Mathematical Literacy and Self-efficacy of First Year Third Level Students

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Abstract

A PISA style test was administered to first year students in three institutions across the third-level sector in Ireland. Immediately following this test a questionnaire was completed seeking to identify factors such as confidence, perseverance, and goal-orientation that may influence a student's mathematical achievement. In this paper, we will discuss some of the results from the test and a section of the questionnaire that referred to the students' confidence in performing those types of mathematical tasks.

Introduction

Much has been written about self-efficacy, which Bandura first described as "judgements of how well one can execute courses of actions required to deal with prospective situations" [1]. Previous studies have shown that self-efficacy is related to engagement in learning [9], and that there is a correlation between self-efficacy and performance on task (for example [10]). Confidence in one's ability to learn mathematics has been found to have a strong positive correlation with mathematical achievement, notably by Fennema and Sherman [4, 5].

Carmichael and Taylor [3] measured three levels of confidence: confidence to succeed in the course, in a mathematics topic and in a specific problem, and found that females and mature students reported lower levels of confidence on all three scales. They found that the specific measure of students' confidence (similar to Bandura's self-efficacy) was the most useful in predicting performance. However, Norwich [6] found general confidence in mathematical ability made significant contribution to performance, but once this effect is accounted for, no extra contribution was made by self-efficacy and concluded there was no simple relationship between task performance and self-efficacy.

In an effort to measure the correlation between self-efficacy and performance the authors designed an experiment where students attempted to solve a problem using a specific mathematical task and then were asked to rate their self-efficacy in that specific type of mathematical task. The results of this experiment are reported here.

The Test Instrument

The OECD Programme for International Student Assessment (PISA) aims to measure the knowledge and skills of 15-year old students. PISA defines

mathematical literacy as an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen [7, p.72]. The questions used in PISA tests are drawn from 4 subdomains (Space and Shape, Change and Relationships, Quantity, Uncertainty), 3 competency clusters (Reproduction, Connections, Reflection), and 6 levels of difficulty. Questions at the lower levels of difficulty can be solved by single-step or routine processes, while items with higher levels of difficulty require students to carry out complex tasks or to exhibit creativity. The PISA style test used in this study emphasised the understanding of concepts, the mastery of processes and the students' ability to function in a variety of real-life situations. The test used 10 items released from PISA 2000 and 2003, and covered all 4 subdomains and 3 competency clusters, but it did not cover all levels of difficulty (1 to 6). A more difficult test containing a larger than usual number of items at levels 5 and 6 was constructed in order to reflect the fact that the participants in this study were older than those involved in PISA and have, in general, achieved a higher level of mathematical attainment. The particular PISA items used are listed in Table 1, and their full text can be accessed from the PISA website [8].

The Participants

186 first year students in three institutions across the third-level sector in the Republic of Ireland (St Patrick's Drumcondra (SPD), IT Tralee (ITT) and NUI Maynooth (NUIM)) sat the test and completed the questionnaire. All students were studying mathematics modules. The SPD students were BA or BEd students who chose mathematics as one of their three first-year subjects. The NUIM students were either BA or Finance students. The BA students chose to study mathematics but the subject was compulsory for the Finance students. The ITT students were Engineering students for whom mathematics was compulsory. In Ireland, the vast majority of students take mathematics in the final examinations (the Leaving Certificate) at the end of secondary schooling. According to the State Examination Commission, in 2008 96.4% of all Leaving Certificate candidates took an examination in Mathematics [11, p.5]. Mathematics can be studied at three different levels for the Leaving Certificate: Higher, Ordinary, Foundation. Of the 186 students involved in this survey, 43% had previously studied mathematics at Higher level in secondary school, and 3% did not complete mathematics in final cycle of school. 45% of the participants were female.

Results of Test

As can be seen in Figure 1, there is a wide spread of results. In particular, not one of the 186 students had all 10 questions correct, and at the other end of the scale nearly 9% of the students got less than 3 correct.

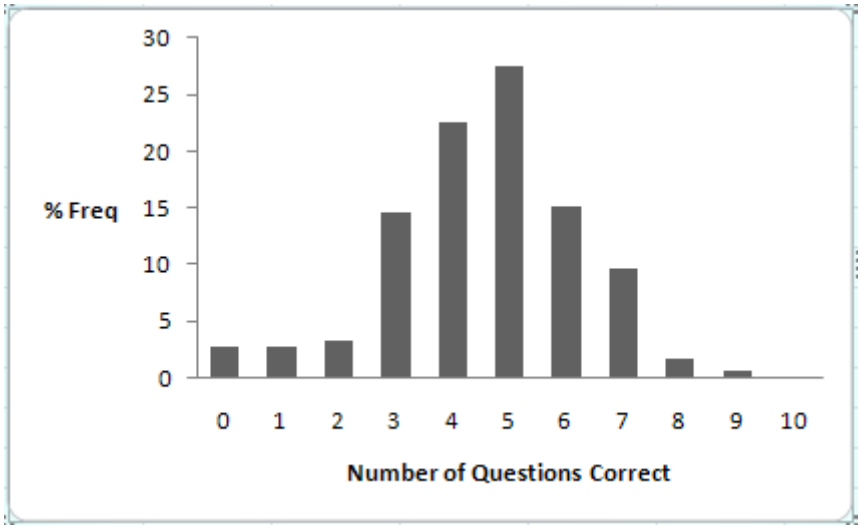

Figure 1: Overall results for test

Table 1 shows the results by question in detail. The question names are those given by PISA, and the levels shown here were assigned by PISA after analysis of their tests. We see that the level 6 questions were found to be much more difficult for the students in our study than the other questions.

Question	Level	Correct	Attempts	% missing	% correct (of attempts)	% correct (of total)
Exchange Rate 1	1	169	179	4	94	91
Exchange Rate 2	2	164	178	4	94	88
Exchange Rate 3	4	137	163	12	84	74
Earthquake	4	117	153	18	76	63
Test Scores	5	109	141	24	77	58
Walking 1	5	150	182	2	82	81
Walking 2	6	25	174	6	14	13
Continent Area (2)	6	13	116	38	11	7
Apples (3)	6	22	168	10	13	12
Carpenter	6	55	167	10	33	29

Table 1: Summary of Results by Question

To give a flavour of the type and level of question, Exchange Rate 1 gave information regarding the exchange rate from one currency to another and students were asked to calculate how much 3000 units of one currency would be in the other currency. In the level 6 question Continent Area students were given a map of Antarctica and asked to estimate its area using the scale given. It was deemed correct if the answer was between 12 and 18 million square kilometres. Only 13 of the 186 gave answers within the required range.

Confidence Questions

After attempting the test, students were asked to fill in a survey which included questions regarding their confidence to successfully complete mathematical tasks that had been required on the test. A 5-point Likert scale was used and their responses were categorized into confident (4 and 5 on the Likert scale) and not confident (1, 2 and 3), as seen below in Figure 2.

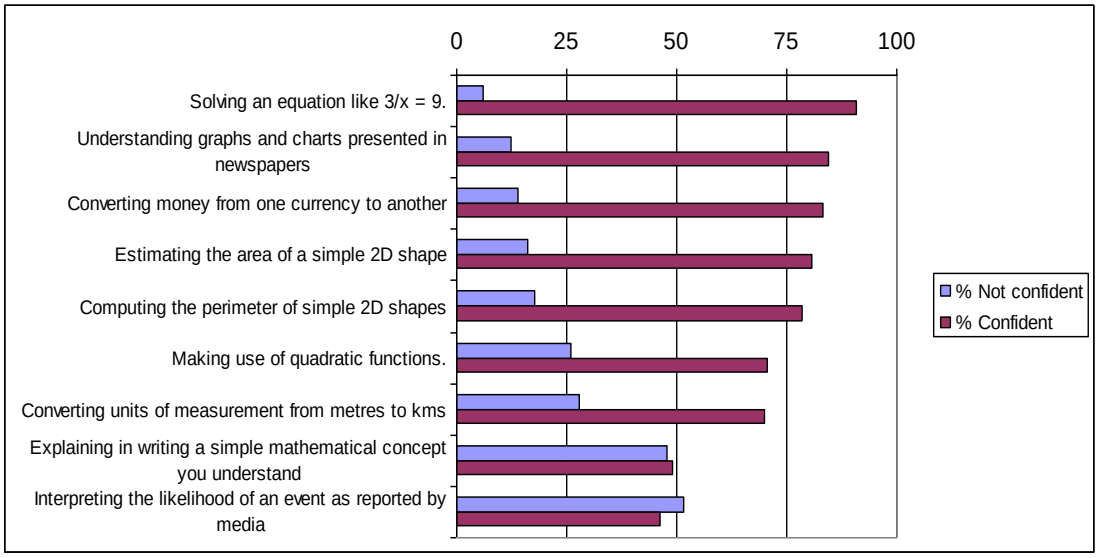

Figure 2: Summary of Self-Efficacy Questions

The majority of students felt confident with most of the mathematical tasks covered in the test, with two notable exceptions. Over half the students said they were not confident interpreting the likelihood of an event. More telling is that nearly half the students who responded to the query about their confidence to explain in writing a (simple) mathematical concept they understand are not confident doing so. It is also interesting to note that over a quarter of the third level students surveyed said that they were not confident converting a measurement from metres to kilometres, while 90% were confident that they could carry out currency conversion calculations.

Competence v Confidence

Now combining the test results with the relevant confidence questions we notice some pairs are closely correlated. But there are some very interesting anomalies (see Table 2 overleaf). For instance, the mathematical topic that students were least confident with was interpreting the likelihood of an event as reported by the media, with only 46% of respondents saying they were confident. Students had previously been asked to select the most appropriate interpretation of the statement “In the next 20 years, the chance that an earthquake will occur in Zed City is 2 out of 3” in the Earthquake question. 53% of students who did not attempt this question were confident in their ability to interpret likelihood, while only 46% of the students who did attempt the question were confident. In the sample as a whole 63% of students answered this question correctly. Moreover, there is little difference between

the groups with 60% of non-confident students answering correctly and 67% of confident students answering correctly.

Task	Related Question	% correct (of attempts)	% confident (of responses)
Solving an equation like 3/x=9	Walking 1	82	91
Understanding graphs and charts presented in newspapers	Test scores	77	84
Converting money from one currency to another	Exchange rate 1	94	83
	Exchange rate 2	94	
Estimating the area of a simple 2D shape	Continent Area (2)	11	81
Computing the perimeter of simple 2D shapes	Carpenter	33	79
Making use of quadratic functions	Apples (3)	13	70
Converting units of measurement from metres to kilometres	Walking 2	14	70
Explaining in writing a simple mathematical concept you understand	Exchange Rate 3	84	49
	Test Scores	77	
	Apples (3)	13	
Interpreting the likelihood of an event as reported by the media	Earthquake	76	46

Table 2: Summary of Competence and Confidence Questions

Examining Table 3, it can be seen that although twice as many non-confident students as confident students answered the Earthquake question incorrectly, the same number of students in both groups answered correctly. This may indicate that students might not have understood the confidence question.

	Incorrect	Correct	Not Attempted	Total
Not Confident	24	58	14	96
Confident	12	58	16	86
Missing		1	3	4
Total	36	117	33	186

Table 3: Earthquake Question Details

On the other hand, although the group had a high self-reported level of confidence for the tasks included in level 6 questions, the performance overall on these questions was quite poor. Returning to the question Continent Area, students were asked how confident they were in estimating the area of 2-

dimensional shapes. Looking at Table 4, we see that 139 of the 150 'confident' students (93%) either did not attempt the question or answered incorrectly. However, it is possible that the students did not regard the map of Antarctica as a "simple 2D shape".

	Incorrect	Correct	Not Attempted	Total
Not confident	9	2	19	30
Confident	92	11	47	150
Missing	2	0	4	6
Total	103	13	70	186

Table 4: Continent Area Question Details

Discussion

There seems to be a mismatch between the students' performance and self-efficacy and there does not seem to be any consistency where students are consistently under-confident or overconfident in their ability to successfully complete a mathematical task. On occasions, it seems there is a misplaced overconfidence in their own abilities, for example estimating the area of a 2-dimensional shape, while other times the students display lower levels of confidence when in fact they are able to complete tasks such as interpreting likelihoods of events. Two skills not always emphasized in second level in Ireland are the interpretation of results found and the written explanation of a mathematical concept, and it is interesting to note that the self-efficacy questions related to these skills returned the lowest confidence levels from the participants. As mentioned above the percentage of correct answers on the first of these tasks was quite high (63% of sample) while those on the second type of task varied from 74% on Exchange Rates 3 to 58% on Test Scores and only 12% on Apples (3).

A major constraint of this test and survey was that the students were generally only given one question to test each type of task, which naturally restricted the students' opportunity to display their ability. It may be that students felt that they were familiar with the mathematical tasks when asked about their confidence, yet didn't recognise when or how to use the skill when presented with a question. It could be that the questions were presented in an unfamiliar style or that they didn't recognise the skill required in context.

However, it is still surprising that many in this survey had such difficulty applying some familiar mathematical concepts to everyday problem solving. As the PISA questions were designed for 15 year olds in second level education. It does raise the question as to how mathematically literate, in PISA terminology, are those students who reach third level education and study mathematics. In addition there were a number of questions where large numbers of students didn't even attempt to answer, up to 38% in the case of the question Continent Area. This could indicate the level of difficulty students may have had in completing the test, but more worryingly, it could also be an

indication of a lack of incentive to persist at a task, a trait needed to succeed in mathematics.

To date, the analysis of this data has not shown a clear relationship between confidence and competence on mathematical tasks. It would indeed back up Norwich's claim that if such a relationship exists, then it is complex. The associated questionnaire is currently being analysed and a general measure of confidence has been calculated using Rasch Analysis [see 2] along with other measures such as persistence, goal orientation and beliefs on the nature of intelligence. It is planned to undertake further analysis with these measures and to use partial scores on the PISA test to investigate the existence of relationships between self-efficacy and performance and engagement in mathematics learning.

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