

Investigating the Impact of Literacy Skills in the Adult Mathematics Classroom

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Language, Literacy and Mathematics

Mathematics can be recognised as a language in its own right, a language which has its own vocabulary, grammar, symbols and punctuation (Ellerton & Clarkson, 1996). The teaching of mathematics, however, takes place within a spoken language, such as English (Zevenbergen, 2001). This spoken language is an essential element of the teaching and learning of the subject (Gorgorió & Planas, 2001). It is the vehicle for communication within a mathematics classroom and provides the tool for teacher-student interactions (Smith & Ennis, 1961). Language permits mathematics learners to ask and answer questions, to convey their understanding and to discuss their answers with others. It also plays a significant role in the processing of mathematical text and the interpretation of questions (Hoosain, 1991).

Changes to Second Level¹ Mathematics Education in Ireland

In September 2010, in light of a number of concerns regarding students performance in mathematics at all levels, the Irish Government introduced a national initiative called Project Maths. This initiative was a major reform of second level mathematics education. The overall aim was to teach mathematics in a way which leads to real understanding (Department of Education and Skills (DES), 2010) and it involved changes to what students learn in mathematics, how they learn it and how they are assessed. There is increased use of problem solving and applications that enable students to relate mathematics to their everyday experiences and apply their knowledge in familiar and unfamiliar contexts (DES, 2010).

The new curriculum, which identifies five strands of mathematics (Statistics and Probability, Geometry and Trigonometry, Number, Algebra and Functions), was implemented in 2010 using a phased approach over a number of years, and the assessment in the examinations was adapted as each strand was rolled out (Prendergast et al., 2017). This adapted assessment reflects the increased prominence of problem-solving and applications in the teaching and learning of mathematics and there is a greater emphasis on reading and understanding problems. Despite emerging evidence of the positive impact of Project Maths on students' experiences of learning mathematics, concern has been expressed regarding the perceived literacy demands of the revised syllabus (Cosgrove et al., 2012; Jeffes et al., 2013; Prendergast, Faulkner & O'Hara, 2016).

¹Equivalent to Key Stages 3 and 4 in the UK

Many teachers feel that students with low literacy levels and students for whom English is not a first language are struggling with comprehension of the material and the wordy nature of some of the questions: *“the language used when phrasing a question poses a major problem for students whose literacy skills would be weak, they can therefore not answer a question they are mathematically capable of doing! This is a major issue!”* (Cosgrove et al., 2012, p. 72). For example, “John has now collected 18 tokens. That is 7 more than he has last week. How many did he have last week?” will often receive the answer ‘25’ (Haylock & Thangata, 2007). Many students (including those studying at Higher Level) have also expressed difficulties with interpreting such word-based problems and with providing written explanations for their solutions to mathematical problems (Jeffes et al., 2013). Students also appear to lack confidence when asked to draw conclusions from a considerable amount of written information (Jeffes et al., 2013).

Widening Access to Higher Education in Ireland

For the past fifteen years, funding towards achieving a significant increase in the number of students from lower socio-economic groups participating in higher education has been provided by both public and private sources in Ireland (National Plan for Equity of Access to Higher Education 2008-2013). As a result, 15% of all first-time entrants to higher education in Ireland are now mature students, with numbers continuing to rise (Higher Education Authority (HEA), 2015). For example, the Dublin Institute of Technology (DIT)’s ‘Access Student Strategy’, which aims to ensure wider participation and equality of outcome in higher education, has as its target for 2020 a mature student quota of 20% of total student numbers, in addition to a young adult Access student quota of 7% of total student numbers (DIT, 2010). The growing number of Access students in higher education has also coincided with the introduction of Project Maths in second level schools with its afore-mentioned emphasis on literacy and language. This research aims to investigate the effect (if any) which Project Maths can have on Access students’ mathematical performance and to view the initiative from their perspective.

The Study

Access Foundation students in the DIT are mainly mature students (23 years of age or older) and young adult students (below 23 years of age) from socioeconomically disadvantaged and educationally disadvantaged backgrounds. In essence, Access students are “non-traditional” students. Schuetze and Slowey (2002) state that with regard to the framework of equality of opportunity, the term “non-traditional” tends to refer to socially or educationally disadvantaged sections of the population, which includes those from working class backgrounds, ethnic minority groups and immigrants.

Methodology

We decided to use a mixed method approach by combining both qualitative and quantitative methods of research. The use of multiple methods was decided upon in order to get an in-depth understanding of the research. The study evaluates Access students’ opinions of Project Maths and compares their scores in a traditional style mathematics examination (which reflects mathematics education in Irish second level

schools prior to the implementation of Project Maths) with their scores in a Project Maths style examination.

Methodological Consideration: Comparability of Test Questions?

When conducting this research the authors were conscious of the fact that the questions in the Project Maths style examination may be deemed to have a higher level of mathematical sophistication than the traditional style examination questions. The ‘Adult Numeracy Concept Continuum of Development’, which was developed by MaGuire and O’Donoghue (2002), demonstrates that conceptual understanding of adult numeracy is a three-phase continuum in which the level of sophistication increases from Phase 1 to Phase 3 (see Figure 1). In the context of this continuum, the traditional style examination questions align with Phase 1 and the Project Maths examination questions align with Phase 2. We acknowledge the value of using examination questions that can be directly compared within the framework of this model, and indeed would recommend that future research incorporate such considerations. Clearly there is an opportunity here for further investigation with a focus on evaluating any confounding effect of using different phase questions on differences in performance on the two examinations. However we designed this research to mimic the current shift in State assessment of mathematics in Ireland. This shift has increased the literacy demands on second level students in an education system which is effectively labelling each style of question as the same, thus a strong case can be made for direct comparability.

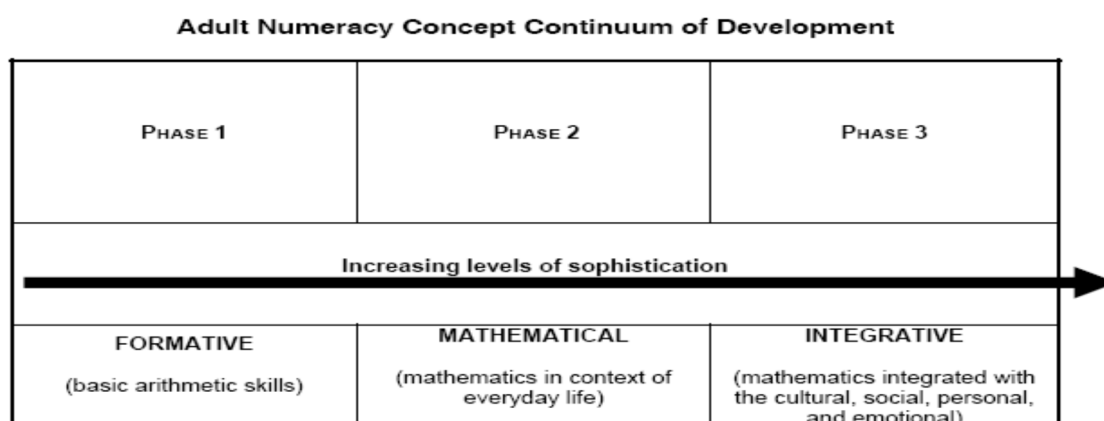


Figure 1. A continuum of development of the concept of numeracy showing increased level of sophistication from left to right (Maguire & O’Donoghue, 2002)

Participants

The participants in this study were fifty Access students who were enrolled in a year-long Foundation Programme in an Irish Higher Education Institute (HEI). The study took place in the 2014/15 academic year. Mathematics is one of six core subjects that all students are required to pass, along with two elective choices, in order to complete the programme. Upon successful completion of the programme, students are granted direct entry onto an undergraduate programme of their choice in the HEI. The aim of the programme is to equip them with the skills to meet the minimum entry requirements of such undergraduate programmes.

Of the participants, 75% were male and 25% female. The majority (78%) were Irish nationals with 71% speaking English as their first language. Other nationalities (such as German, Russian, Congolese and Somali) accounted for 22% of students. Ages ranged from 17 to 54 years with a median age of 31 years. All of the data was collected by us in 2014 in the participants' first semester of the programme.

Quantitative data

In order to get a quantitative measure of the effect of Project Maths on Access students, we decided to compare the scores of students in a Project Maths style examination with their scores in a traditional style mathematics examination. Each examination consisted of ten questions from the Junior Cycle Number strand and each question was taken from Irish second level textbooks and previous State examination papers. Students had fifty minutes to complete each examination. The questions based on the Project Maths method of assessment reflected the emphasis on understanding, problem solving and applications. The questions in the traditional style examination were technically the same questions but had numbers changed and were mathematical procedure and skill-based only with the removal of any context or language. For example:

Project Maths Style Examination Question:

Usain Bolt, the fastest man on earth, has a stride length of $2\frac{4}{5}$ m when he is at full stride.

In a 100m sprint, how many strides would Usain take to cover the final 30m when he is at full stride?

Traditional Style Examination Question:

Evaluate $46 \div 3\frac{2}{3}$

Students completed the traditional style examination first and then the Project Maths style examination directly afterwards. Ten marks were awarded per question. Each student received a mark out of 100 for each assessment.

At the end of the Project Maths style examination, there were also three closed-ended questions. The questions explored which examination the participants preferred, which examination they found more difficult and whether their English language skills had an impact on their performance in the Project Maths examination.

Qualitative data

In addition to the three closed-ended questions at the end of the Project Maths style examination, there were also a number of open-ended questions which all participants were invited to answer. The questions enquired about the main differences between both examinations, the students' opinions of Project Maths and what could be done to help Access students become accustomed to the changes brought about by Project Maths. The responses to these questions were transcribed, analysed and arranged into themes by the authors.

Results and Findings

Quantitative data

A paired-samples t-test was performed on the pairs of examination scores. The mean score on the traditional examination (M:47.44; SD:19.44) was found to be statistically significantly different ($t(df=49)=2.717$, $p=0.009$) to that on the Project Maths examination (M:41.94; SD:19.54). See Figure 2 below for a comparison of the mean scores. A 95% confidence interval for the mean difference on the tests for students on this Access programme was calculated as (1.918, 10.199). The effect size given by Cohen's d is 0.38.

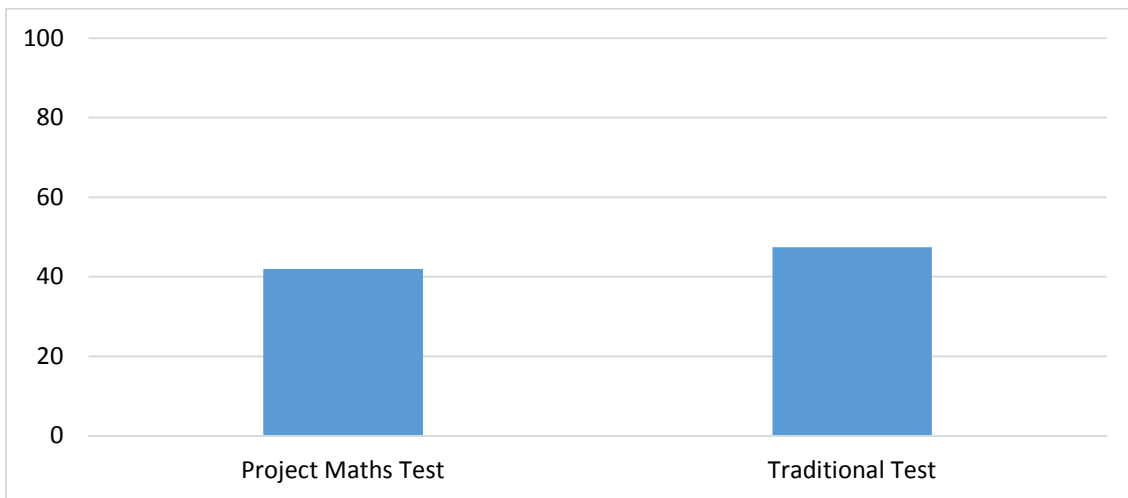


Figure 2. The mean scores on the tests were statistically significantly different. The figure shows the mean scores of Access Programme students in the Higher Education Institute on each test.

The response rate on the three closed-ended questions was between 70% and 86%. Of those who responded, 54% preferred the traditional style examination, 62% found the Project Maths examination more difficult and 89% believed that English language skills were an important factor in their performance in the Project Maths examination.

Qualitative Findings

Qualitative data analysis was carried out on the Access students' responses to the questionnaire data and several themes emerged under each question which provides further insight into students' performances in both the traditional and Project Maths examination papers.

Upon analysis of the question *"In your opinion, what were the main differences between the Project Maths and the Traditional Style questions?"*, three themes emerged from the 41 responses. The dominant distinction which 63% of students made between the two examinations, was that the Project Maths examination used words and involved analysis, thought and real life context, while the traditional examination was seen as being much easier and "just numbers". One student summarised this view point by stating: "Project Maths is full of reading and more thinking while traditional is very straightforward

maths". A smaller proportion of students (22%) noted that the Project Maths examination was better, despite the fact that it was considered more difficult: "it's useful – it allows you to think about a real situation – traditional is the opposite". The final theme which emerged in terms of the differences between the two examination papers was mentioned in 7% of student responses and stated that the traditional mathematics examination was familiar to them.

Students were also asked "*What is your opinion of Project Maths?*". Upon analysis of this data (for which there were 43 respondents), three major themes emerged. The dominant opinion on Project Maths (mentioned by 58% of respondents) was that it is better than the traditional style as it encourages genuine understanding of real life contexts. One student stated that "it allows for a better understanding as you could be familiar with the scenario, it's not just symbols". Of the respondents, 16% reported that they found Project Maths to be difficult because of the language used in it: "I think it's good but they should use visual aids too to help people who struggle with text", with another student stating that "it's very unhelpful if a student is dyslexic or has attention difficulties". A similar proportion of students (17%) noted that they found Project Maths difficult for reasons relating to basic arithmetic which makes it difficult to tackle the word problems: "I struggle with fractions so that was an issue for me". One student detailed their general frustration with Project Maths owing to a "difficulty understanding what needs to be done" and finding it very "time consuming".

The final question that students were asked was "*What can be done to help Access students become accustomed to the changes brought about by Project Maths?*". Of respondents to this question, 71% mentioned the facilitation of more practice for Access students with this type of mathematics in the form of homework assignments or practice in class: "we need more time to learn and lots of interaction and working together". Two students requested that maths vocabulary could to be taught to help them decode the Project Maths problems a bit more strategically. One student suggested that basic arithmetic and algebra needed to be strong before students could tackle Project Maths problems with another student backing this up by stating that "a mixture of both the traditional way and the Project Maths way" would be best.

The qualitative analysis of the students' questionnaire data supports the quantitative findings that students find the Project Maths examination more difficult while also providing some further insights into why this might be. Although difficulties with the Project Maths paper are expressed by many students, it should also be noted that 58% of students supported Project Maths as a better way of teaching and learning the subject. This is in spite of the many literacy and language difficulties associated with the reformed curriculum.

Discussion: Challenges faced with Language and the Learning of Mathematics: Supporting our Students

Along with the findings of the 'Research into the impact of Project Maths on student achievement, learning and motivation' (Jeffers et al., 2013) and 'Teaching and Learning in Project Maths: Insights from Teachers who Participated in PISA 2012' (Cosgrove et al., 2012) reports, this study highlights concern for learners in how they manage the literacy

demands of the reformed mathematics curriculum in Ireland. Statistically significant differences were found in the results of student scores in a traditional style mathematics examination with their scores in a Project Maths style examination. To support this, 89% of respondents believed that their English language skills were an important factor in their performance in the Project Maths examination. In effect, these results illustrate that students' language and literacy skills had acted as somewhat of a barrier to the learning of mathematics. The findings highlight the important role that literacy skills have in the teaching and learning process. A learner can have excellent mathematical ability but this is futile unless they can competently communicate and understand the language in which they are being taught and examined (Prendergast, Faulkner & O'Hara, 2016).

However this is not just a problem for adult learners. Primary school children's difficulties with mathematics have been summarised under four main headings: memory difficulties, language and communications difficulties, literacy difficulties and difficulties with low self-esteem (Krick-Morales, 2006). Language and literacy skills therefore play a key role in the biggest challenges for students trying to learn mathematics at any age. Much of the research in the area of mathematics education emphasises the importance of enabling students to use mathematical language effectively and accurately. The development of such a skill involves an ability to listen, question, discuss as well as read and report (Into Learning, 2015). All of these skills are now at the core of the reformed mathematics curriculum in second level education in Ireland. Hence, it is more important than ever that an importance is placed on the expression of mathematical ideas in order to develop mathematical concepts (Jeffers et al., 2013). One of the reported causes of failure in mathematics is poor comprehension of the words and phrases being used. This may be because some of the language used within the mathematics classroom has dual meanings in everyday life and some of the vocabulary will only be found in a mathematical context (Halliday, cited in Pimm, 1987). Both of these vocabulary types can cause confusion to the learner in their own right. As mathematics educators we must familiarise ourselves with the mathematics register and how imperative it is to use precise language when teaching the subject (Khisty & Chevli, 2002).

It must be noted that in spite of the challenges faced with language and the learning of mathematics, a majority of respondents in this study supported Project Maths as a better way of teaching and learning the subject. Overall, they felt enabled it them to relate the mathematics to real life contexts allowing for real understanding of the material to take place. As educators, it is encouraging to see that despite their difficulties, our students could see the bigger picture and realise that the previous focus on rote learning of material to pass examinations was not beneficial in the long term. The reformed approach has helped them realise that mathematics is about more than "just numbers". This is in line with adult numeracy policy in the UK which emphasises that learning mathematics should be functional and lead to increased employability and economic effectiveness (Oughton, 2009).

However despite such welcome sentiments, the findings also highlight that there are many language related challenges in the teaching and learning of mathematics, particularly regarding the use and potential overuse of word problems. For example, in

the Project Maths examination, many students were unable to complete questions that they were mathematically capable of doing in the traditional examination. With this in mind, Zevevbergen and Lerman (2001) question whether the posing of tasks into everyday contexts serves as a distraction from the main mathematical underpinnings of the task. This is an interesting debate. While putting mathematics into context has many advantages such as making the content more meaningful and relevant to students, it often creates another layer of disadvantage, especially for students with weak literacy skills (Zevevbergen & Lerman, 2001). Another angle which may be of relevance, is the findings of Cooper and Dunne's (1999) study. They determine that those from lower socio-economic backgrounds are more likely to perform poorer than their middle-class peers on mathematical word problems which have been built around contextualised tasks. Cooper and Dunne argue that students from working-class backgrounds are often unable to recognise the specificity of the mathematical tasks when they are embedded in "realistic" contexts. In contrast, middle-class students are more likely to identify the mathematical discourse and respond appropriately. This is an area which warrants further study and may have important implications for the teaching and learning of Access students.

Other language related challenges such as the time consuming nature of word problems, also have implications for practice and measures must be put in place to help students overcome such challenges. There were a number of suggestions by students in the qualitative data and some of these focused around the promotion of more "interaction" and collaboration between students. This highlights the importance of classroom discussion in the teaching and learning of mathematics and indeed any subject. Discussion plays a significant role in the acquisition of mathematical language and in the development of mathematical concepts. Our students can clarify ideas by discussing concepts and processes with their peers. Discussion with the teacher or lecturer has also been found to be extremely useful. Research carried out by Khisty and Chevli (2002) concluded that the teacher or lecturer should assist students, as the need arises, with the mathematical language necessary for them to express or clarify their ideas more accurately (Khisty & Chevli, 2002). This enables students to clarify mathematical ideas particularly where context could be causing difficulty in the formulation of ideas (Gibbs & Orton, 1994).

Conclusions

Mathematical ideas are understood by making connections between language, symbols, pictures and real life situations (Haylock & Cockburn, 2003). Research into young children's' mathematical development has found that without sufficient language to communicate the ideas being developed, to interact with peers and their teachers, mathematical development can be seriously curtailed (Perry & Dockett, 2005). The same developmental issues in mathematics must be considered in light of the findings within this research in which Access students, some of whose first language is not English, with others having poor literacy skills, are attempting to engage with word-heavy mathematical questions.

However despite the associated difficulties and challenges, the findings of this study emphasise that the use of contextualised tasks in mathematics should be not avoided entirely. Indeed the majority of students felt that the Project Maths approach was a better way of teaching and learning the subject. The findings do emphasise that more support is needed to help students overcome such challenges and to ensure that their language and literacy skills are not a barrier to the learning of mathematics.

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