

Is there a perceived increased in emphasis on literacy in Mathematics and could it have an effect on boys' performance in Mathematics?

Introduction

The proposals outlined within the Donaldson's "Successful Futures"¹ will lead to alterations to the way in which Mathematics is delivered and ultimately assessed in schools. Donaldson outlines the increase of numeracy both in Mathematics and across the wider curriculum with the idea that pupils will be given opportunities to develop and use their numeracy skills in a range of contexts.

"Mathematics helps children and young people to make sense of the world around them and to manage their lives. It gives them skills they need to interpret and analyse information, solve problems and make informed decisions."¹ Donaldson's proposals place a greater emphasis on numerical reasoning with the intention to produce more numerical competent pupils. He refers to successful models from other nations such as Singapore and how education professions will have to adapt these models to suit us in Wales. The work of mathematicians such as George Polya could be used to suggest methods to teach reasoning from his book "How to solve it?"² along with modern practitioners like Dr Yeap Ban Har, whose work can inform us about mathematical education in Singapore particularly at KS2 and early KS3.

However, in recent years, there have been already been a significant number of changes to the formal assessments faced by Welsh secondary school pupils in Mathematics, namely changes to the GCSE Mathematics papers and the introduction of a GCSE Numeracy qualification along with the Welsh National Numeracy Tests at KS3.

As secondary school teacher my initial thoughts when I first saw the specimen GCSE papers was that there was a significant increase in the amount of "words" in the paper rather than an increase on the numerical skill needed to solve the problem. I strongly believe that good, solid numeracy skills are very important and that the greater depth and challenge proposed by Donaldson is a positive change. But currently, my concern would be that a pupil with good numeracy skills might not be able to answer the question if they had poor literacy skills. This would mean that the exam was no longer truly testing the pupil's mathematical ability as there is a greater level of literacy skills needed to access the paper. Therefore, I would be interested to investigate whether this opinion is shared by colleague and pupils and whether it would impact on pupil performance, in particular boys, in Mathematics.

Literature Review

Traditionally, Mathematics is a subject where the gender gap is often in favour of boys making it one of the only subjects where this is the case. This is widely accepted both in the UK and worldwide and can be demonstrated with the analysis of UK GCSE results and PISA results³ over numerous years. However, there are multiple factors that might explain why boys often outperform girls in Mathematics.

Firstly, as a subject Mathematics involves the need to have good spatial awareness for topics such as geometry. It could be argued that boys often possess better spatial skills than girls due to the way they play in early childhood⁴. Boys tend to participate in games and play that involve more movement and physical activity than girls. This is a generalisation and in future generations these 'traditional' stereotypical behaviours might become less apparent in boys and girls. However, there is also a biological difference between boys and girls and on a very basic evolutionary level there might always be the need of the male brain to respond differently to a female brain as traditional 'male' tasks⁵ often require spatial awareness e.g. hunting.

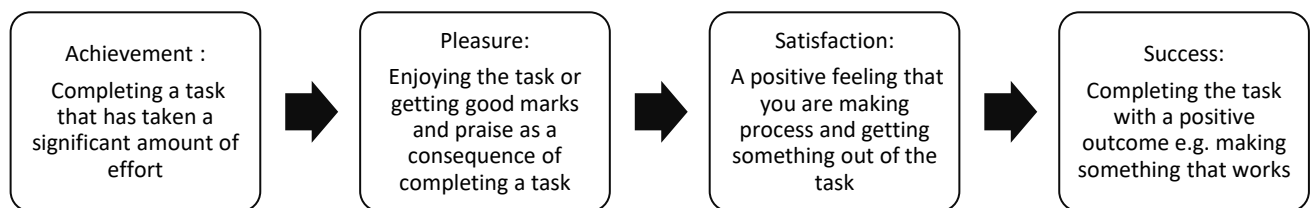
There have also been numerous studies into the performance of boys and girls in different settings e.g. same sex class v mixed classes. Often these studies have focussed on improving boys' performance in subjects other than Mathematics but there are some studies that focus on Mathematics specifically. From reading some of these types of studies a prevailing theme is the element of competition. It is generally found that girls perform less well than their male counterparts in competition⁶. Niederle and Vesterlund⁷ found that girls and women actively avoid environments where competition is needed.

I think that is significant for Mathematics in schools as, as a subject it often contains competition. - Mathematics is a subject where responses are quickly validated as correct or incorrect and often there is little room for opinion or different viewpoints. It is a very 'right or wrong' subject where traditionally answers are rarely up for discussion. This is suited to most boys mentally which could help to explain why they achieve in mathematics over other subjects.

If boys feel that they are suited to a subject it is going to improve their motivation to achieve. "In psychological terms, motivation is seen as an internal state or condition that serves to activate, energise or direct behaviour and to give the behaviour impetus, direction and focus⁸." If a pupil is bored they are

unlikely to learn effectively. Research has found that if a person is intrinsically motivated then they are more likely to try and achieve at a task than an extrinsically motivated person⁹. In school, often when pupils are asked to complete new or difficult tasks this is met with resistance. Pupils are not always intrinsically motivated to do tasks, especially if they feel that there is no benefit to them in completing the task.

As boys tend to have a greater confidence in their mathematical ability than girls they tend to be more motivated and work through the chart below¹⁰:



This cycle has a great impact on helping to get boys working in maths keeping them achieving ahead of girls consistently. Therefore, it is important that these initial experiences with Mathematics are important to set pupils up for a successful future in the subject.

The roots of a pupil's attitude towards a topic is influenced at a young age. Piaget's theory says that all children will develop at the same rate; this is not the case in practice. His theory is criticised because there is no reference to the social interactions that a child will experience or the environment in which the child is brought up.

A theory that takes into account a child's social interaction is that of Vygotsky. He believed that language plays an important role in learning and that language results from social interaction. This means that conversations with adults are important in a child's development and that allowing a child to verbalise their thoughts will help them to learn. Primarily this impacts on literacy and the vocabulary of a child. However, we could suggest that a parent's own attitude and approach to Mathematics would impact on the attitude of the child to the subject. If the language used by the parent around the subject of Mathematics is positive then it would follow that the attitude of the child may be more positive. From personal experience, people, often women, are far more likely to have say things like "I could never do Maths at school". It is socially accepted to say this where as there is much more of a stigma around saying that you have issues with your literacy skills. As Vygotsky mentions this mind set is picked up by the child and I think that this particularity impacts girls' attitude towards mathematics.

Vygotsky's theory is echoed by Jerome Bruner¹¹. He also suggested that a child's social and cultural background can impact on their learning and development. The principle of his theory is a spiral curriculum. A spiral curriculum involves revisiting the same topic again and again to strengthen understanding. Male role models in boys' lives may have a more positive attitude towards Mathematics, especially if the skills are used in their everyday/working life and this more positive attitude can be passed onto the child. With their own interactions they naturally develop a spiral curriculum where mathematical skills are tested outside of school in real world scenarios.

Further to this, the basic mathematical operators of addition, subtraction, multiplication and division are revisited over and over again. This repeated use of the same skills helps to embed the ability to complete the skill and helps to demonstrate the relevance of a skill.

However, Skinner raises the idea that mistakes can be de-moralising, leading to the questions are mistakes good or bad and is it correct to have the 'right or wrong' mentality in mathematics? If there is truly going to be an increase in the level of challenge and reasoning skills with mathematics lessons, as Donaldson advocates, pupils will have to become more resilient and accepting of making mistakes. This might impact have a greater impact on boys' performance if they are not also taught to develop the resilience to go alongside the increased challenge.

In addition, it is generally accepted that girls have better literacy levels than boys¹². Yet again, this is a widely accepted belief and there have been numerous studies to demonstrate this. Similarly, to boys' improving girls in Mathematics, there will be numerous factors and issues that might make this the case. From a Mathematics point of view, it could be concluded that the lower literacy skills have a smaller effect on performance in Mathematics than other subjects and that existing examinations successfully test mathematical ability.

However, as mentioned in the introduction, at first glance, the new GCSE papers appear to have an increase in the reading demands. Could this have an effect on pupil outcomes, particularly boys, as weaker literacy skills might hamper the pupils' ability to demonstrate their mathematical skills?

Methods and Analysis

Outlined in Basit, 2010, there are different paradigms that can be applied in educational research. As with the majority of the literature reviewed, this research would be a normative paradigm. A traditional approach to research where there would be data that could be analysed and, if done on a large enough scale, could be generalised. However, this means that there are assumptions and generalisations about boys and girls outcomes so some of the “uniqueness” of individuals would not be accounted for.

To investigate this hypothesis the methods used will be based mainly on inductive reasoning. That is, that the outcome of the hypothesis is unknown as yet, with the aim of having an unbiased start point. Once the information is obtained throughout the research, a conclusion should then be made. The alternative would be a deductive method where you start with an initial hypothesis and research to disregard the other possibility until you are left with one. I have decided against this option as in my hypothesis I have included the idea of perception which means that my hypothesis might not be the case at all, therefore the outcome of the hypothesis is unknown.

However, both inductive and deductive research methods have their issues, namely bias. In a deductive, you might be biased towards the outcome that has been decided upon and would not investigate the alternate options stringently. Whereas if an inductive method is used you might be subtly biased towards an outcome as it is difficult to have a totally impartial view on an issue. The aim of the research method is to try to ensure that you have taken the appropriate steps to minimise bias and to maximise the reliability of your findings. To investigate my hypothesis I will use a variety of methods in an attempt to avoid bias.

Firstly, I would look to consider the opinions of other Maths teachers by asking them to complete a questionnaire about the recent changes. As described in Basit, 2010 “a poorly devised questionnaire can make the task of data collection extremely difficult and time consuming.”¹³ To try to develop a useful question, I would firstly develop a pilot questionnaire which I would ask the teachers in the Maths department to answer. The responses from the pilot questionnaire might lead me to adapt or change some of the main questionnaire. I would then ask a larger sample of secondary school mathematics teachers to complete the main questionnaire so that it would increase the sample size. For example, all the secondary schools in Pembrokeshire and Carmarthenshire. This should provide a wider range of opinions from staff in different schools, areas and environments. Additionally, it could lead to common themes within the responses that could further be investigated.

Both the pilot and main questionnaire^A would be anonymous so that people would feel free to complete the questionnaire open and honestly. I would inform the participants of the nature of the questionnaire and make the conclusions available to them afterwards. The questionnaires would be numbered so if a participant wished to withdraw their responses they could do so by quoting the number of the questionnaire sheet they filled in. I believe that with the nature of the type of questions there would be a minimal risk that any personal or sensitive information would be gathered however as per BERA guidelines¹⁴ the option to remove their responses would be available to the participants. There would be no 'bribe' or reward offered to the individuals to participate as I feel that the responses would be more genuine that way. This might lead to a small number of responses which is regarded as a significant disadvantage of questionnaires; therefore, as mentioned, I would send the questionnaires to a large sample of secondary school teachers so that hopefully the number of responses would still be noteworthy.

Despite the anonymous and voluntary nature, the questionnaire will consist of a series of closed questions to provide quantitative data which could then be used to generate a profile of the individuals that complete it. These initial questions would be straight forward to answer and be very factual.

The open questions would generate qualitative data based on the participant's opinions. Each of these questions would contain a Likert scale to try to gather data about the participant thoughts and feelings but in a way that could still be analysed. The scale would have an even number of options. Due to the fact that with an odd number of options you could just fill in the middle option. The use of the even number forces the participant to show an indication as to if they agree or disagree with the statement. This should provide more telling and less neutral responses.

Further to the Likert scale, there would be a space for participants to fill in a written response if they wish. I would use a "word cloud" app to analyse these responses to help identify common themes within the various responses. This data would provide an insight into the opinions of current teachers and would indicate if there is or is not a perception that the new GCSE paper have a greater reading demand.

To start to triangulate the information and to look at the hypothesis from all sides, I would also select a group of pupils to complete a similar questionnaire^B. Triangulation is widely mentioned in all research

methods textbooks and is important as “when analysing data, it is important to step back and think about the wider picture.”¹⁵ The selected group would consist of 40 pupils, specifically:

20 boys predicted a C grade or above, of these:	10 pupils with a reading age equal to or above chronological age
	10 pupils with a reading age below their chronological age
20 girls predicted a C grade or above, of these:	10 pupils with a reading age equal to or above chronological age
	10 pupils with a reading age below their chronological age

Cohen and Manion¹⁶ refer to a sample size of 30 being widely regarded as the minimum number of cases if statistics analysis is to be carried out on the data. A sample size of 40 pupils would represent approximately 50% of a standard year 11 cohort in my current school. The size of the school does limit the number of pupils that could be included in the group. However, it would represent a significant portion of the cohort so would provide valid data for that cohort.

I have selected both boys and girls to see if there are any differences or similarities to their attitudes or opinions towards maths exams. As I ultimately want to see if the literacy aspect has an impact, I have chosen pupils that should possess numeracy skills (indicated by their predicted grade) but would have sub-categories based on their reading ages. This might provide information as to whether the changes in the exam papers have a greater impact on one sub category or another. The predicted grade would have been generated with both teacher input, previous test marks including their non-verbal test scores.

As with the teacher questionnaire, BERA guidelines¹⁴ would need to be followed. Pupils would be informed that they have been selected to take part in a questionnaire about their opinions on exams in mathematics. They would receive a consent form and the use and anonymity of the information gather would be made clear to them. The same numbered questionnaire method would be used to enable participants to recall their responses should they wish.

The responses and data gleaned from both the pupil and teacher questionnaire would gave an indication as to if there is a perceived emphasis on literacy in the new GCSE Mathematics papers. It could show whether both pupils and teachers share the same view point or whether they differ. Further to this, it should show if there are differences in boys and girls opinions.

To further validate the findings from the questionnaire I would perform follow-up group interviews with the pupils that were in the sample. The grouping of the pupils in the interviews might affect the discussion within the group, so this would have to be considered. Reading ages or gender could be mixed or separated with the different combinations possibly leading to different interactions and outcomes from the interviews. It would be unrealistic to interview the pupils several times in all the different possible combinations.

Therefore, the two focussed groups would be as follows:

4 boys from the original 20 participants in the questionnaire, of these:	2 pupils with a reading age equal to or above chronological age
	2 pupils with a reading age below their chronological age
4 girls from the original 20 participants in the questionnaire, of these:	2 pupils with a reading age equal to or above chronological age
	2 pupils with a reading age below their chronological age

The pupils would be asked if they would consent to taking part in the group interview and then 4 would be randomly selected. No offer of time off lessons would be given as this might provide a biased incentive to participate in the interview. The interviews would take place in the school during the second half of the lunch break with the intention of taking 15 to 20 minutes. This time would enable pupils to eat first and might make the atmosphere more relaxed and less formalised. There would be two separate groups of girls and boys as my hypothesis specifically includes the question of impact on boys' performance. It would be interesting to see if there was a difference in the opinions of the two groups and would triangulate the responses from the questionnaires.

As summarised by Tuckman, 1972¹⁷ there are merits to using both interviews and questionnaires. I feel that an interview after the initial questionnaire will provide the opportunity for participants to verbalise their opinions in more detail. It can sometimes be easier to verbalise opinions rather than writing them down as then you encounter more literacy issues. As the group would contain pupils with reading ages below chronological age the reliance on written responses could be a significant issue in gaining true responses in the questionnaire.

The same open questions from the questionnaire would be asked during the discussions mainly to see if the verbal responses matched the general themes analysed from the written responses. Individual responses from the questionnaire would not be read out to maintain anonymity but the 'word cloud' could be used as

a prompt or way to start the conversation as the group interview scenario could feel staged and unnatural initially.

Although an interview has the potential to provide valid, honest responses; there could be a real issue with the reliability of the responses. Within a group of people there will be different social interactions along with different personality types. For example, one group might contain a very dominant, talkative person that controls the flow and content of the interview. In this event, the opinions of the other members of the group might be influenced by this person or not even heard at all. These disadvantages are outlined in detail by Watts and Ebbutt, 1987¹⁸. Within the interview, it would be important to foster an atmosphere where each group member had the opportunity to speak openly about their opinions. This would be difficult to achieve and there is no guarantee that it would necessarily happen. After the interview that would have to be acknowledged and factored in when analysing the responses from the interviews. Having a fairly small interview group with 4 members should mean that it would be feasible that all members will have the opportunity to express their own thoughts.

The process of collecting and recording the outcomes of the interview are evaluated by Cohen and Manion¹⁴ where there are numerous possible techniques from detailed transcripts to summarising participants responses. As the purpose of the interview is to triangulate the questionnaire responses I would aim to identify the general themes along with any specific unique individual themes from the interview. A transcript would be written from the recording of the interview. Permission for recording the interview would have been obtained as it would have been outlined in the consent form the participants would have signed. As with the analysis of the questionnaire responses, I would create a “word cloud” from the transcript. This would identify any changes in the terminology used by pupils and provide more qualitative data about pupils’ opinions on the matter.

I have decided against a teacher interview as I feel that the responses from the questionnaire would be sufficient to generate a general ‘feeling’ of staff opinion on the hypothesis. As unlike with the pupils’ the issues around written responses would not be as significant. Furthermore, my belief is that the use of lessons observations would not be beneficial for investigating this particular hypothesis, as it refers to examination papers. However, if further research was to be undertaken, lesson observations would provide an insight into the impact of the new numerical reasoning skills that the Donaldson changes will bring into the curriculum over the coming years.

These interviews and questionnaires would provide evidence to whether there is a perception that the literacy demands have changed in the GCSE papers. To observe whether or not the new GCSE papers could have an impact on performance a brief case study could be carried out. The 40 pupils focus group would be provided with 3 new-style GCSE questions^D and during the next lesson the same 3 questions rewritten so that the word count was greatly decreased. These questions would be given to the pupils during normal maths lessons in standard test conditions which is a scenario that regularly happens within maths lessons. The same amount of time would be given to complete each question set. Between the two lessons the answers would not have been given to the pupils as this could impact the score on the second attempt of the questions. The new-style GCSE question would be answered first because the pupil should be able to read and interpret the required mathematical operation to solve the problem. If the old-style question was answered first it could be argued that this would act as a form of revision or prompting which the pupil would mentally access the next day to answer the new style question. Marks from these questions sets could then be analysed and conclusions could then be drawn.

The final step in the research would be analysis both previous and the new GCSE Mathematics papers to investigate whether the literacy demands has actually changed. Selected exam papers would be analysed using a computer programme that calculates the reading age of texts. This would provide quantitative data into the reading ages of the papers; any changes would be identified by this data. Intermediate papers would be used for this analysis as the grade range on these papers is B to E. Although, examination boards have to adhere to standards and regulations I could not find any specific standards which govern the reading age of the papers they produce¹⁹.

However, there are other factors than reading age that could be perceived as adding to literacy demands. For instance, the amount of words and the time needed to read and comprehend the information could be considered factors. Research into reading speed is available although the results are varied. For example, McCracken (1967)²⁰ said that 300 words per minute is the minimum reading speed for Grade 7 a UK Year 8. However, a study by Carver (1982)²¹ found that an 18-year-old college student also had an average word per minute rating of 300. These studies used text that was suited to the chronological age of the participants. So, we could conclude that if a GCSE paper is written for a 16 year, that on average they too should read the paper at a rate of 300 words per minute.

Likewise, to the analysis of the reading ages of the examination papers; a word count of the new and previous examination papers could be completed. One more, providing quantitative data which would demonstrate if there is a greater demand in the amount of reading time in the paper rather than changes in the complexity of the language used which is what the reading ages would indicate. The perception of increased literacy emphasis could be justified by this data, as if there are more words to physically read this is going to take time and mean less time to process and answer the questions.

To conclude, a variety of research methods would be employed to investigate the stated hypothesis. To improve the validity and reliability of the conclusions both interviews and questionnaires would be completed. As perception is mentioned in the hypothesis these methods would provide the qualitative data regards to conclude if there is a perceived emphasis on literacy from both a teacher and pupil perspective. The brief case study using both the new-style and old-style questions would give an indication as to whether the different style of question has an impact on the pupils' ability to answer it as the required mathematical skill would be the same in both question sets. The literacy demand would be the only difference. Finally, analysis of the actual exam papers in terms of reading age and amount of words would give quantitative evidence as to if there has been an increase in the literacy demands of the papers. Amalgamating and looking at all the evidence collected as a whole should then allow a conclusion to be made about the hypothesis.

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Appendixes

A. Teacher Questionnaire

1. How many years have you been teaching GCSE Maths?

Questionnaire #1

- | | | |
|--------------------------------------|--------------------------------------|---|
| ☐ 1 year | ☐ 4 – 5 years | ☐ 9 – 11 years |
| ☐ 2 – 3 years | ☐ 6 – 8 years | ☐ 12 years or more |

2. Which GCSE Mathematics tier/s have you taught?

- | | | |
|-------------------------------------|---------------------------------------|---------------------------------|
| ☐ Foundation | ☐ Intermediate | ☐ Higher |
|-------------------------------------|---------------------------------------|---------------------------------|

Please indicate to what extent you agree or disagree with the following statements and please express your opinions in further detail in the spaces provided:

3. The new GCSE Mathematics paper involves more reading than previously.

Disagree

Agree

☐	☐	☐	☐	☐	☐
1	2	3	4	5	6

4. The new GCSE Numeracy paper involves more reading than you expected.

Disagree

Agree

☐	☐	☐	☐	☐	☐
1	2	3	4	5	6

5. My pupils will struggle to access the new papers.

Disagree

Agree

☐	☐	☐	☐	☐	☐
1	2	3	4	5	6

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C. Links to new WJEC GCSE Mathematics and Numeracy Specimen Materials

Mathematics:

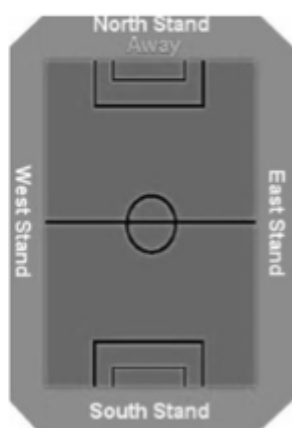
<http://resources.wjec.co.uk/pages/ResourceSingle.aspx?rId=696>

Numeracy:

<http://www.wjec.co.uk/qualifications/mathematics/r-mathematics-gcse>
[2015/WJEC%20GCSE%20Mathematics%20-%20Numeracy%20SAMs%20\(From%202015%20-%20WALES%20ONLY\)%20\(28-10-14\).pdf?language_id=1](http://www.wjec.co.uk/qualifications/mathematics/r-mathematics-gcse)

D. Experiment Questions

2. The diagram shows the ground layout of the Liberty Stadium.



During a recent game, the number of spectators in the

West Stand was	7345
East Stand was	6339
South Stand was	4991.

The North Stand is kept for away team spectators.
All 1093 away supporters were in the North Stand.

Showing all your working, calculate the total attendance at the game, giving your answer correct to the nearest 100.

[3]

2. Find the total of the following numbers and round your answer to the nearest 100

[3]

7345

6339

4991

1093