Developing Vocabulary in Mathematics with Children who are Deaf

A study submitted in partial fulfilment of the requirements for the degree of Master of Science / Master of Arts of the University of Hertfordshire

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Abbreviations

ANS approximate number system

BPVS British Picture Vocabulary Scale

CD Children who are deaf

CI Cochlear implants

ELL English language learners

NVIQ Non-verbal Intelligence Quotient

NVWM Non-verbal working memory

OLM Oral Language Modifier

SD standard deviation

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Abstract

This is a study of 41 secondary school children who are deaf (mean age 13 years 2 months) based in an oral setting. A list of key Mathematics vocabulary words was generated from the GCSE Mathematics 2007 specification exam papers. Assessments and intervention resources were created to support the teaching of these key words. A 5week intervention on the topic of 'Time vocabulary' was recorded. Subjects showed a significant increase in their vocabulary knowledge. Subjects with a higher baseline score made more significant progress. Controlling for gender or first language did not have a significant impact on vocabulary knowledge.

1. Introduction

As a qualified Special Educational Needs Coordinator and Teacher of the Deaf with a subject specialism in Mathematics, I work at a specialist secondary school for children who are deaf. The school follows an oral communication philosophy, maximising the use of any residual hearing. Sign language is not used for teaching in the classroom. The emphasis is placed on students being immersed in a language-rich environment. During a school drive on vocabulary, I realised it was important to place more focus on vocabulary in Mathematics. The subject has a large technical glossary and problem-solving questions are notoriously difficult for all students to answer. This has been made more difficult in the 2017 GCSE specification which has additional content and more problem-solving questions (Professional 2016). This is even more true for students who have delayed or disordered language difficulties due to deafness. I carried out an online search for materials to use to help teach Mathematics vocabulary. Those I found were mostly aimed at primary school students and only available for individual topics. There was nothing comprehensive for the secondary students I was working with, and nothing telling me which words were important. Instead, based on my teacher judgement, I wrote some simple Mathematics vocabulary assessments, testing words I considered important and largely unknown. These were welcomed by the team I worked with and we used them in this form for 2 years, revising questions as we went along. They were largely seen as a prompt to include these words in our teaching. Due to this initial success, I decided to develop the assessments into a complete intervention package based on robust research and decision making. I set out to find which words should be focussed on, design materials to support the teaching of vocabulary and track more closely which words students had learnt/still needed to work on. This research documents the development of the intervention, known as Count on Words, and evaluates the success of the intervention when one of the topics was taught to students in my setting. This project first looks at word selection and creation of the vocabulary assessment and then measures the success of a vocabulary intervention on a group of students in Years 8 and 9.

2. Literature review

2.1 Introduction

The literature review contains 5 sections. The first two sections look at the impact deafness has on language skills and then on mathematical attainment. This is followed by a review of how language skills interact with mathematical attainment. Finally, a review of the current approaches used to develop vocabulary and design vocabulary assessments. The term ‘children who are deaf’ (CD) is used to refer to a vastly heterogenous population. There are many variables which might lead to differences in vocabulary knowledge, including age of identification, level of hearing loss, level of maternal education, additional needs and first language (Yoshinaga-Itano & Sedey, 1998). Therefore, caution must be taken when drawing conclusions.

2.2 Impact of Deafness on Language Skills

Despite earlier identification with the Newborn Hearing Screening Programme and advances in technology such as digital hearing aids and cochlear implants (CI), for many CD language development is still behind that of their hearing peers. This has been widely confirmed for CD who have been identified early and where early intervention supporting language development has been in place (Sarant et al 2009, Vohr et al 2012, Lederberg et al 2013, Netten et al 2015 and more recently Meinzen-Der et al 2018). In a systematic review of studies, Lederberg et al (2013) identified the main areas of weakness for CD as the development of grammar, theory of mind and literacy. The size of vocabulary knowledge in CD, both expressive and receptive, is lower on average than their hearing peers (Lund 2016). This is true for size of vocabulary knowledge and the depth of understanding (Walker et al 2019). CI users learn new vocabulary in a similar way to hearing children when matched for vocabulary size, not age (Lund 2019). Vocabulary delay is a barrier to further language development through reading and writing. Language ability is a significant predictor in reading ability for CD (Mayberry 2011). Vocabulary is the biggest predictor in reading accuracy and comprehension for CD (Kyle and Harris 2010, Kyle et al 2016). A reduced vocabulary can also result in poor non-verbal working memory (NVWM) for CD (Marshall et al 2015). Worsfold et al (2018) found that the spoken language ability of CD aged 8 has a predictive relationship on their reading comprehension aged 17. This supports the case for continued targeted intervention of language skills in secondary education.

A language delay has a cascading effect on CD's subsequent development and life opportunities. Communication skills are linked to theory of mind (Lederberg et al 2013), social and emotional functioning, and behavioural problems (Netten et al 2015). CD aged 5, are behind age matched peers when identifying lies and sincere statements (Kelly et al 2019). In the UK, poor language and reading comprehension in CD aged 6-10 increased their risk of having emotional and behaviour difficulties in school during their teenage years (Stevenson et al 2018). Communication skills are also fundamental for the development of mathematical reasoning in CD (Kritzer 2009a; Edwards et al 2013). Mathematical and reading achievement of hearing children at the age of 7 has both substantial and positive associations with social economic status in adult life (Ritchie and Bates 2013). It is logical that this would also apply to CD and highlights the importance of this research.

Reduced vocabulary knowledge in CD has been attributed to many factors. Despite advanced amplification, CD do not receive consistent access to language and their experience is different to their hearing peers (Moeller et al 2015). CD do not overhear conversations clearly, they miss out on this opportunity to pick up new words vicariously and therefore need explicit teaching (Lund 2016, Duncan and Lederberg 2018). A rich language environment in the home is proven to have a positive impact on a child's language abilities (Vohr et al 2014). Maternal education (Cupples et al 2018, Walker et al 2019) and the level of parental involvement has a direct impact on language acquisition (Moeller and Schick 2006, Sarant et al 2009, Boons et al 2012). Strategies such as recasting, reformulation and open-ended questions promote growth in expressive language, whilst parental use of dialogue reading produces faster vocabulary development (Cruz et al 2012).

2.3 Impact of Deafness on Mathematical Attainment

In order to discover why CD underperform in Mathematics, it is useful to know when the difference in outcomes between deaf and hearing students begins. Many studies have attempted to understand this (Zarfaty et al 2004; Bull et al 2018; Hitch et al 1983; Leybaert and Van Cutsem 2002; Huber et al 2014). Number representation is the ability to recognise the number of objects and reproduce that number without having to know its name or assign an abstract symbol to it. It is an early mathematical skill that is usually learnt prior to starting formal education, through everyday life or accidentally through play. It does not require any language skill or taught additional mathematical knowledge to achieve it. In a small study designed to test number representation in CD, it was observed that they performed as well in the task as their hearing peers and they performed better when the task was presented spatially (Zarfaty et al 2004). This suggests that CD are at no initial disadvantage when it comes to number representation and difficulties arise later on, or in other areas. Bull et al (2018) studied approximate number system (ANS) acuity, a similar entry level mathematical skill that was tested without needing to know number names or symbols. Students were shown 2 sets of dots and they had to point out the bigger set, they did not have time to count them and the dots varied in size to avoid surface area being used as a determiner. In this study CD (with a mean age of 9 years) showed significantly less acuity than their hearing peers.

Counting between 1 and 20, forwards and backwards, including simple addition (e.g. add one more), is an Early Learning Goal (DFE 2017). This is the National Standard expected by the time a child finishes the Early Years Foundation Stage, aged 5. In a small study (Hitch et al 1983) designed to test the method of counting in orally educated CD, students were asked to mark simple addition problems as true or false, with no linguistic knowledge required. It was discovered that they had the same level of accuracy as the hearing children when matched by non-verbal intelligence quotient (NVIQ) rather than age. They also took the same amount of time to answer a question, suggesting they may use similar methods as the hearing children. Leybaert and Van Cutsem (2002), also investigated students' counting skills. Students aged 4-6years were asked to count as high as possible without any manipulatives to support them. The CD were all signers and used Belgian French Sign Language which has a base 5 counting system, despite the spoken language using a base 10 counting system. The CD produced a much shorter counting string, with the older signers still struggling to count beyond 15, on average. This placed them 2 years behind the hearing children. Errors were linked to when the CD had to go past each subset of 5 numbers, suggesting the difficulty was with their mode of communication. Interestingly, the same CD were also tested on one to one correspondence through object counting and creation of sets tasks (up to a maximum of 14). Here the CD performed in line with their hearing peers at an age expected level. Rodriguez-Santos et al (2018) found no difference in basic numerical skills between CD and hearing peers matched for NVIQ and verbal comprehension. Looking at slightly broader arithmetic skills, CD with CI aged 7-11, matched the performance of hearing children (Huber et al 2014). The test included addition, subtraction, multiplication, division, number comparison and complement tasks. The test was deliberately non-verbal, using numbers and mathematical symbols only, with no story problems. Caution should be taken here as the CD's scores were below the hearing students on all sub tests, but not significantly. This may vary with a larger sample size.

The following examples look at a broader selection of mathematical skills over a broader age range. Here, it is well documented that CD typically lag behind their hearing peers (Kritzer 2009a; Pagliaro and Kritzer 2013; Nunes et al 2009; Moreno 2000 and Edwards et al 2013; Ariapooran 2017; Borgna et al 2018). Kritzer (2009a), found over 60% of the CD studied (aged 4-6 years) had difficulties with story problems, skip counting, number comparisons, reading/writing 2- and 3-digit numbers, and addition and subtraction facts. In a similar study by Pagliaro and Kritzer (2013) with CD aged 3-5 years, they were found to be chronologically behind in number understanding, problem solving, measuring, estimating, time and sequences. Nunes et al (2009) investigated multiplicative reasoning, which is the foundation for place value and measurement. If the skill of multiplicative reasoning is not secure, it will have an impact on other areas of Mathematics. In its simplest form it is an introduction to problem solving. The study showed that CD students (with a mean age of 6 years 5 months) were significantly behind hearing peers in this area of mathematics, even when mapped for NVIQ not age. Moreno (2000) tested CD (aged 7-9 years) against their hearing peers across a wide range of mathematical competencies including counting, additive and multiplicative reasoning, memory scan and time concepts, and found them to be behind in all areas. Edwards et al (2013) tested CD (mean age 10 years) on arithmetic and geometric reasoning and likewise, found them to be behind matched hearing peers in both skills. Ariapooran (2017) matched female CD with their hearing peers for age and attainment. The CD had lower mathematical performance alongside lower mathematical motivation and higher anxiety. A study with older CD attending college, found that their ability to perform basic number processing skills such as comparing the magnitude of numbers, memorising digit order or simple calculations, was the same as hearing students (Epstein et al 1994). However, the average mean response time was slower in every task. In another study of college students (mean age 19), CD's abilities to estimate in numerical and real-world concepts were again significantly behind their hearing peers (Borgna et al 2018).

Mathematical ability is linked with NVIQ in deaf students (Leybaert and Van Cutsem 2002; Moreno 2000) as it is in hearing students (Huber et al 2014). When matched for NVIQ, CD, especially those with at last average NVIQ, have the same potential to achieve as children who are hearing (Geers et al 2003, Maller and Braden 2011). However, we know that deaf students are behind their hearing peers mathematically (Kritzer 2009a; Moreno 2000; Pagliaro and Kritzer 2013; Edwards et al 2013). We also know that deaf students are typically delayed in achieving their linguistic ability (Lederberg et al 2013; Netten et al 2015; Meinzen-Der et al 2018). It makes sense that this, in turn, delays their mathematical ability (Leybaert 2002; Huber et al 2014). In order for a student to achieve their mathematical potential they must achieve their linguistic potential (Huber et al 2014).

2.4 Impact of Language Skills on Mathematical Attainment

Studies into educational outcomes in hearing children around the world have also found language skills and vocabulary knowledge to be contributing factors to mathematical success (Bleses et al 2016, Singer et al 2018, Aragon et al 2019, Purpura and Ganley 2014, Pimperton and Nation 2010). Expressive vocabulary scores of hearing children as young as 16 months is an early measure of language development, whilst showing a greater correlation with language and literacy achievement, it was also linked to mathematical skills (Bleses et al 2016). Singer et al (2018) found language skills, specifically vocabulary and phonological processing, were the biggest predictors in the performance of arithmetic calculation in hearing children, when compared against working memory and the ANS. A study with hearing 4year olds in Spain, found working memory had the biggest impact at the early years stage, followed by processing speed and receptive vocabulary (Aragon et al 2019). Purpura and Ganley (2014) found vocabulary to be a significant predictor of numerous early mathematics skills in hearing children, including number comparison, number order, numeral identification, and story problems. Pimperton and Nation (2010), investigated the mathematical ability of poor comprehenders in hearing children. These children, aged 7-8, had average or above average word reading skills and were matched by age and NVIQ with age appropriate comprehenders. The poor comprehenders actually scored higher on average than their matched controls on the numerical operations test (although not significantly) but performed at a significantly lower level on the mathematical reasoning test. Their vocabulary score was a significant predictor of mathematical reasoning. Conversely, Chow and Ekholm (2019) in a study on 6-7year olds in the USA, found understanding of syntax was the greatest predictor of Mathematics performance and actually ruled out vocabulary as a predictor. However, in order to evaluate vocabulary, they used a receptive vocabulary test that was not Mathematics specific, plus the Mathematics assessment was based on calculations and problems with digits and symbols and so did not rely on vocabulary knowledge to complete it.

From an early age, mathematical delay in CD can be attributed to a lack of exposure to mathematical concepts and language in the home (Kritzer 2009b), regardless of the mode of communication or its fluency. In a study involving 6 CD, activities, interaction and engagement over a full day was recorded for each child. The quality and quantity of references to Mathematics concepts in the home was greater for the 3 CD who were more mathematically successful. The CD were purposefully involved in the conversations and expected to contribute. This deliberate engagement in mathematical conversation is important as we know CD are less likely to overhear conversations for example, about the speed of a car or the weight of the shopping. Interactions with a questioning nature promote participation and interest from the CD. Parents of CD have been known to limit their interactions to simple, concrete exchanges where a fixed answer is all that is required (Moeller and Schick 2006). Concrete language does not promote the development of higher-level thinking skills such as comparison, evaluation and prediction which are required for developing theory of mind and early mathematical thinking.

A statistically significant correlation between mathematical ability and reading age has been found in CD aged 9-14 (Vitova et al 2013), and deaf college students (Kelly and Gaustad 2007). When Edwards et al (2013) controlled their results for language ability they found that the difference in results between the hearing and CD disappeared, suggesting that it was the language skills that affected poor performance, not Mathematics skills. When investigating the predictors of early reading skill of CD aged 5, Cupples et al (2013) found that NVIQ and receptive vocabulary were predictor variables for mathematical reasoning. Moreno (2000), found the main predictors of mathematical delay in CD was linguistic ability and additive reasoning. Huber et al (2014) designed a study to look at possible predictors of arithmetic skills such as reading skills, NVIQ and hearing variables. Hearing variables had no impact on arithmetic skills but speech perception (of sentences) was significantly related to NVIQ. The biggest predictor of arithmetic achievement for hearing children was NVIQ, but they found that reading skills had the biggest impact for CD (despite the arithmetic test being non-verbal). Even when language skills were not being tested, they may have been required originally in order to learn the arithmetic skill.

Swanwick et al (2006) compiled an interesting evaluation of Mathematics exam papers undertaken by 14year olds in the UK. They analysed a sample of papers completed by CD and compared it to the analysis on all papers compiled by the exam board. Several conclusions and areas for further investigation emerged. The first of those relevant to this study was CD's lack of understanding of key vocabulary concepts including 'more than', 'less than' and 'how many more'. The second was the ability to determine the key technical information in the instructions which was embedded in a language-rich context. Students with weak reading ability perform better when Mathematics questions require limited reading, contain no difficult vocabulary, and use clear, simple diagrams (Crisp 2015).

2.5 Developing Vocabulary

Studies on teaching academic language to CD are relatively infrequent or based on small sample sizes. The conclusion from a systematic review (Strassman et al 2019), was that research into English language learners (ELL) should be used to inform teaching academic language to CD. In a review study of vocabulary teaching, Manzo et al (2006) found that developing and using a systematic plan for teaching vocabulary throughout the year maximized and facilitated improved understanding of essential vocabulary for students, particularly ELL.

Lund and Douglas (2016) devised a study to compare different methods for teaching new vocabulary to pre-school CD. Teachers of the Deaf were trained to apply the interventions with 9 CD over 6 weeks, focussing on 3 types on instruction. They found children learnt the most words through explicit teaching. Follow-in labelling had the second biggest impact, where the child's own interest directed which words were taught. Incidental exposure with no direct teaching had the least impact. In a larger study of 68 CD, Duncan and Lederberg (2018) also found explicit teaching to be a significant predictor of gains in vocabulary. Reformulation, where the adult expands on the CD's utterances, was another significant predictor. This study involved children taught in a group setting and showed that explicit teaching and recasting can have an impact in a typical classroom environment. A study in Northern Ireland with five Year 1 classrooms with children who were hearing, promoted early mathematical vocabulary instruction through a resource called Number Talk. A picture book was specifically written for the intervention to facilitate explicit teaching of early number vocabulary (Moffett and Eaton 2017). A key finding from the study was that the teachers involved demonstrated an increased awareness of the importance of mathematics vocabulary and indicated that changes in classroom practice had supported children's language and learning.

The research and advice around teaching mathematical vocabulary, unsurprisingly overlaps in its findings with teaching vocabulary to CD. In a review study of research-based evidence on mathematical vocabulary, Riccomini et al (2015) recommends explicit instruction, connections to prior knowledge, use of visuals, multiple exposures over time, games like activities, mnemonics and use of technology. CD are more likely to recall Mathematics words that are familiar or are strongly linked to an image, and concrete terms are easier to remember than abstract ones (Lang and Pagliaro 2007). Lund and Douglas (2016) used pictures or objects to support all 3 types of instruction in their study discussed above. A picture racetrack game using photographs was shown to improve signed vocabulary acquisition for two pre-school CD (Davenport et al 2017). An intervention on Mathematics vocabulary for CD aged 10-12 using DVDs with American sign language found that, combined with pre-teaching, the DVDs supported the acquisition of target vocabulary (Cannon et al 2010).

Rubenstein and Thompson (2002) describe 11 different difficulties associated with learning mathematical language. They were considering the difficulties for all language learners; it would be fair to assume that the impact on CD would be greater.

(1) meanings are context dependent (e.g., *foot* as in 12 inches vs. the *foot of the bed*)

(2) mathematical meanings are more precise (e.g., *product* as the solution to a multiplication problem vs. the *product* of a company)

(3) terms specific to mathematical contexts (e.g., *polygon, parallelogram, imaginary number*)

(4) multiple meanings (e.g., *side* of a triangle vs. *side* of a cube)

(5) discipline-specific technical meanings (e.g., *cone* as in the shape vs. *cone* as in what one eats)

(6) homonyms with everyday words (e.g., *pi* vs. *pie*)

(7) related but different words (e.g., *circumference* vs. *perimeter*)

(8) specific challenges with translated words (e.g., *mesa* vs. *table*)

(9) irregularities in spelling (e.g., *mode and modal*)

(10) concepts may be verbalized in more than one way (e.g., *15 minutes past* vs. *quarter past*)

(11) students and teachers adopt informal terms instead of mathematical terms
(e.g., *diamond* vs. *rhombus*).

2.6 Vocabulary Assessments

Vocabulary can be assessed in different ways. A receptive vocabulary assessment can ask students to point to a picture, e.g. the British Picture Vocabulary Score (BPVS), in response to a spoken word. This approach relies on hearing the word which may not be appropriate for CD. Assessments for signed receptive vocabulary may use pictures or video recordings as part of the test e.g. DCAL assessment. Expressive vocabulary can be assessed through the written, spoken or signed word in response to pictures or questions.

Read and Chapelle (2001) conducted a review study of vocabulary assessments and their use for ELL in American classrooms. They describe vocabulary assessments in three dimensions: discrete or embedded; selective or comprehensive; and context-independent or context-dependent. Vocabulary assessments traditionally test the learner's knowledge of (discrete) pre-selected high frequency words (selective). They are often presented with no linguistic context (context independent). Read and Chapelle (2001) warn that ELL teachers may avoid these types of traditional vocabulary assessments because they are not relevant to any curriculum content. They advise that tests should be designed with purpose and context, giving learners and teachers an incentive to engage. Dougherty Stahl and Bravo (2010) also noted that teachers felt let down by standardised tests, because they didn't test the vocabulary their students had learnt or the depth of students' knowledge. They suggest teachers should be confident in designing their own vocabulary assessments, starting with a list of words that are essential for understanding curriculum content. These words are likely to come from other curriculum assessments, such as national qualifications. The words should be pre-tested, explicitly taught and used throughout the teaching of the topic and then post-tested. After a thorough search, one Mathematics vocabulary assessment was found to exist (Powell 2017). This was based on words that were found on the grade 3 and 5 USA Mathematics curriculum (age 7 or 9 years) and in commonly used textbooks. Many of these terms were initially introduced lower down in the curriculum. They used a variety of student response methods including matching definitions from word banks, multiple choice, drawing pictures and using short answers.

3. Method

3.1 Methodology

This is an action research project. This approach is commonly used in education and health care settings where practitioners can use small scale research to directly impact their work. It follows a cyclical approach of action and critical reflection (Thomas 2013). Research is usually completed alongside other work commitments which can put pressure on the practitioner's available time. Establishing a control group can also be difficult for ethical reasons.

This study used primary sources and quantitative methods. Data was collected on vocabulary to inform the production of a vocabulary assessment. The intervention was a before and after study in which the dependent variable, the performance on a Mathematics vocabulary assessment, was measured before and after intervention on the same group of CD.

3.2 Vocabulary Selection

The objective was to produce word lists for the 14 different topics that the Mathematics curriculum is divided into in my setting. This would then promote systemic vocabulary teaching. These topics are: Time; Angle and Shape; Sequences and Graphs; Number skills; Calculations; Fractions; Algebra skills and Equations; Probability; Statistics; Transformations; Perimeter Area and Volume (PAV); Decimals; Percentages; Ratio and Proportion. Each list would be 15 words long to allow room for students to progress each year and to provide flexibility and differentiation. For example, for a student with a short concentration span or slow processing speed it may be more appropriate to only give them a section of the test. This meant we needed a list of 210 technical Mathematics words.

Mathematics has a vast glossary of technical terms and it’s hard to know which are more important. Some words are only used for high level Mathematics skills, some are cross-curricular, and some are frequently used outside of the classroom. In order to assess and teach a relevant list of vocabulary, a framework was required. GCSEs are ~~a~~ nationally recognised qualifications that almost all students will sit in the UK and are used in my setting. They are used as a benchmark for employers and further education providers. Students who don’t pass GCSE Mathematics will continue to receive Mathematics lessons until they either pass the GCSE or finish their compulsory education. Mathematical vocabulary that will be needed at GCSE level, is introduced from birth through the Early Learning Goals. It was therefore considered that the vocabulary used in the GCSE Mathematics qualification would be an appropriate framework for selecting the words for this intervention programme. At this setting, the aim is for all students to achieve a grade at GCSE Mathematics. All students start on the GCSE curriculum from Year 7 (approximately age 11). It is not always realistic for their target to be a pass at grade 4, but if they can achieve any grade of 1 or above, they will be entered for the qualification. By using a list of vocabulary that needs to be understood and used in the GCSE Mathematics exam, staff can better prepare the students to access the information in GCSE questions.

I contacted the exam board and requested a list of technical words. However, they were only able to provide a list of command words. So, I started the process of analysing past exam papers. At the time of investigation, there had been 5 series of examination papers released under the new 2017 GCSE Mathematics specification.

Students can take the qualification at Higher or Foundation level and there are 3 papers at each level. This gave a total of 30 papers to investigate. As the last few questions on the Foundation paper were also the first few questions on the higher paper (approximately 8 questions) these were counted separately so the total word count could be found without including duplicates. Only papers written by Edexcel were looked at, as this was the examination board used at the setting.

Every word used in each of the 30 GCSE papers was recorded and the frequencies tallied. The rubric used in an exam paper can be categorised as command words, carrier language and technical language. Not all these words needed to be considered for the intervention. Command words e.g. complete or explain were not included as these are common to other subjects. Carrier language is used to hang the sentence together, it can also be thought of as general knowledge e.g. charity or satsuma. These are words that can be changed by an Oral Language Modifier (OLM) and so were not included. Students with particularly low language levels who needed this support, could receive and OLM as part of their exam access arrangements. The Mathematics words number, counter, shape, space and cube (as in counter) were treated as general knowledge and so not included. Only technical language was included in the word count and it was recorded every time it appeared in a question or diagram. Words were counted separately unless separating them changed their meaning e.g. the words ‘cumulative frequency’ when separated into ‘cumulative’ and ‘frequency’ have the same meaning, but when ‘frequency tree’ is separated ‘tree’ loses its mathematical meaning. Common variations of words were grouped together including plurals and different tenses e.g. high/higher/highest and pay/pays/paid. Several words had more than one meaning which had to be counted separately e.g. square the shape and square the number. Words which would be taught as a group were also counted as a group, e.g. Monday, Tuesday, Wednesday etc. This complexity in categorising words meant the process could not be done by a computer programme and had to be counted in person.

This produced a list of 390 technical Mathematics words. The words were ordered first by the number of papers they appeared on and second by their total frequency. In this way, a word that appeared once on ten different papers would rank higher than a word that appeared on one paper ten times. I had originally thought I would be able to differentiate words based on whether they came from the foundation or higher GCSE papers. However, there wasn't a clear correlation between the frequency of a word and its difficulty e.g. graph appears 76 times in total and 61 of those are on the higher paper despite it being a word typically first taught at primary level. 17 words appeared on higher papers only. Of these, 11 words related to foundation topics and therefore it was important that they were included. That left 6 words that only appeared on the higher papers and only related to the higher GCSE specification. These words all related to statistics: quartile, histogram, box plot, cumulative, bound and upper. Statistics is a difficult topic because of the heavy word content. It was therefore decided to include these higher-level words in the word list, to increase exposure to them. This would also avoid the ceiling affect for more able students.

The GCSE specification divides the subject into 5 areas: Number; Algebra; Statistics & Probability; Geometry & Measures; and Ratio, Proportion & Rates of Change. In my setting, these 5 categories are then broken down into the 14 smaller topic areas stated above, to form the scheme of work. Initially, I assigned the words to each topic in order to collect the 15 most frequent words. However, some topics had many more words than others e.g. Statistics, and Angle and Shape. High occurring words were not making it into the top 15, whilst less frequent words were being included because the topic wasn't as language heavy, e.g. Fractions or Algebra. Instead, I prioritised the top 210 words regardless of their topic area. For the full list of key Mathematics vocabulary see Appendix A.

There were many words that linked to money and finance. This is due to the questions in GCSE Mathematics papers being linked to real world situations. These were assigned to the decimal and percentages topics. It was surprising how many words relating to imperial units were counted. This was unexpected as imperial units had been removed from the 2017 curriculum. The words appeared in questions relating to ratio and proportion. For example, the conversion between miles and kilometres would be given and students then asked to do further calculations based on the information given. This highlights the importance of exposure to these words. Without this word count these words may not have been given much importance.

3.3 Creating Vocabulary Assessments

The original vocabulary assessments had been used at the setting with Key Stage 3 students for two years prior to this research. The format had worked well, with minor flaws ironed out over time and it was therefore considered sensible that the format was kept the same. Not all the original words remained after the vocabulary selection process. Successful questions from the originals were retained. We had also increased each topic assessment from 10 to 15 words. As the vocabulary selection process did not inform the difficulty of the words, they were listed based on professional judgement and the order they first appear on the Mathematics curriculum.

The vocabulary assessments were going to be embedded into the scheme of work as part of our regular topic testing. We wanted them to be a quick snapshot of vocabulary knowledge, easy to complete and easy to mark. We ruled out writing the definition of the word or using the word in a sentence for several reasons. Although this would give an in-depth picture of vocabulary understanding, it would be limited by language ability. Secondly, it would be time consuming to complete, which would have a negative impact on the participant. Finally, it would also be time consuming to mark and marking would be subject to interpretation. Instead, we decided on a cloze-procedure format. I wrote a question that required a one-word answer; the key word that we were testing. Subjects had to demonstrate their knowledge by reading the sentence (or having it read to them) and expressing the missing word. The first letter of the word was given to prevent ambiguity as there are many synonyms in Mathematics, creating more than one potentially correct answer. Originally there were two types of question used. Those that had the key word missing from the sentence and those where the key word was the answer to the question. On advice taken from the Speech and Language therapy department, in order to make comprehension of the assessments easier, only the type of question where the key word was missing would be used. The questions were written with simple language to support understanding for those with low reading ability. Any names and scenarios were common to the subjects. Only vocabulary knowledge was required to answer the questions, mathematical knowledge did not have to be applied. Where possible, other key Mathematics terms were not included in the question. Subjects expressive knowledge of the words being tested. However, when students complete GCSE papers, they would require receptive knowledge of the vocabulary. As expressive knowledge is a harder skill than receptive knowledge, this was considered an appropriate approach. If students can express the word, then they should understand it receptively in a GCSE question.

Year 7 students (not included in the study) were given the assessments to complete as a pilot. From this I learnt that several questions had to be changed. For example, in the question **the opposite of longest is s…** many students answered **smallest**. While this wasn't the word that was being tested, as **shortest** is the opposite, it was a reasonable answer to the question. Students had clearly understood the intent of the question. If this was a Mathematics question (as opposed to a vocabulary question) they would be able to apply the skill of finding the opposite of **longest.** The shortest or the smallest object are likely to be the same answer in this situation. This question was corrected by stating **(not smallest)** at the end of the question.

3.4 Recruitment

All Year 8 and Year 9 students were eligible for recruitment into this study. Students for whom baseline and final assessment scores were available, and who received the intervention were included in final analysis.

3.5 Intervention

Only one of the 14 Mathematics topics was going to be used in the intervention period. The Mathematics scheme of work at the setting was teaching the topic of Time so it was agreed that the intervention would also focus on Time words. This would increase exposure to the vocabulary and allow subjects to apply the words in context during their Mathematics lessons. The intervention was named Count on Words to provide subjects and staff with a frame of reference. The intervention consisted of 5 x 20minute sessions on the topic of Time. One session was delivered each week. The sessions were delivered by Mathematics teachers and supported by speech therapists. The Mathematics teaching team included 3 Qualified Teachers of the Deaf, 1 Teacher of the Deaf in training, and a non-specialist teacher providing maternity cover. Every effort was made to minimise disruption. The intervention ran during a timetabled Mathematics lesson. The intervention was not a replacement of the normal curriculum teaching but provided additional vocabulary support. Subjects were kept in their normal Mathematics sets, in their normal classrooms with their normal Mathematics teacher. The groups were set by mathematical ability, with 5-7 students in each set. Each year group consisted of 4 sets with a teaching assistant supporting sets 3 and 4.

All subjects were given the Time vocabulary assessment (Appendix B) at the beginning of their first session to gain their baseline data. This tested their knowledge of the 15 most frequently occurring words in the GCSE on the topic of Time, as collated previously. Teachers marked the baseline tests for their own groups following clear guidelines. When marking the tests, 2 marks were given for a completely correct answer, 1 mark for a clear intention of the correct word with a spelling or word variation error (e.g. day instead of days), or 0 marks if their answer was wrong or no attempt was made. Once marked, these results were not shared with the subjects to prevent them becoming over familiar with the assessment questions.

The teaching resources for the intervention were designed to promote exposure and repetition to the topic words both expressively and receptively. Activities included work on understanding definitions, spellings and memory. They were designed to capture subjects' interest with visuals, jokes and games. All sessions started with an activity that was on the desk as subjects walked into the classroom. This was to focus the subjects' attention immediately on the lesson and mediate any issues caused by lateness. For session 1 this was the baseline test. In session 2 this was a card match activity (Appendix C), session 3 was a word scramble (Appendix D), session 4 was a word search (Appendix E), and in the final session subjects were given a blank page to write down all the Time words they could think of. After this task, each session included a discussion picture (Appendix F). These pictures linked the topic to other school subjects to encourage links with Mathematics outside of the classroom. This included a picture of the melting Dali clock (art), a sun dial (history), a time travel machine (science, media), analogue and digital clocks (technology) and a world record (sport). During the discussion the teacher was encouraged to use topic words frequently. The main activity promoted the understanding of the word. In the first session, subjects played Kim's Game, which is a memory game using images and words. This is an opportunity for the teacher to explain the definitions and start to create links. Some words are very hard to depict in visual form, such as seconds or minutes, here a clock was used with the word written underneath. One of these pictures is removed and subjects have to try and remember what it was. In the second session the teacher selects one of the topic words to focus on (based on the information gained from the baseline assessment). The Word Wizard (Appendix G) is used to support explicit teaching of the word, including how it is said, spelt and what it means. In session 3 subjects played Bingo, where they are only given the pictures and have to remember the matching words. In session 4 the main activity is called Thinking Hat. Subjects have to work out which topic word the teacher is thinking of by asking questions. Session 5 is based on recall; subjects play Last One Standing where they have to think of as many words as possible in the topic. All word variations are allowed. Every session includes a joke related to the topic.

Subjects are asked to guess the punchline. At the end of the session they take part in a game: I went to the market (memory); hangman (spelling); bleep (understanding); concentration (memory); and finally, in week 5, they complete the assessment again.

It would not be appropriate for all subjects to do identical interventions due to the wide ability range. Worksheets and games were adaptable e.g. word scramble could have the word box removed to make it harder. Teachers used their knowledge of the children to adapt activities appropriately and differentiate each week. The final task after 5 weeks was to administer the vocabulary assessment again to ascertain if there had been any progress.

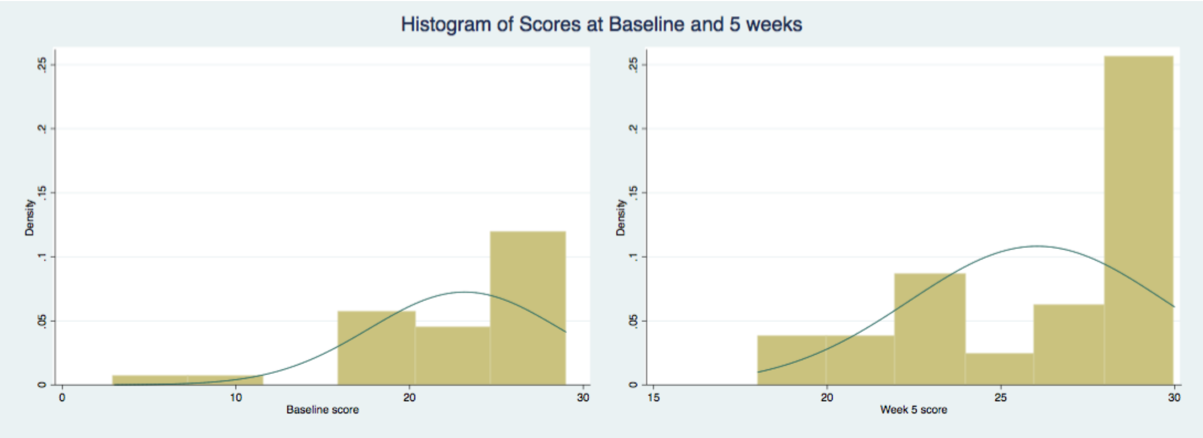
3.6 Ethics

Data was collected as part of the settings routine procedures and as such there are no individual consent forms. Consent was sought from the setting to use the data gathered in this paper. Ethical approval was granted by the Research Ethics Committee, University of Hertfordshire. See Appendix H for copies of the approved documentation.

3.7 Statistical Analysis

Data were entered using Microsoft Excel and analysed using STATA version 14 (Stata Corporation, College Station, TX, USA). Initial tests for data normality were conducted using the Shapiro Wilk test for data normality (histograms of data are shown in figure 3.1). Based on non-normality of the data, non-parametric (robust) statistical methods were used which do not assume normality of data. Correlations were tested using Spearman’s and equality of distributions of the different groups was tested using the Wilcoxon Mann Witney test. A p value of 0.05 is considered to represent strong evidence to reject the null hypothesis of no difference between the groups.

Figure 3.1 Histogram of Scores at Baseline and 5 weeks



4 Results

4.1 Subjects

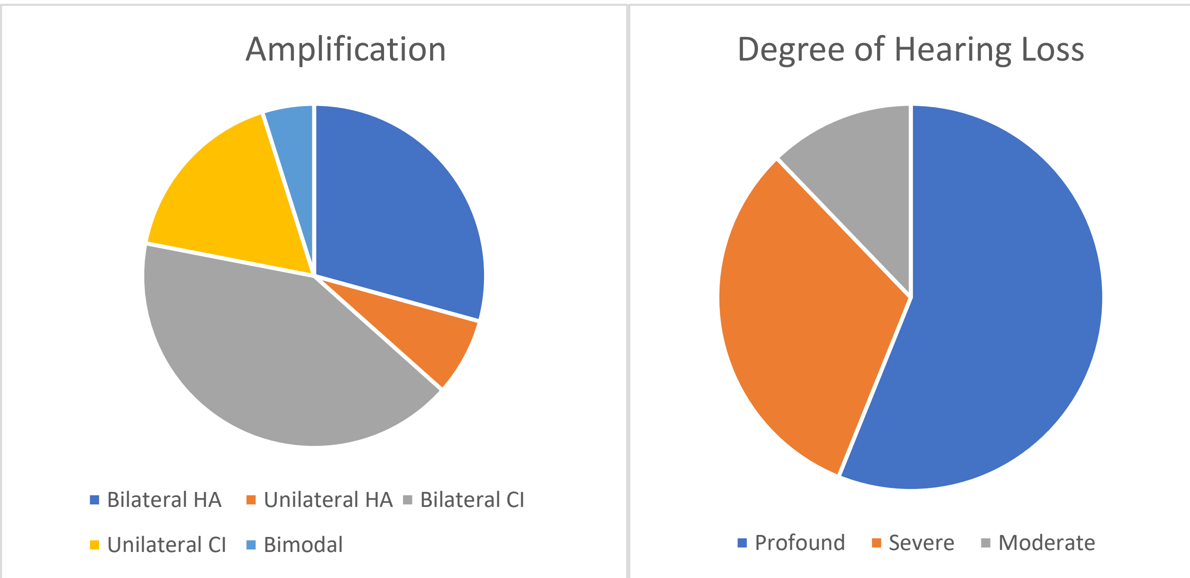
	Year 8	Year 9	Total
Number of participants	22	19	41
Mean age (years: months)	12: 7	13: 11	13: 2
Number female	12	10	22
Number spoken English	17	13	30

Table 4.1 Subjects' characteristics

All 48 students at the setting in Year 8 and Year 9 were recruited as subjects for the intervention. Five subjects were absent during the baseline process. They were present for the intervention and completed the final vocabulary assessment, but their results were not included. One subject left the setting during the intervention period and another did not attend at all. One new student joined the setting during the intervention period but as he had not completed the baseline his results were not included. Complete results were obtained from 41 out of the original 48 subjects.

Of the 41 students included in analyses ages ranged from 12 years 2 months to 14 years 2 months, with a mean age of 13 years 2 months. 22 subjects were in Year 8 and 19 subjects in Year 9. There were 22 females and 19 males. They had a variety of audiological needs and assistive equipment as outlined in figure 4.1 below. 15 subjects use HA only, 24 have CI only and 2 are bimodal. Hearing loss ranges from moderate (12%) to profound (56%).

Figure 4.1 Subjects' Audiological Profile



All subjects were on a pathway to study GCSE Mathematics with targets ranging from grade 1 to grade 7+. 33% of subjects had special educational needs in addition to their hearing impairment. These included visual impairment (VI), specific language and communication need (SLCN), auditory neuropathy spectrum disorder (ANSD), specific learning difficulty (SpLD) and social emotional and mental health needs (SEMH). Figure 4.2 shows the distribution of additional needs.

Figure 4.2 Subjects' Additional Needs

All subjects attend a specialist secondary school for children who are deaf. The setting has an oral communication philosophy and the intervention was delivered orally, in keeping with this. All subjects attended this setting regularly. When asked about their preferred communication mode subjects cited spoken English or a signed approach (Sign Supported English and British Sign Language) as their first languages, figure 4.3. Any further reference to sign includes both of these approaches.

Figure 4.3 Subjects First Language

In order to gain a profile of the subjects' general vocabulary knowledge we used their scores from the BPVS II. This assessment is administered by the speech and language therapy department to assess subjects' receptive vocabulary knowledge. The subject must listen to a word and then select a picture from a choice of four. Their answer requires a non-verbal response which removes any difficulty with clarity of speech. However, the assessment is delivered orally which is difficult for subjects who don't have access to speech sounds and rely on lip reading. Subjects may request the written form of the word, but the assessment is not standardised for this. A standardised score of 100 represents the absolute average and standardised scores 85-115 are within the average range; 68% of the population. Scores between 70 and 130 represent 95% of the population. It is important to mention that this assessment is standardised on the hearing population and therefore the results must be interpreted with caution. There is no English vocabulary test standardised on the deaf population. An overview of subjects' reading abilities is indicated by the Access Reading scores. Access Reading is the assessment used at the setting to establish students with low reading levels who will need access arrangements for exams.

Again, this assessment in standardised on the hearing population. Figure 4.4 includes information about the subjects' language profile.

Figure 4.4 Subjects' Language Profile

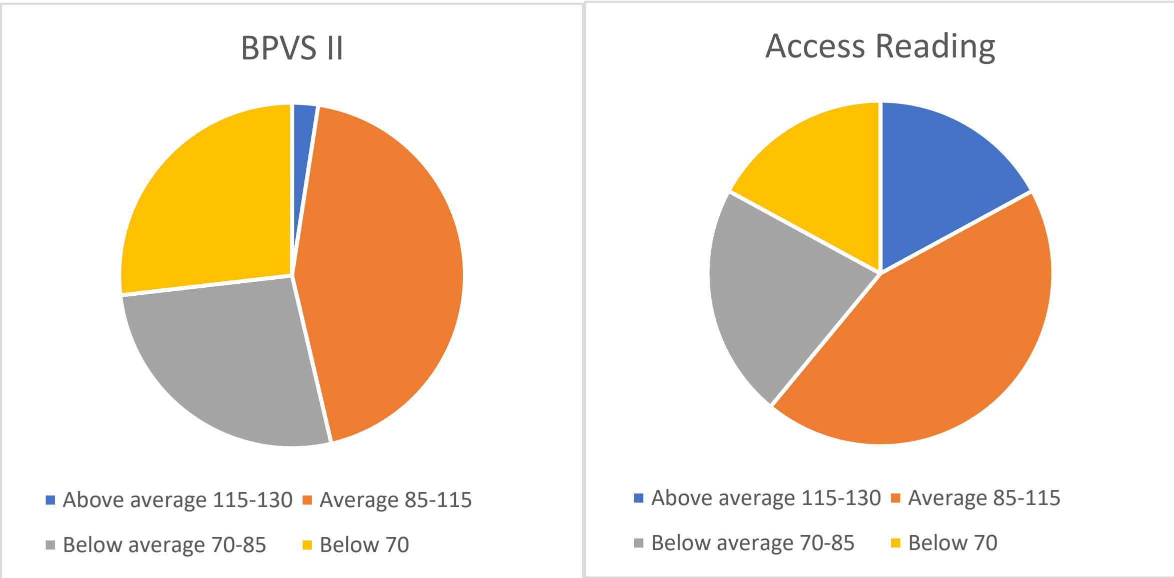
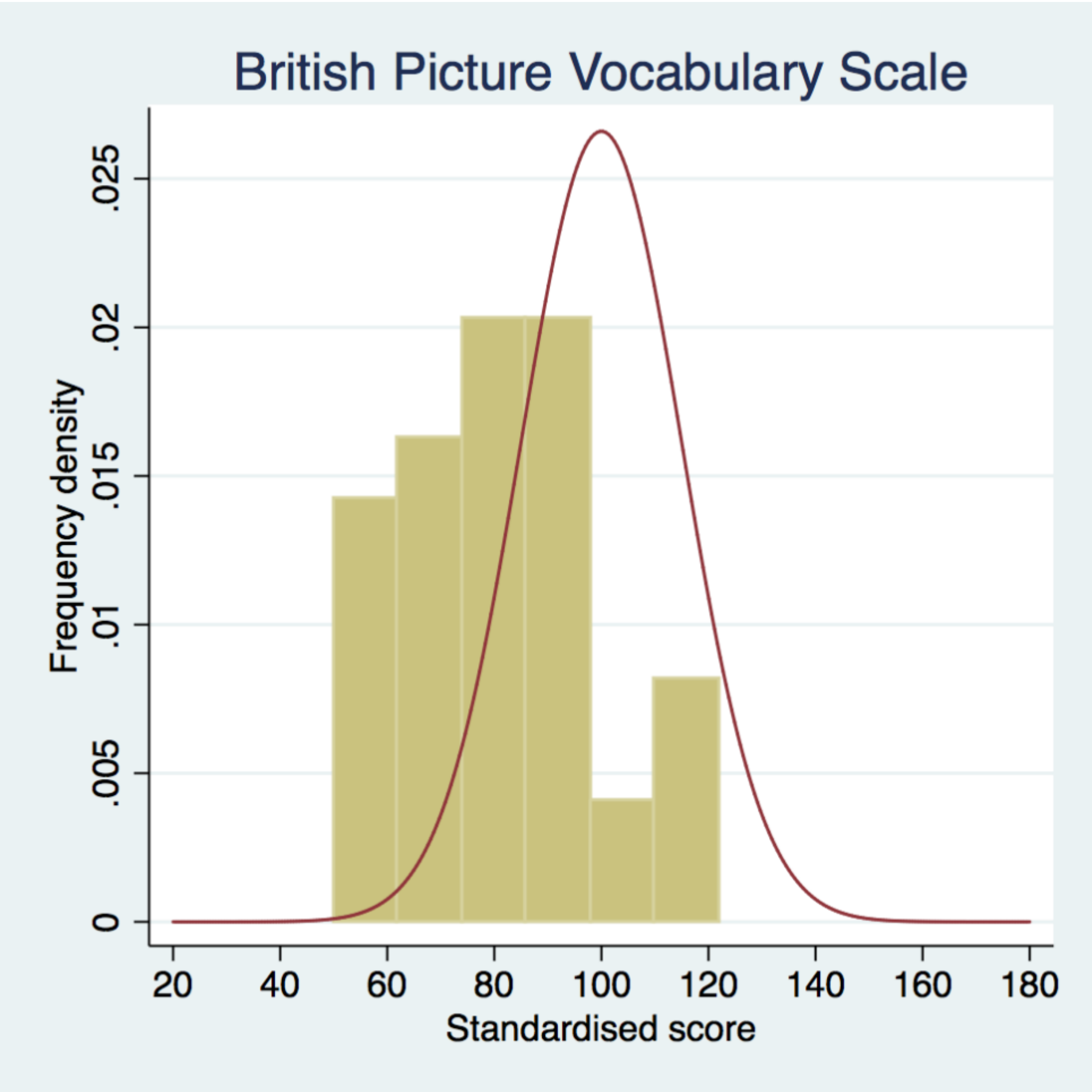


Figure 4.5 shows the distribution of subjects' BPVS scores. 27% of the subjects scored below the standardised score of 70 on the BPVS compared to the 2.5% expected nationally. No subjects scored in the top 2.5%. The red line represents a normal distribution of score 100, sd 15 (100 being the BPVS average).

Figure 4.5 British Picture Vocabulary Scale scores for all participants (n=41)

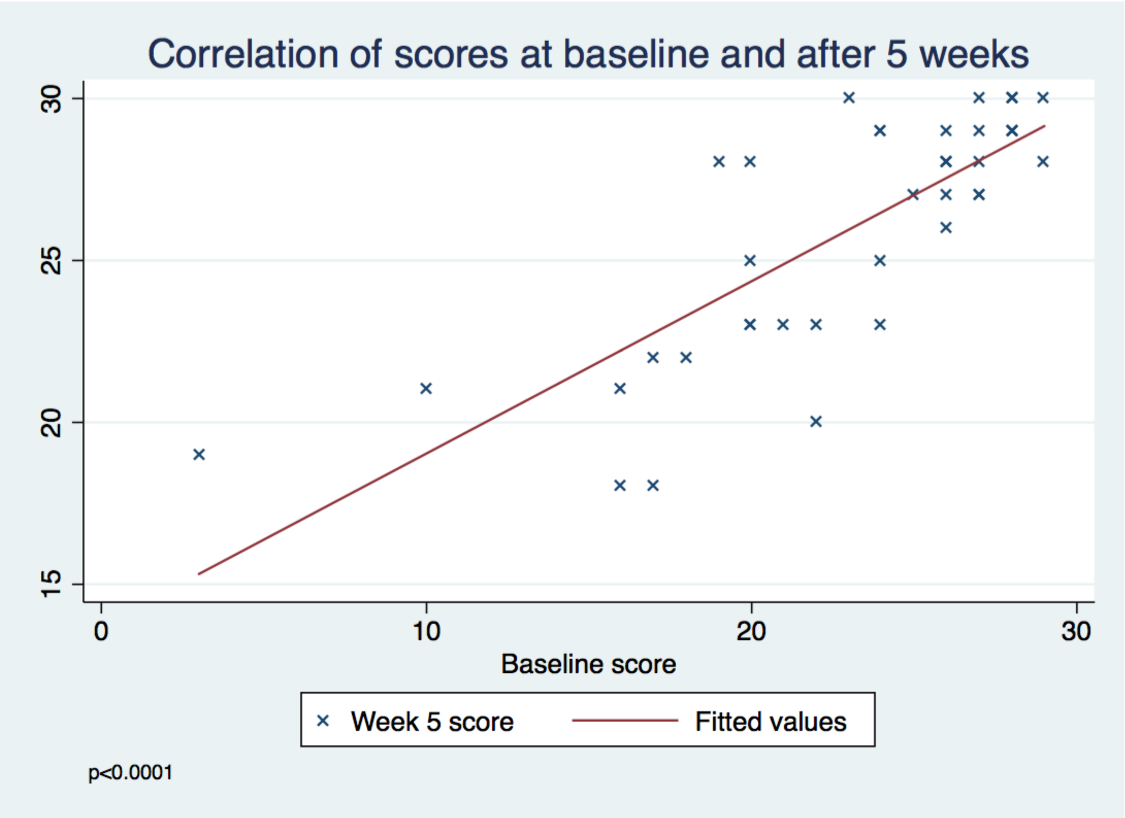


BPVS subject scores with normal (100,15) overlay

4.2 Before and after data analysis

Overall, there was a positive correlation ($p<0.0001$) between subjects' scores at baseline and after 5 weeks (figure 4.6). Subjects with a higher baseline score were associated with having a higher score after 5 weeks.

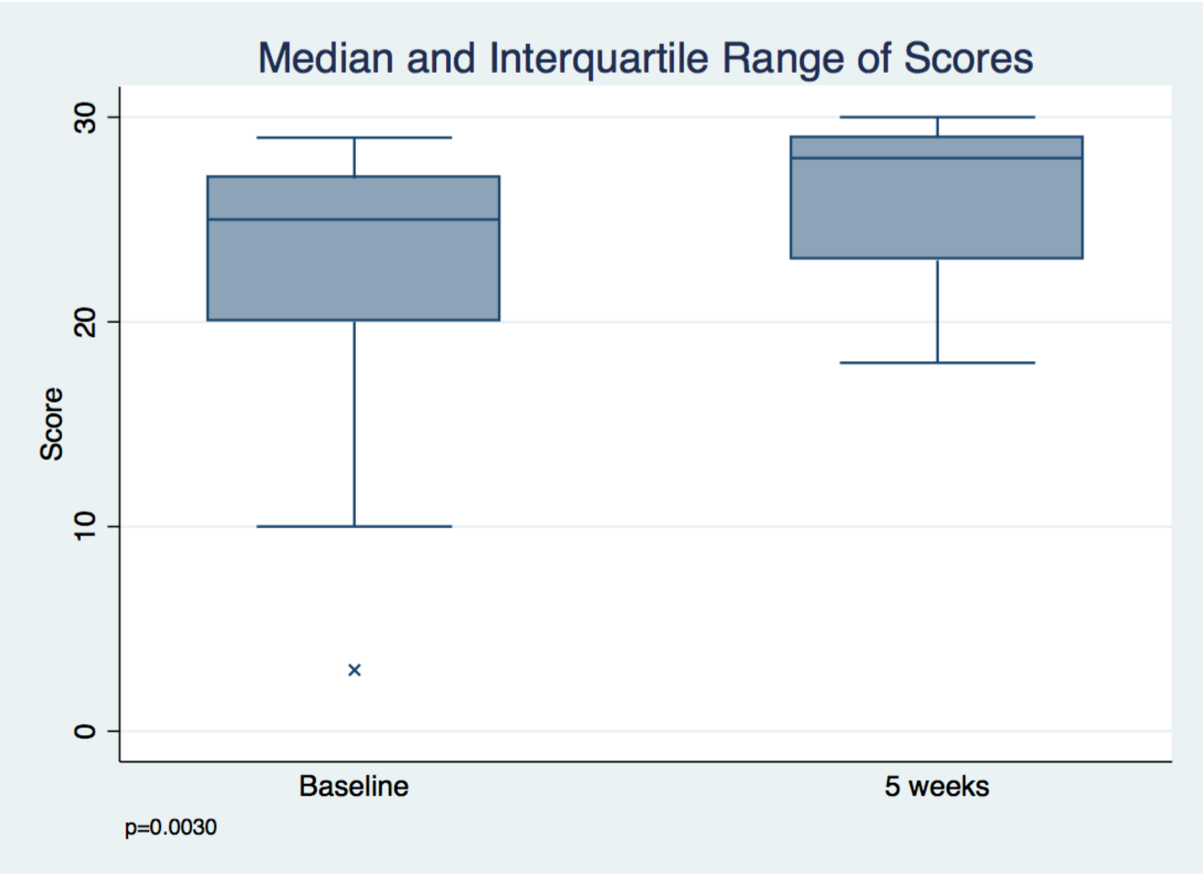
Figure 4.6 Correlation of Mathematics vocabulary scores at baseline and after 5 weeks



Among the 41 subjects, there was a statistically significant increase in score after 5 weeks of intervention, from a mean of 23.2 (SD 5.5) to a mean of 26 (SD 3.7), p = 0.003. After the 5week intervention the mean score increases by 2.8 points, demonstrating subjects' improved vocabulary knowledge. The decreased standard deviation shows the reduced variation within the group.

Figure 4.7 shows the median and interquartile range of baseline and post-intervention scores. One individual scored 3 on the baseline assessment. Teachers reported that all their subjects participated fully with the assessments and this score was deemed to be a true representation of the participant's ability. On further inspection, this result belonged to subject 53 who scored 19 post-intervention. The subject had additional needs including ANSD and SLCN and it may be that explicit teaching is particularly successful for them.

Figure 4.7 Median and interquartile range of vocabulary scores at baseline and after 5 weeks



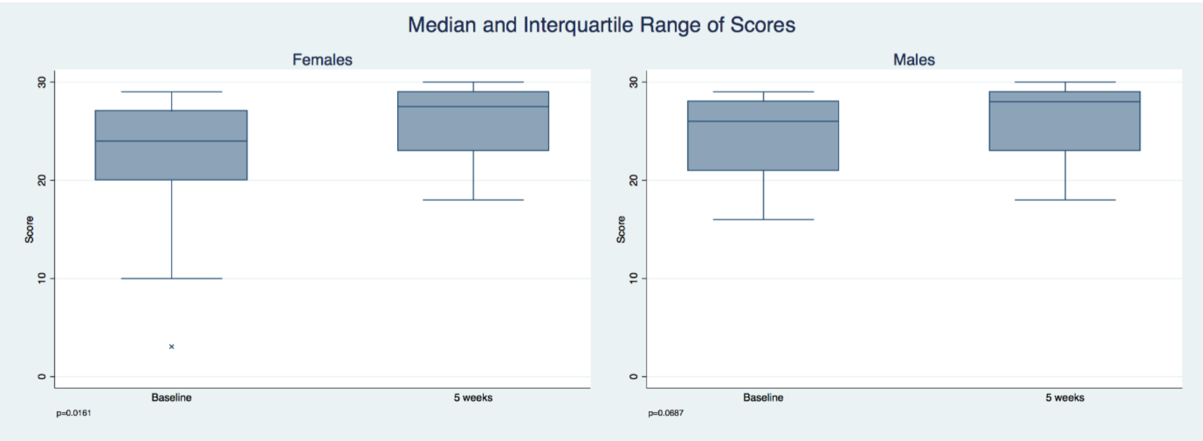
In order to understand if any variables had a more significant impact on the results, the results were investigated by gender difference and by first language.

4.3 Gender

Among the 22 female subjects, there was a statistically significant increase in score after 5 weeks of intervention, from a mean of 22.3 (SD 6.4) to a mean of 26.0 (SD 3.6), p=0.0161. This is largely driven by the one (female) participant who scored 3 at baseline. Among the 19 male subjects, there was an increase in score after 5 weeks of intervention, from a mean of 24.2 (SD 4.3) to a mean of 26.2 (SD 3.9), p=0.0687. For both groups, after the 5week intervention the mean scores increases; female by 3.7 points and male by 2 points, demonstrating subjects' improved vocabulary knowledge. The decreased standard deviation shows the reduced variation within the groups.

When comparing the results by gender, the baseline score for the female subjects had a lower mean score and larger standard deviation than the male subjects. After the 5week intervention, the difference between the groups reduced, as can be seen in figure 4.8. The improvement made after 5weeks by the female subjects was not significantly different from the male subjects (P=0.1929). This means that gender did not have a significant impact on results.

Figure 4.8 Median and interquartile range of scores by gender

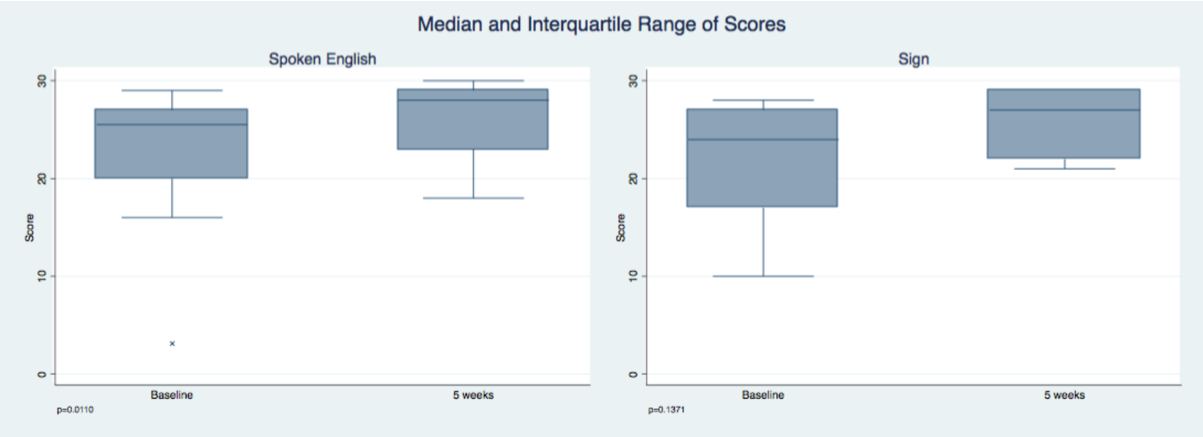


4.4 First Language

Among the 30 subjects whose first language is spoken English, there was a statistically significant increase in score after 5 weeks of intervention, from a mean of 23.5 (SD 5.4) to a mean of 26.3 (SD 3.8), p=0.0110. Among the 11 subjects whose first language is sign, there was an increase in score after 5 weeks of intervention, from a mean of 22.3 (SD 5.8) to a mean of 25.4 (SD 3.4), p=0.1371. This was not statistically significant; however, the group size was small (11). For both groups, after the 5week intervention the mean score increases; spoken English by 2.8 points and sign by 3.1 points, demonstrating subjects' improved vocabulary knowledge. The decreased standard deviation shows the reduced variation within the groups.

When comparing the results by first language, the baseline score for subjects whose first language is sign had a lower mean score and larger standard deviation than subjects whose first language is spoken English. After the 5week intervention, the difference between groups reduced, as can be seen in figure 4.9. The improvement made after 5weeks by subjects whose first language is sign was not significantly different from the subjects whose first language is spoken English (P=0.6538). This means that first language did not have a significant impact on results.

Figure 4.9 Median and interquartile range of scores by first language

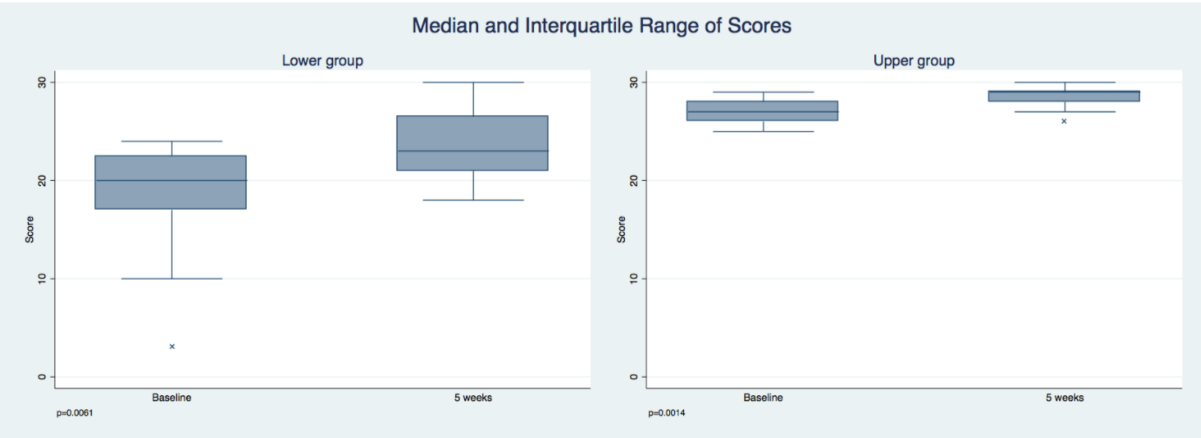


4.5 Dichotomised Baseline Scores

In order to understand if there were any differences in improvements among individuals with lower baseline scores compared to higher baseline scores, the baseline scores were dichotomised. Among the 20 subjects whose baseline score was in the lower half of the group, there was a statistically significant increase in score after 5 weeks of intervention, from a mean score of 19 (SD 5.2) to a mean score of 23.5 (SD 3.7), p=0.0061. Among the 21 subjects whose baseline score was in the upper half of the group, there was a statistically significant increase in score after the 5 weeks of intervention from a mean score of 27.1 (SD 1.1) to a mean score of 28.5 (SD 1.2), p=0.0014. For both groups, after the 5week intervention the mean increases demonstrating subjects' improved vocabulary knowledge. Whilst the lower group appear to have improved more, (lower group increased mean score by 4.5, upper group increased mean score by 1.4) when comparing the p values, the increase of the upper group is more significant. The decreased standard deviation shows the reduced variation within the lower group. The standard deviation for the upper group increased by 0.1. It should be observed that this group were close to the top score of the test (30 marks) at the baseline and therefore had less potential for improvement.

When comparing the improvement made from baseline score, there was a statistically significant difference in the improvement between subjects whose baseline was in the upper half compared to subjects whose baseline was in the lower half (p=0.0025). This means that baseline score did have a significant impact on results, with a greater impact on subjects in the upper group.

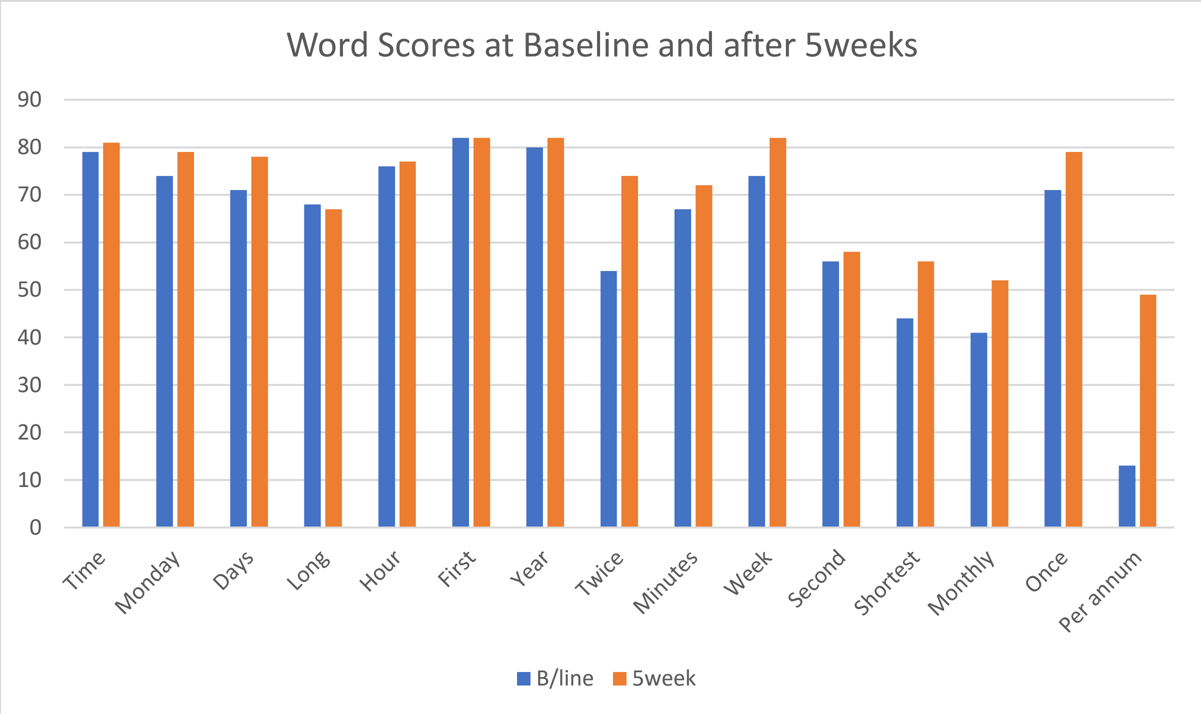
Figure 4.10 Median and interquartile range of scores dichotomised



4.6 Word Analysis

Figure 4.11 shows the total score per word from the 41 subjects at baseline and after the 5week intervention. The greatest improvement was made with the word ‘per annum’, this was also the lowest scoring word on the baseline test. This would suggest that the subjects did not know the word previously and learnt it through exposure during the intervention. ‘Twice’ had the second greatest improvement followed by ‘shortest’ and ‘monthly’. The biggest impact was made with the more difficult words. These words were considered more difficult based on their frequency of use and when they appear on the Mathematics curriculum. Therefore, exposure to these words, outside of the intervention, is likely to be less frequent.

Figure 4.11 Word scores at baseline and after 5 weeks



A score of 2 is given for the correct word, spelt correctly. This indicates that the subject has secure knowledge of the word. A score of 1 is given if there is a spelling or word variation error. This indicates that the word is known or familiar, but the subject needs more exposure to make it secure. A score of 0 indicates that the word was unknown and requires explicit teaching. Table 4.1 shows how all the scores changed for individual words for every subject. The column 0-1 shows us that on 22 occasions subjects scored 0 on a word in the baseline test and a score of 1 after 5 weeks. The category with the biggest change was 0-2 which happened on 53 occasions. Subjects went from scoring 0 indicating they did not know the word, to producing the word with the correct spelling and scoring 2. This would indicate that the subjects learnt the words through exposure during the intervention. There were

33 incidences of negative scores. This may be due to subjects not being secure in their spelling or understanding of the word in the baseline test, despite scoring 2. Alternatively, it could indicate that exposure to word variations during the intervention had confused their understanding. Examples of this were ‘longer’ instead of ‘long’, ‘day’ instead of ‘days’ and ‘month’ instead of ‘monthly’.

Score	**0-1**	**1-2**	**0-2**	**2-1**	**2-0**	**1-0**
Total	22	34	53	19	11	3

Table 4.2 Single word score changes after 5 weeks

5. Discussion

The language gap between CD and their hearing peers is widely acknowledged in research (Sarant et al 2009, Vohr et al 2012, Lederberg et al 2013, Netten et al 2015 and Meinzen-Der et al 2018). Vocabulary knowledge is a key area of weakness for CD, both the quantity of expressive and receptive vocabulary known (Lund 2016) and the depth of understanding (Walker et al 2019). This gap in vocabulary is linked to a delay in reading ability (Mayberry 2011), comprehension (Kyle and Harris 2010, Kyle et al 2016), NVWM (Marshall et al 2015), theory of mind (Lederberg et al 2013), social and emotional functioning (Netten et al 2015, Kelly et al 2019, Stevenson et al 2018) and economic status in adult life (Ritchie and Bates 2013). This study follows the work conducted at one setting to reduce the gap in Mathematics vocabulary knowledge through a systematic plan (Manzo et al 2006). Key points from the quantitative results will be discussed below. The first section will explore the production of vocabulary assessments, including word selection. The second section looks at the intervention process and the subjects' results. Finally, anecdotal evidence gathered throughout this process is discussed.

5.1 Vocabulary Assessments

Vocabulary knowledge in hearing children has been linked to mathematical achievement (Bleses et al 2016, Singer et al 2018, Aragon et al 2019, Purpura and Ganley 2014, Pimperton and Nation 2010). Research with CD also supports this link (Vitova et al 2013, Kelly and Gaustad 2007, Edwards et al 2013, Moreno 2000, Huber et al 2014). This is not surprising, considering the vast glossary of technical Mathematics terms and their many areas of complexity (Rubenstein and Thompson 2002). Vocabulary isn't just a means of naming objects and processes. We use language when we teach, in our delivery and explanations, in our questioning and in our feedback.

The only existing robust Mathematics vocabulary list that could be found was based on the USA Mathematics curriculum and aimed at primary students (Powell 2017) which was not suitable for a secondary UK setting. A list of technical Mathematics vocabulary was generated based on a curriculum assessment (Dougherty Stahl and Bravo 2010)- the Mathematics GCSE. 210 technical words that occurred most frequently (by paper) were selected. Assessments were written based on these words. The assessments were designed with purpose and context (Read and Chapelle 2001) giving learners and teachers an incentive to engage (Dougherty Stahl and Bravo 2010). A discrete design was chosen for the assessments (Read and Chapelle 2001) and questions were written using simple language (Crisp 2015). For the purpose of this intervention, only the Time vocabulary assessment was used.

5.2 The Intervention

From an early age mathematical delay in CD can be attributed to a lack of exposure to mathematical concepts and language in the home (Kritzer 2009b), with parents simplifying their interactions (Moeller and Schick 2006). Maternal education (Cupples et al 2018, Walker et al 2019) and the home language environment (Vohr et al 2014) are predictors of language development. This intervention aims to close the language gap by providing a rich language environment for students during a series of Mathematics lessons. Explicit teaching is recommended for improving Mathematics vocabulary with hearing children (Riccomini et al 2015) and for improving vocabulary in CD (Lund 2016, Lund and Douglas 2016, Duncan and Lederberg 2018). The intervention required very little time or resources. It was delivered 20minute sessions once a week over a period of 5 weeks. Most settings could accommodate this as a regular starter activity. One teacher commented, 'the resources were well designed and engaging – the lessons are ready to step right into and deliver'. Many visuals were included in the teaching resources (Lang and Pagliaro 2007) as well as games to capture students' interest (Riccomini et al 2015). The intervention focussed on the topic of Time whilst simultaneously being taught Time in their Mathematics lessons. This was done to increase exposure to the key vocabulary (Kritzer 2009b, Riccomini 2015). As parental involvement has a direct impact on language acquisition (Moeller and Schick 2006, Sarant et al 2009, Boons et al 2012), exposure could also be increased by simultaneously sharing the vocabulary word lists with parents/carers during future interventions.

After the 5week intervention, subjects showed a significant increase in vocabulary scores on the topic of Time. The increase in scores relates to new vocabulary learning, improved spellings and correct word variation selection. The variation between students' knowledge had reduced. A more cohesive group of subjects, with similar vocabulary knowledge, should be easier to teach. Gender and first language were ruled out as impact variables. However, it was found that baseline scores did have an impact on results, with a higher baseline score predicting greater improvement. This demonstrates that vocabulary intervention is not just important for CD with known language difficulties but also for higher functioning students. Subjects made more progress on words with lower baseline scores. This suggests that an intervention on a topic with more technical language has the potential to make an even more significant impact. The setting will continue to deliver the intervention on the other 13 topics.

The subjects' baseline scores can be considered high with a mean of 23.2 out of 30. This indicates their knowledge of the Time vocabulary words was good prior to the intervention. Time is a topic that is introduced at primary level. It is a functional element of the Mathematics curriculum and it is often taken for granted that this is a secure topic by secondary level. Time language is highly cross-curricular and is used frequently in the home and other settings. This would suggest that exposure to Time language is already high. Based on the vocabulary selection process prioritising frequently used words in the Mathematics GCSE, it is not possible to make this assessment harder. It would be interesting to compare these results with an intervention on one of the other topics, for example Statistics, where the vocabulary is highly subject specific and includes higher GCSE terms.

5.3 Anecdotal evidence – impact on staff

An intervention can have an impact on professionals as well as subjects, improving awareness and changing practice (Moffett and Eaton 2017). Teachers delivering the intervention found subjects were engaged and enjoyed the activities, particularly the games. They noticed that new vocabulary was transferred to other Mathematics lessons, although not always correctly, as subjects experimented with their new learning. One teacher said, “this will change my approach to teaching language in Maths”. Teachers changed their perception of what was considered a difficult word. Subjects with a range of abilities and SEN could learn new vocabulary including concepts like ‘per annum’, that wouldn’t normally be discussed until later in their education. Subjects were able to define the word despite not being able to apply it in a mathematical sense.

5.4 Limitations

5.4.1 Vocabulary Selection

During the vocabulary selection process, the number of papers a word appeared on was used as the first order of ranking. This could have been enhanced by counting the number of questions a word appeared in. From the data gathered, it is not possible to know if the understanding of a word is significant in being able to answer a question. Sometimes it is possible to answer a question without reading it, for example by looking at the diagram. Only words that are written on the question paper have been considered (receptive language) not words that students are required to write as an answer (expressive). This research only looked at one exam board, it would be interesting to see if other exam boards use technical words with the same frequency. The word count was conducted by one person, a second- or third-word count could find anomalies and improve reliability of the study. The nature of the word count meant that many technical words were not included if they didn't appear on a GCSE paper e.g. locus. This skill, and therefore the language associated with it, would still need to be taught to students. When sharing words out into the 15 topic groups it was necessary to move words away from their most obvious topic. If this exercise was repeated it is possible that the words would be assigned to different topics.

5.4.2 Mathematics Vocabulary Assessment

Whilst every effort was made to use simple language, the assessment design relied on the subjects' ability to understand carrier language. This could be improved with the introduction of pictures in the assessment. It was impossible to eliminate all other technical language from the questions e.g. 'The **first** day of the week is M'. This question is testing the understanding of the word **Monday,** but **first** is also a technical word. There is an opportunity to guess, as subjects are given the first letter. However, this still demonstrates they can recall the word. The words were ordered by difficulty, based on the order they appeared in the curriculum combined with professional opinion. This is subjective. A future study could look at grading the words by difficulty, using the baseline results. As vocabulary difficulty is dependent on exposure to a word, the baseline results would give this information.

5.4.3 The Intervention

The study had a sample size of 41 subjects. Whilst this is a reasonable size for a study on CD it would be considered a small sample size amongst wider research. This makes it difficult to confidently estimate differences in groups, especially when subjects are then divided into subgroups. The sample also has a heterogenous nature and this should be considered before making generalisations. This study only followed the intervention of one topic out of the 14. As addressed in the discussion, other topics, with a wider range of mathematical difficulty, may produce different results. Whilst every group was given the same resources for the intervention, the delivery was not consistent. As I had written the resources and was conducting the research, I had more confidence and familiarity with them when teaching my groups. One of the teachers delivering the intervention had not received a significant amount of Teacher of the Deaf training due to his temporary contract. Teachers were given discretion to modify activities in the interests of differentiation. This was to account for the vast range of abilities amongst subjects (GCSE targets ranged from grade 1 to grade 9). There was no control group, so comparisons could not be made with students who did not receive the intervention. As this was an action research project, collecting information on the effectiveness of a school-based intervention, it would not have been ethical to exclude students to create a control.

6. Conclusion

Improving Mathematics vocabulary knowledge amongst CD is an area with limited research. This study has introduced a robust list of technical words that are important for students studying towards the GCSE Mathematics exam in the UK. The list provides professionals with a framework to work from. These words, including word variations, should be introduced in expressive and receptive formats in order to increase students’ exposure to them. The vocabulary assessment on Time has been successfully implemented as part of an intervention package known as Count on Words. The assessment allowed subjects to demonstrate their expressive vocabulary knowledge and for professionals to track progress.

Targeted, explicit instruction was delivered in an oral setting in 5 x 20minute sessions over 5 weeks. This made a significant impact on the Mathematics vocabulary knowledge of 41 students with a mean age of 13 years 2 months. Subjects with higher baseline scores made greater progress. There was no significant difference in progress when controlled for gender or first language. Settings for CD should plan Mathematics vocabulary teaching into their scheme of work.

At this setting, we will continue to deliver Count on Words across all 14 topics. Assessments will be adapted to include pictures where possible and reduce the amount of language included. Results from the baseline tests will be used to rank the words in order of difficulty. Planning can then be made to increase exposure to these words in teaching, displays and resources. Looking outside of the Mathematics department, cross-curricular links will be made, starting with Science due the large amount of vocabulary and content crossover.

References

Aragón, E., Cerda, G., Delgado, C., Aguilar, M., Navarro, J. (2019) 'Individual differences in general and specific cognitive precursors in early mathematical learning', 31(2), *Psicothema,* 31(2), 156-162.

Ariapooran, S. (2017) 'Mathematics Motivation, Anxiety, and Performance in Female Deaf/Hard-of-Hearing and Hearing Students', *Communication Disorders Quarterly*, 38(3), 172-178.

Bleses, D., Makransky, G., Dale, P. S., Hojen, A., Ari, B. A. (2016) ‘Early productive vocabulary predicts academic achievement 10 years later’, *Applied Psycholinguistics*, 37(6), 1461-1476

Boons, T., Brokx, J.P., Dhooge, I., Frijns, J.H., Peeraer, L., Vermeulen, A., Wouters, J. and Van Wieringen, A., (2012) ‘Predictors of spoken language development following pediatric cochlear implantation’, *Ear and hearing*, *33*(5), 617-639

Borgna, G., Walton, D., Convertino, C., Marschark, M. and Trussell, J., (2018) 'Numerical and real-world estimation abilities of deaf and hearing college students', *Deafness & Education International*, 20(2), 1-21.

Bull, R., Marschark, M., Nordmann, E., Sapere, P. & Skene, W.A. (2018) ‘The approximate number system and domain-general abilities as predictors of math ability in children with normal hearing and hearing loss’, *British Journal of Developmental Psychology*, 36(2), 236-254.

Cannon, J.E., Fredrick, L.D., Easterbrooks, S.R. (2010) ‘ Vocabulary instruction through books read in American sign language for English-language learners with hearing loss’, *Communication Disorders Quarterly*, 31(2), 98-112

Chow, J. & Ekholm, E. (2019) ‘Language domains differentially predict mathematics performance in young children’, *Early Childhood Research Quarterly*, 46(1), 179-186

Crisp, V. (2015) ‘Exploring the difficulty of mathematics examination questions for weaker readers’, *Educational Studies,* 41(3), 276-292

Cruz, I., Quittner, A., Marker, C., DesJardin, J.L. & CDaCI Investigative Team (2012) ‘Identification of effective strategies to promote language development in deaf children with cochlear implants’, *Child development*, 84(2), 543-559.

Cupples, L., Ching, T.Y., Button, L., Leigh, G., Marnane, V., Whitfield, J., Gunnourie, M. and Martin, L. (2018) ‘Language and speech outcomes of children with hearing loss and additional disabilities: identifying the variables that influence performance at five years of age’, *International journal of audiology*, 57(sup2), S93-S104.

Cupples, L., Ching, T.Y., Crowe, K., Day, J., Seeto, M. (2013) ‘Predictors of Early Reading Skill in 5-Year-Old Children With Hearing Loss Who Use Spoken Language’, *Reading Research Quarterly,* 49(1), 85-104

Davenport, C.A., Alber-Morgan, S.R., Clancy, S.M. & Kranak, M.P. (2017) ‘Effects of a Picture Racetrack Game on the Expressive Vocabulary of Deaf Preschoolers’, *The Journal of Deaf Studies and Deaf Education*, 22(3), 326–335

DFE (2017) Statutory Framework for the early years foundation stage. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/596629/EYFS_STATUTORY_FRAMEWORK_2017.pdf [Accessed 30th October 2019]

Dougherty Stahl, K.A. & Bravo, M.A. (2010) ‘Contemporary Classroom Vocabulary Assessment for Content Areas’, *Reading Teacher,* 63(7), 566-578

Duncan, M.K. and Lederberg, A.R. (2018) ‘Relations Between Teacher Talk Characteristics and Child Language in Spoken-Language Deaf and Hard-of-Hearing Classrooms’, *Journal of Speech, Language and Hearing Research,* 61(12), 2977-2995

Edwards, A., Edwards, L., Langdon, D. (2013) ‘The Mathematical abilities of children with cochlear implants’, *Child Neuropsychology,* 19(2), 127-142

Epstein, K. I., Hillegeist, E. and Grafman, J. (1994) ‘Number processing in deaf college students’, *American Annals of the Deaf,* 139(3), 336–347

Geers, A.E., Nicholas, J.G. & Sedey, A.L. (2003), ‘Language Skills of Children with Early Cochlear Implantation’, *Ear and Hearing*, 24(1), 46S-58S

Hitch, G. J., Arnold, P., & Phillips, L. J. (1983) ‘Counting processes in deaf children’s arithmetic’, *British Journal of Psychology*, 74, 429–437

Huber, M., Kipman, U. & Pletzer, B. (2014) ‘Reading instead of reasoning? Predictors of arithmetic skills in children with cochlear implants’, *International journal of pediatric otorhinolaryngology*, 78(7), 1147-1152

Kelly, C., Morgan, G., Freeth, M., Siegal, M. & Matthews, D. (2019) ‘The Understanding of Communicative Intentions in Children with Severe-to-Profound Hearing Loss’, *The Journal of Deaf Studies and Deaf Education,* 24(3), 245–254

Kelly, R. & Gaustad, M. (2007) ‘Deaf college students’ mathematical skills relative to morphological knowledge, reading level, and language proficiency’, *Journal of Deaf Studies and Deaf Education,* 12:1, 25-37

Kritzer, K. L. (2009a) ‘Barely started and already left behind: A descriptive analysis of the mathematics ability demonstrated by young deaf children’, *Journal of Deaf Studies and Deaf Education*, 14(4), 409-421

Kritzer, K.L. (2009b) ‘Families with young deaf children and the mediation of mathematically-based concepts within a naturalistic environment’, *American Annals of the Deaf*, 153, 474-483

Kyle, F.E., Campbell, R. and MacSweeney, M. (2016) ‘The relative contributions of speechreading and vocabulary to deaf and hearing children's reading ability’, *Research in developmental disabilities*, 48, 13-24

Kyle, F.E. and Harris, M. (2010) ‘Predictors of reading development in deaf children: A 3-year longitudinal study’, *Journal of Experimental Child Psychology,* 107, 229-243

Lang, H., & Pagliaro, C. (2007) ‘Factors predicting recall of mathematics terms by deaf students: Implications for teaching’, *Journal of deaf studies and deaf education*, 12(4), 449-460

Lederberg, A.R., Schick, B. & Spencer, P.E. (2013) ‘Language and literacy development of deaf and hard-of-hearing children: Successes and challenges’, *Developmental Psychology*, 49(1), 15-30

Leybaert, J. & Van Cutsem, M. (2002) ‘Counting in sign language’, *Journal of Experimental Child Psychology,* 81, 482-501

Lund, E. & Douglas, M. (2016) ‘Teaching Vocabulary to Preschool Children with Hearing Loss’, *Council for Exceptional Children,* 83:1, 26-41

Lund, E. (2016) ‘Vocabulary Knowledge of Children With Cochlear Implants: A Meta-Analysis’, *The Journal of Deaf Studies and Deaf Education*, 21(2), 107–121

Lund, E. (2019) ‘Comparing Word Characteristic Effects on Vocabulary of Children with Cochlear Implants’, *The Journal of Deaf Studies and Deaf Education,* 24(4), 424–434

Maller, S.J., Braden, J.P. (2011) Intellectual Assessment of Deaf People: A Critical Review of Core Concepts and Issues. In: Marschark M., Spencer P., eds. The Oxford Handbook of Deaf Studies, Language, and Education, (vol. 2). New York: Oxford University Press, pp. 473–85.

Manzo, A.V., Manzo, U.C. & Thomas, M.M (2006) ‘Rationale for systematic vocabulary development: Antidote for state mandates’*, Journal of Adolescent & Adult Literacy*, 49(7), 610-619

Marshall, C., Jones, A., Denmark, T., Mason, K., Atkinson, J., Botting, N. and Morgan, G., (2015), ‘Deaf children's non-verbal working memory is impacted by their language experience’, *Frontiers in Psychology*, *6*, 527

Meinzen-Derr, J., Sheldon, R., Grether, S., Altaye, M., Smith, L., Choo, D.I. and Wiley, S., (2018) ‘Language Underperformance in Young Children Who Are Deaf or Hard-of-Hearing: Are the Expectations Too Low?’, *Journal of developmental and behavioral paediatrics,* 39(2), 116-125

Moeller, M.P., Schick, B. (2006) ‘Relations Between Maternal Input and Theory of Mind Understanding in Deaf Children’, *Child Development,* 77(3), 751-766

Moeller M.P., Tomblin J.B. OCHL Collaboration (2015) ‘Epilogue: Conclusions and Implications for Research and Practice’, *Ear Hear*, 36, 92S–98S

Moffett, P. & Eaton, P. (2017) ‘The impact of the Promoting Early Number Talk project on classroom mathematics talk’, *Early Child Development and Care’,* 189(11), 1763-1775

Moreno, C., (2000) Predictors of Mathematics attainment in hearing impaired children, London Institute of Education, University of London Unpublished Ph.D Thesis

Netten, A., Rieffe, C., Theunissen, S., Soede, W. Dirks, E. Korver, A. Konings, S. Oudesluys Murphy, A. Dekker, F. & Frijns, J. (2015) ‘Early identification: Language skills and social functioning in deaf and hard of hearing preschool children’*,* *International journal of pediatric otorhinolaryngology,* 79(12), 2221–2226

Nunes, T., Bryant, P., Burman, D., Bell, D., Evans, D. & Hallett, D. (2009) ‘Deaf Children's Informal Knowledge of Multiplicative Reasoning’, *Journal of Deaf Studies and Deaf Education*, vol. 14, no. 2, 260-277

Pagliaro, C.M. & Kritzer, K.L., (2013) ‘The math gap: A description of the mathematics performance of preschool-aged deaf/hard-of-hearing children’, *Journal of deaf studies and deaf education*, 18(2), 139-160

Pimperton, H. & Nation, K., (2010) ‘Understanding words, understanding numbers: An exploration of the mathematical profiles of poor comprehenders’, *British Journal of Educational Psychology,* 80(2), 255-268

Powell, S.R., Driver, M.K., Roberts, G. & Fall, A.M. (2017) ‘An analysis of the mathematics vocabulary knowledge of third- and fifth-grade students: Connections to general vocabulary and mathematics computation’, *Learning and Individual Differences,* 57, 22-32

Professional, T., (2016) ‘Summing up maths changes.’ *The Times Educational Supplement,* (5212).

Purpura, D.J. & Ganley, C.M. (2014) ‘Working memory and language: Skill-specific or domain-general relations to mathematics?’, *Journal of Experimental Child Psychology*, 122, 104-121

Read, R. & Chapelle, C.A. (2001) ‘A framework for second language vocabulary assessment’, *Language Testing,* 18(1), 1-32

Riccomini, P.J., Smith, G.W., Hughes, E.M. & Fries, K.M. (2015) ‘The Language of Mathematics: The Importance of Teaching and Learning Mathematical Vocabulary’, *Reading and Writing Quarterly*, 31(3), 235-252

Ritchie, S. J., & Bates, T. C. (2013) ‘Enduring links from childhood mathematics and reading achievement to adult socioeconomic status’, *Psychological Science*, 24, 1301–1308

Rodriguez-Santos, J.M., Garcia-Orza, J., Calleja, M., Damas, J. & Iza, M. (2018) ‘Nonsymbolic Comparison in Deaf Students: No Evidence for a Deficit in Numerosity Processing’, *American Annals of the Deaf,* 163(3), 374-393

Rubenstein, R. & Thompson, D. (2002). ‘Understanding and supporting children's mathematical vocabulary development.’ *Teaching Children Mathematics*, 9(2), 107–112

Sarant, J.Z., Holt, C.M., Dowell, R.C., Rickards, F.W., & Blamey, P.J. (2009) ‘Spoken language development in oral preschool children with permanent childhood deafness’, *Journal of Deaf Studies and Deaf Education,* 14(2), 205-217

Singer, V., Ruiz, C., Cuadro, A. (2018) ‘The influence of linguistic abilities and the approximate number system in the efficacy of arithmetic calculation’ *Bordon Journal of Education,* 70(3), 185-197

Stevenson, J., Pimperton, H., Kreppner, J., Worsfold, S., Terlektsi, E., Mahon, M. & Kennedy, C. ‘Language and reading comprehension in middle childhood predicts emotional and behaviour difficulties in adolescence for those with permanent childhood hearing loss’, *The Journal of Child Psychology and Psychiatry,* 59(2), 180-190

Strassman, B.K., Marashian, K. & Memon, Z. (2019) ‘Teaching Academic Language to d/Deaf Students: Does Research Offer Evidence for Practice?’, *American Annals of the Deaf*, 163(5), 501-533

Swanwick, R., Oddy, A., & Roper, T. (2006) ‘Mathematics and deaf children: an exploration of barriers to success’, *Deafness & Education International*, 7(1), 1-21

Thomas, G. (2013). How to do your Research Project. Thousand Oaks, CA: Sage Publications.

Vitova, J., Zdrazilova, T., Jezkova, A. (2013) ‘Successes of Students with Hearing Impairment in Math and Reading with Comprehension’, *Procedia – Social and Behavioural Sciences,* 112, 725-729

Vohr, B.R., Topol, D., Girard, N., St Pierre, L. & Tucker, R. (2012) ‘Language outcomes and service provision of preschool children with congenital hearing loss’, *Early Human Development,* 88(7), 493-498

Vohr, B.R., Topol, D., Watson, V., St Pierre, L. & Tucker, R. (2014) ‘The importance of language in the home for school-age children with permanent hearing loss’, *Acta Paediatrica*, 103, 62– 69

Walker, E.A., Redfern, A. & Olsen, J.J. (2019) ‘Linear Mixed-Model Analysis to Examine Longitudinal Trajectories in Vocabulary Depth and Breadth in Children Who Are Hard of Hearing’, *Journal of Speech, Language & Hearing Research*, 62(3), 525-542

Worsfold, S., Mahon, M., Pimperton, H., Stevenson, J. and Kennedy, C. (2018) ‘Predicting reading ability in teenagers who are deaf or hard of hearing: A longitudinal analysis of language and reading’, *Research in Developmental Disabilities*, 77, 49-59

Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., Chung, W. (2017) ‘Early hearing detection and vocabulary of children with hearing loss’, *Pediatrics*, 140(2),

Zarfaty, Y., Nunes, T., & Bryant, P. (2004) ‘The performance of young deaf children in spatial and temporal number tasks’, *Journal of Deaf Studies and Deaf Education*, 9(3), 315-326

Appendix A: Full list of key Maths Vocabulary

NUMBER			ALGEBRA		STATISTICS	
Number Skills	**Number Calculations**	**Fractions**	**Sequences/Graphs**	**Skills/Equations**	**Probability**	**Statistics**
one-six	total	half/halves	graph	solve	probability	frequency
high/er/est	times x	whole	grid	equation	spinner	pictogram
single	share/ed	large/st	straight	term/s	tails/heads	chart
both	difference	small/est	coordinates	simplest (form)	likely	range
between	calculator	size	next	expression	coin	average
each	estimate	value	sequence	form	possible	median
figures	factor/s	fraction	pattern	formula	table	pie (chart)
greater/est	multiple	sum	midpoint	factorise	chooses/en/ing	interval
much	prime	more than	sketch (curve)	subject	equal/ly	scatter
many	square (^ 2)	order	axis/es	expand	dice	mean
odd (even)	standard (form)	sector	region	simultaneous	(probability) tree	represent/s/ing
least	ordinary (number)	integer	curve	solution	set	*quartile
every	error	simplify/ies	intersect/pt/ion	algebra/ically	distribution	*box plot
digit/s	*bound	inequality/ies	gradient	prove/proof	random	*histogram
most	*upper	equivalent	turning point	function/s	biased	*cumulative

GEOMETRY/MEASURES				RATIO, PROPORTION AND RATES OF CHANGE		
Angle & Shape	**PAV**	**Transformations**	**Time**	**Decimals/Money**	**Percentages/Finance**	**Ratio/Proportion**
triangle/ular	length/s	diagram	hours/ly	buy/buys/bought	cost/s/ing	ratio
circle/ular	centimetres	line	time (as in clock)	price	percentage	litre
side/s/ed	cuboid	angle	Mon - sun	decimal	more	gram
cube (shape)	measure/d/ment	parallel	days	money	lower/est	weight
square (shape)	distance	centre	long/est	cheap/er/ly	less	speed
right-angled	metre/s/kilometre/s	transformed/tion	twice	pay/id	increase/d/s	per
solid	width	rotate/ion	first/second	sell/sold	change/ed	congruent
base/d	height	reflect/ion/ed	year	nearest	special offer	miles
trapezium	area	quadrilateral	minutes	spend/t	earnings	mass
parallelogram/s	perimeter	rectangle/ular	week/s/ly	enough	rate	scale/ar
tangent	volume	maps (on to)	seconds	significant (figures)	invest/s/ment	similar
cone	surface	vector	once	amount	interest	density
polygon (shape)	radius	perpendicular	Month/ly	decimal places	compound (int)	inversely
elevation	circumference	about (location)	(per) annum	account (as in bank)	profit	proportion/al/ity
prism	diameter	translate/ion	short/est	payments	savings	directly

Appendix B: Time Vocabulary Assessment

Time Vocabulary Name…………………

Complete the sentence with a key Maths word.

You have been given the first letter.

A clock tells you the t………..

The first day of the week is M…………

There are 7 d…………. in a week

The train was late. They had to wait a l ……… time.

A unit of time is an h…………

Jodie won the race. She came f…………

You have a birthday every y……….

If something happens two times it happens t…………

The bus was a few m…………. late

Sophie goes swimming once a w…………

A small unit of time is a s…………

The opposite of **'longest'** is s………….. (not smallest)

My wages are paid m…………

Christmas happens only o……….. a year

Another way of saying every year p……. a………..

Appendix C: Card Match Activity

TIME WORD CARDS

Monday	hour	hours	hourly
Tuesday	day	days	daily
Wednesday	week	weeks	weekly
Thursday	month	months	monthly
Friday	year	years	yearly
Saturday	second	minute	once
Sunday	seconds	minutes	twice
first	second	short	shortest
long	longest	time	per annum

Appendix D: Word Scramble Activity

Word Scramble Name:................................

Unscramble the **'time'** words

1. NMODYA ________________
2. DSAY ________________
3. SMNITUE ________________
4. SSOCED ________________
5. DYRFIA ________________
6. ARUYTHSD ________________
7. CENO ________________
8. TFRSI ________________
9. RAEYS ________________
10. EGONTLS ________________
11. AETUYSD ________________
12. SCSDENO ________________
13. DYUSNA ________________
14. TMEI ________________
15. OSHMTN ________________
16. KEWSE ________________
17. UAASRDYT ________________
18. WECIT ________________
19. DEEYNWDSA ________________
20. RPEMUNAN ________________

Word Box

Once	Friday	Saturday	Months
Days	Time	First	Twice
Thursday	Second	Years	Monday
Minutes	Tuesday	Seconds	Wednesday
Shortest	Longest	Weeks	

Appendix E: Word Search Activity

Word Search!

Name: ______________________ Date: ______________________

Find and circle each of the words from the list below. Words may appear forwards or backwards, horizontally, vertically or diagonally in the grid.

Y	A	M	T	R	O	H	S	L	S	Y	T	E	R	A	Z	O	F
A	Q	E	K	F	N	O	T	U	N	S	U	E	M	G	H	H	X
D	D	F	K	T	W	S	N	D	R	S	F	T	E	I	O	Y	O
N	D	E	W	E	E	D	N	I	N	R	D	W	W	U	T	N	P
M	A	I	E	T	A	O	F	L	I	L	Y	N	R	W	Q	S	I
X	C	K	R	Y	C	O	M	D	O	O	D	L	O	H	O	U	R
E	L	O	Y	E	A	V	A	X	O	N	Y	U	R	C	I	Q	J
Y	H	C	S	S	K	Y	W	Z	Y	A	G	A	G	A	E	G	C
S	Y	A	D	S	E	U	T	E	D	Q	E	E	T	N	E	S	Y
D	P	V	H	S	V	O	H	R	D	Y	Y	P	S	O	O	Y	P
A	Q	Y	A	D	S	R	U	H	T	N	A	L	I	T	M	L	E
R	B	P	P	U	F	T	G	J	E	C	E	D	I	C	M	D	R
F	I	P	L	Q	A	Q	A	A	M	T	S	S	N	A	N	L	A
T	Y	D	F	S	W	O	G	G	M	P	U	W	D	O	D	T	N
K	H	T	A	E	C	N	I	F	V	E	I	N	P	A	M	T	N
D	C	X	E	R	Q	C	T	G	C	W	Y	E	I	R	Y	N	U
G	O	K	S	F	Y	E	D	N	N	F	E	R	R	M	E	A	M

Wednesday Tuesday per annum Thursday Saturday
shortest longest second Sunday Monday year seconds
weekly minute hourly Friday yearly twice week short
time day hour daily first once long

Appendix F: Discussion Pictures

ENRICHMENT

TIME

ENRICHMENT

TIME

ENRICHMENT

TIME

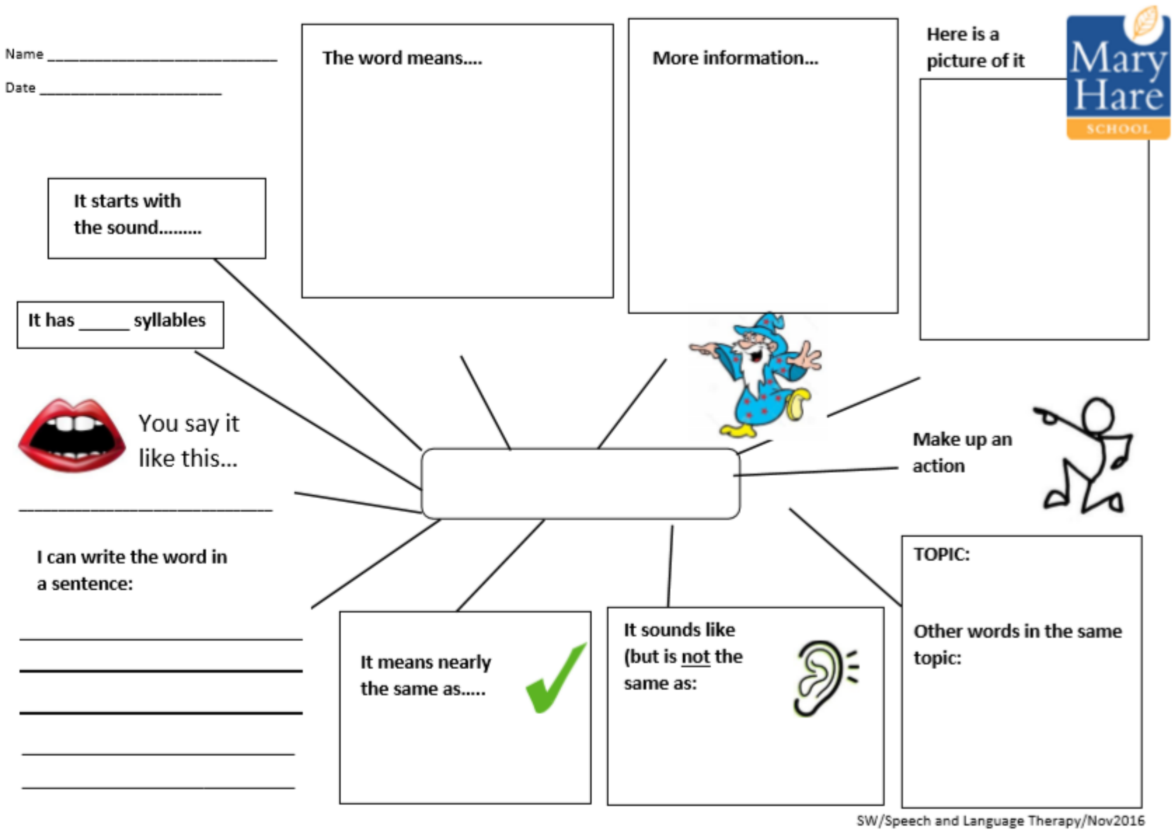
ENRICHMENT

TIME

ENRICHMENT

TIME

Appendix G: Word Wizard Activity



Name ___________________________

Date _______________________

The word means....

More information...

Here is a picture of it

Mary Hare SCHOOL

It starts with the sound.........

It has _____ syllables

You say it like this...

____

Make up an action

I can write the word in a sentence:

It means nearly the same as.....

It sounds like (but is not the same as:

TOPIC:

Other words in the same topic:

SW/Speech and Language Therapy/Nov2016

Appendix H: Ethical Approval Documents

University of Hertfordshire UH

SOCIAL SCIENCES, ARTS AND HUMANITIES ECDA

ETHICS APPROVAL NOTIFICATION

TO Rachael Lethbridge

CC Lorna Gravenstede

FROM Dr Brendan Larvor, Social Sciences, Arts and Humanities ECDA Vice Chairman

DATE 03/02/20

Protocol number: **EDU/PGT/CP/04466**

Title of study: Developing Vocabulary in Maths

Your application for ethics approval has been accepted and approved with the following conditions by the ECDA for your School and includes work undertaken for this study by the named additional workers below:

no additional workers named

General conditions of approval:

Ethics approval has been granted subject to the standard conditions below:

Permissions: Any necessary permissions for the use of premises/location and accessing participants for your study must be obtained in writing prior to any data collection commencing. Failure to obtain adequate permissions may be considered a breach of this protocol.

External communications: Ensure you quote the UH protocol number and the name of the approving Committee on all paperwork, including recruitment advertisements/online requests, for this study.

Invasive procedures: If your research involves invasive procedures you are required to complete and submit an EC7 Protocol Monitoring Form, and copies of your completed consent paperwork to this ECDA once your study is complete.

Submission: Students must include this Approval Notification with their submission.

Validity:

This approval is valid:

From: 03/02/20

To: 30/03/20

Please note:

Failure to comply with the conditions of approval will be considered a breach of protocol and may result in disciplinary action which could include academic penalties.
Additional documentation requested as a condition of this approval protocol may be submitted via your supervisor to the Ethics Clerks as it becomes available. All documentation relating to this study, including the information/documents noted in the conditions above, must be available for your supervisor at the time of submitting your work so that they are able to confirm that you have complied with this protocol.

Should you amend any aspect of your research or wish to apply for an extension to your study you will need your supervisor's approval (if you are a student) and must complete and submit form EC2.
Approval applies specifically to the research study/methodology and timings as detailed in your Form EC1A. In cases where the amendments to the original study are deemed to be substantial, a new Form EC1A may need to be completed prior to the study being undertaken.

Failure to report adverse circumstance/s may be considered misconduct.
Should adverse circumstances arise during this study such as physical reaction/harm, mental/emotional harm, intrusion of privacy or breach of confidentiality this must be reported to the approving Committee immediately.