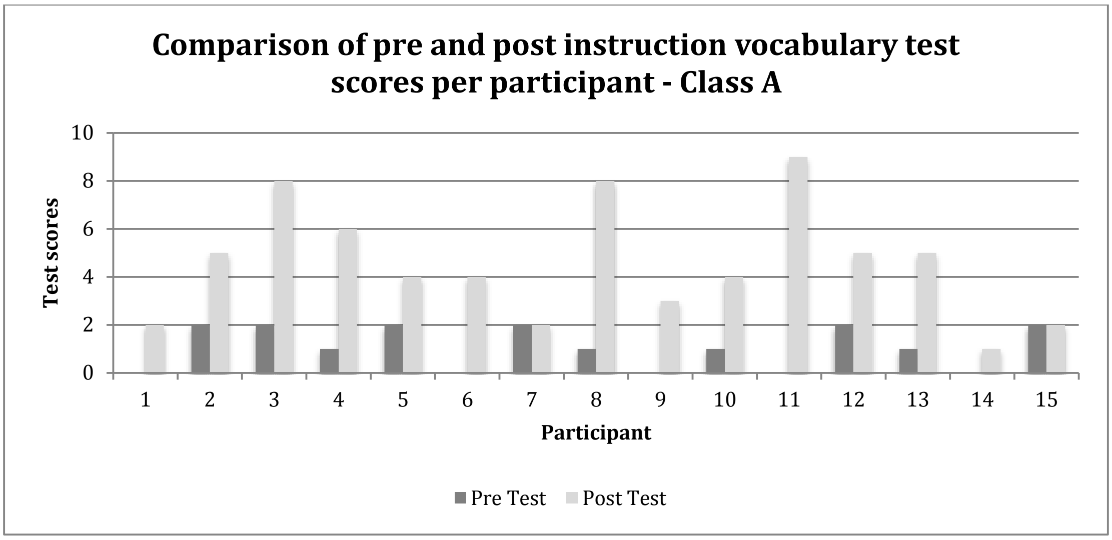


Figure 1. Bar chart showing the vocabulary test scores of Class A at the beginning and end of the 6-week instructional period at participant level.

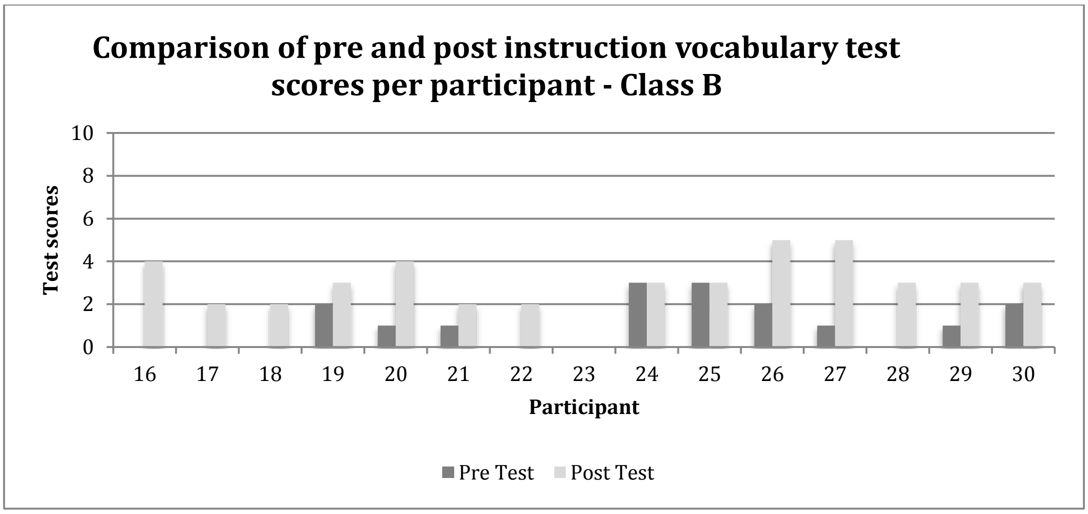
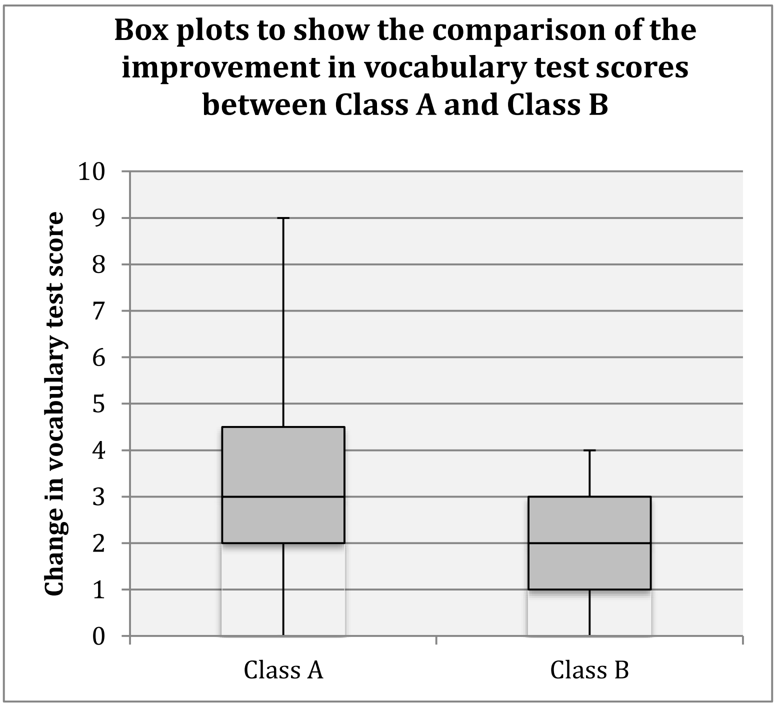


Figure 2. Bar chart showing the vocabulary test scores of Class B at the beginning and end of the 6-week instructional period at participant level.



Comparing the results of the vocabulary test scores of both classes, Class A made the greatest gains in vocabulary improvement, illustrated by the averages, although Class A's range of improvement was much broader than that of Class B.

Figure 3. Comparison of the improvement in vocabulary test scores over the 6-week instructional period.

Table 1. A comparison of class averages and measures of spread based on the improvements in vocabulary test scores.

	Class A	**Class B**
Mean	3.5	1.9
Median	3	2
Mode	3	2
Data points (n)	15	15
Minimum	0	0
Maximum	9	4
Range	9	4
Interquartile range	2.5	2
Variance	6.7	1.8
Standard Deviation	2.5	1.4

This amount of improvement in the vocabulary test scores appears to be related to the participants' reading ages; the product-moment correlation coefficient (r) is 0.55, indicating a weak positive correlation.

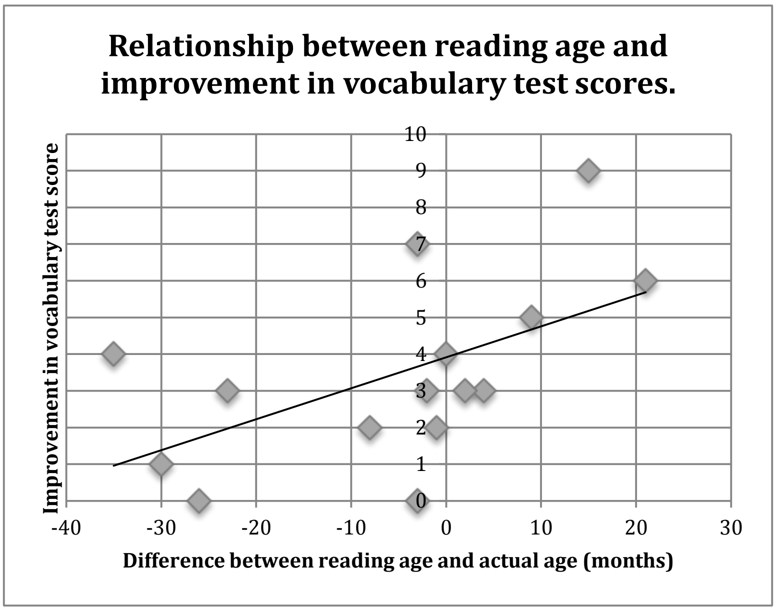


Figure 4. Scatter graph with regression line showing the correlation between the difference in reading age and actual age, and the improvement in vocabulary test scores.
Analysis of the questionnaire scores also shows a weak positive correlation with the vocabulary test scores (product-moment correlation coefficient, r = 0.48).

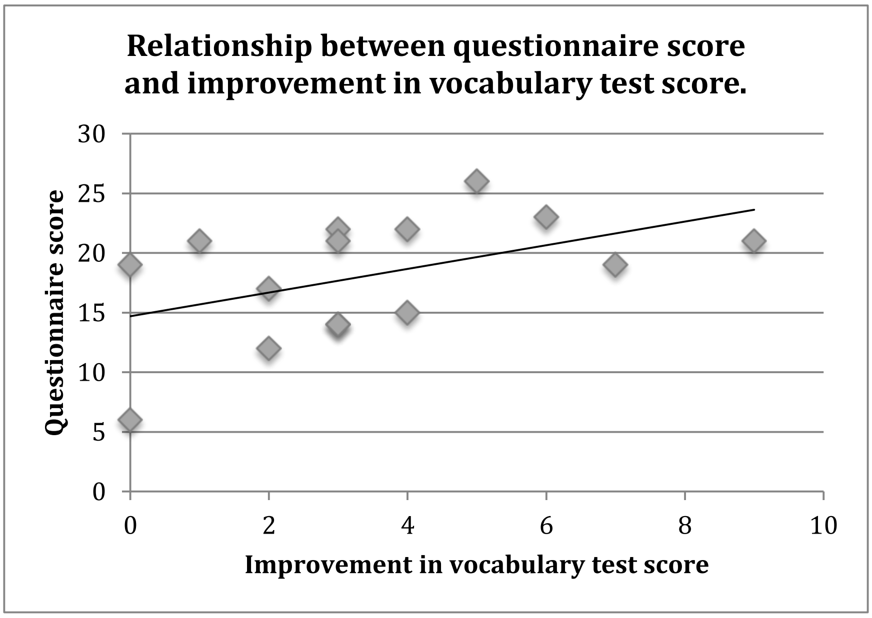


Figure 5. Scatter graph with regression line showing the relationship between the improvement in the vocabulary test score and the questionnaire score.

Finally, when comparing the results of both classes in the unit assessment, there is an insignificant difference in their scores, with Class A scoring a mean average of 54% compared with 51% in Class B. However, only a third of the total marks available in the unit assessment required knowledge of technical mathematical vocabulary; when analysing only these marks, Class A scored 66% compared to Class B who scored 48%.

Discussion

Overall, the use of the Frayer Model as a method of vocabulary instruction appears to improve the comprehension of technical vocabulary in mathematics, although greater gains are generally seen in students who engaged well with the model and who had higher literacy levels in terms of reading age. Participant 15, with a reading age of 26 months lower than their actual age, did not make any improvements between their pre- and post-instruction vocabulary test results, and scored only 6 on the questionnaire; additionally they commented that the model was not enjoyable, despite efforts to teach the students how to use and engage with the model, as recommended by Singleton and Filce (2015). At the other end of the spectrum, participant 3 has a reading age of 21 months higher than their actual age, and made an improvement of 6 marks on the vocabulary test; plus they recorded a high score of 23 in the questionnaire.

This may indicate that reading age has some impact on the effectiveness of this method. Indeed, Stanovich (2008) writes about the 'Matthew effect' whereby stronger reading comprehension leads to stronger vocabulary knowledge and vice versa. Marzano (2004) suggests that good vocabulary knowledge is due to a rich background knowledge, which would explain why some students struggled with completing the 'connections' section of the model, arguably the most important element for effective long-term retention and recall. This result is in line with the writings of Monroe and Pendergrass (1997) who warn that background knowledge is a success factor.

When considering the performance of the participants during the unit assessment, it was encouraging to see that the students in Class A scored significantly higher in vocabulary-rich questions than Class B, signalling that this purposeful vocabulary instruction has indeed lead to gains in academic achievement, although perhaps at the expense of learning other mathematical skills, shown by very similar overall assessment results between the two classes.

An interesting observation occurred when studying the definitions that participants gave of the mathematical word 'product'; prior to the vocabulary instruction, some students in Class A believed this word to be related to items that they would buy from a shop, and falls into the category of everyday words that take a different mathematical meaning, as Gough (2007) discusses. The interesting result from the post-instruction test showed that, even though the correct mathematical definition of 'product' was taught using the Frayer Model, some students still reverted back to their original, everyday definition in the test. This confirms that definitions in this subcategory of mathematical words do indeed cause problems for some students, and that the Frayer Model may not be the right tool to use for such vocabulary, an area of investigation worth researching in more depth in the future.

The broad range of improvement in class A may indicate that this is a more efficient and effective method of learning mathematical vocabulary for some students, yet it is not advantageous for all students, highlighting the fact that teaching needs to be as personalised as feasibly possible so as to enable all students to make their greatest potential progress.

Further Investigation

Although the result show a positive reflection of the model, further investigation would be needed to confirm that it is this model in particular that has provided the benefit, and not just the purposeful and increased time spent on vocabulary instruction. Some of the participants commented that they preferred using mind maps to learn vocabulary, finding them easier to produce and more helpful in recalling information, the positive aspect of this reflection being that mind maps too are a form of graphic organiser. In which case it may be conclusive that graphic organisers in general are beneficial, and students should be given the choice of which to use.

During my observations of students completing the Frayer model, I noticed that I could accurately use the model and the associated questioning, responses and general discussion as a method of formative assessment. Upon marking the students' work, I was also able to ascertain which students understood the concepts behind the vocabulary, as there was a marked difference in completed models, despite discussing the new terminology as a class; it may be worth considering their use as plenaries or exit cards in future.

Limitations

Many researchers describe the importance of discussion in using this model (Furner, Yahya and Duffy, 2005; Gough, 2007; Thompson and Rubenstein, 2014). In delivering this vocabulary instruction, I was aware that it was difficult to find enough time during lessons to implement it with the appropriate level of discussion required without sacrificing time used to practise the skills content. Indeed, one of the participants commented that they would have liked more time during lessons to discuss and complete the vocabulary model. However, with the new GCSE bringing a significant increase in content (Department for Education, 2013a), finding more time to teach vocabulary in maths lessons is increasingly difficult.

Another limitation of this study involves the validity of the reading ages; these were determined 4 months before I conducted the study, so may not have provided completely accurate reflections of reading comprehension ability of the participants. I endeavoured to mitigate any inaccuracies by comparing their actual age at the time the reading age was determined.

Conclusion

Vocabulary knowledge is a success factor in the mathematical achievement of students of all abilities (Aiken, 1972; Morgan, 1999; Schleppegrell, 2007). The language of mathematics has a complex structure with technically specific vocabulary that can form a barrier to achievement in lessons and assessments (Chinn, 2012; Gough, 2007), which is more of any issue now that the new GCSE tests problem solving to a greater extent (Department for Education, 2013a).

There is much evidence to show that the use of graphic organisers is a successful way to represent the elements of new mathematical vocabulary (Frayer, Fredrick and Klausmeier, 1969; Singleton and Filce, 2015), although Monroe and Pendergrass (1997) warn of their limitations with low ability students who may not have such a rich background knowledge.

The findings of this action research indicate that there is evidence to suggest that the Frayer Model of graphic organiser can have more success in a low-ability class than direct vocabulary instruction alone, as received by the control group. However, it may not be a method that all students engage with, and there appears to be a weak correlation here with a student's reading age, an indication of reading comprehension ability. Importantly, the findings confirm that this is not a method of vocabulary instruction that suits all students, and the teaching of vocabulary, like all other aspects of teaching, should be personalised as much as is feasibly possible.

An unexpected finding of the use of this model is its potential as a method of formative assessment. However, the model needs sufficient time to be completed, a resource that is in increasingly short supply in the mathematics classroom.

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