Measuring Students' Persistence on Unfamiliar Mathematical Tasks

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182 students responded to a number of Likert-scale items regarding their persistence on mathematical tasks. Rasch analysis was then used to construct a measure of persistence from their responses and to assign persistence scores to each student. The same students, all of whom were enrolled in the first year of a third-level programme, also completed a 30-minute test involving mathematics items from PISA. The latter, although commensurate with the students' level of mathematical education, represented largely unfamiliar tasks to the students and required the transfer of previously learned mathematical knowledge and skills to a new context. The students' performance on these items was used to construct a second measure of persistence. Initial findings indicate that although the correlation between the self-reporting measure and the evidence provided by the PISA-type test is statistically significant, there are some inconsistencies between the self-reported data and observed behaviour.

Keywords: persistence, unfamiliar tasks, self-reporting measures

Introduction

Dweck (1986) put forward a theory on the relationships between students' beliefs concerning the nature of intelligence, their goal orientation, their confidence, and their willingness to seek challenges and to persist when faced with difficulties during their learning of mathematics. The authors undertook a study to test this theory for students studying mathematics in their first year at third-level. Findings on some aspects of the role of confidence, theory of intelligence and goal orientation in determining students' persistence have been discussed in O'Shea, Breen and Cleary (2010). This paper focuses on a comparison of self-report and behavioural measures of a student's persistence on unfamiliar mathematical tasks –that is, tasks involving familiar skills but presented in an unfamiliar context, or tasks invoking skills not typically required in students' prior experience. An account of the results and the reliability of the self-reporting measure will be presented.

Sample

The study was conducted in the second semester of the 2007/2008 academic year and the participants were all in the first year of their respective programmes at one of three third level institutions: namely St Patrick's College, Drumcondra (BEd or BA (Humanities) programme), the National University of Ireland, Maynooth (BA or BA (Finance)) and the Institute of Technology, Tralee (Higher Certificate in Engineering or BSc). All students had either chosen to study Mathematics or were required to study it as part of their programme. The survey was administered during class and students were invited to participate in the study. 182 students completed the survey; of these 82 (45.3%) were male.

Questionnaire

The students anonymously completed a 20-minute questionnaire in which they were asked to respond to sets of rating scale items addressing Confidence, Theory of Intelligence, Goal Orientation (Learning or Performance) and Persistence. The items for the first three traits were gathered from a number of sources (for full details see Breen, Cleary and O'Shea 2009). However, the Persistence items were constructed for this study, based on hypotheses put forward by Dweck and Elliott as to the behaviour of, and strategies employed by, students when presented with mathematical tasks (Dweck 1986; Dweck and Elliott 1988). These are shown in Table 1. All items used a 5-point Likert scale (with 1 representing 'disagree strongly', 2 representing 'disagree', 3 'not sure', 4 'agree' and 5 'agree strongly'). Personal information (including gender and level of mathematics achievement at post-primary school) was also collected from the participants.

Persistence
1. When presented with a mathematical task I cannot immediately complete, I increase my efforts.
2. When presented with a mathematical task I cannot immediately complete, I persist by changing strategy.
3. When presented with a mathematical task I cannot immediately complete, I give up.
4. When presented with a choice of mathematical tasks, my preference is for a challenging task.
5. When presented with a choice of tasks, my preference is for one I know I can complete.

Table 1: Rating scale items for Persistence

Critique of self-report measures

Fulmer and Frijters (2009) detail a number of concerns with respect to the use of self-report measurement scales (in measuring motivation) such as the application of existing scales to different subject areas without proper validation, the use of existing scales with different age-groups without regard for developmental differences in traits of interest, the assumption of the unidimensionality of a rating scale without verification, the use of responses to ordinal level Likert scale as interval level data, and the presence of positively and negatively worded items increasing cognitive demands and reducing reliability. However, the use of Rasch analysis in analysing Likert scale self-reported data, as was undertaken here, addresses these concerns.

Other weaknesses of self-report measures, as outlined by Fulmer and Frijters (2009) remain. For instance, there may be inconsistencies between observed behaviour and self-reported data, a respondent's interpretation of items may differ from the researchers', or items containing contextual references as well as references to the construct may result in inconsistencies in responses. Also, the neutral category in Likert scale items used may be chosen by respondents for different reasons (e.g. feeling unsure, indifferent); yet Fulmer and Frijters also highlighted problems with Likert scale items with an even number of response categories. In light of these concerns regarding the use of self-report measures, the authors decided to construct a second measure of persistence by measuring students' overt behaviour when presented with unfamiliar mathematical tasks. This was achieved by measuring the students' choice to pursue and their level of engagement with the tasks. A PISA-style test was constructed using 10 items released from PISA 2000 and 2003 (OECD 2006), covering all 4

subdomains and 3 competency clusters, but not all levels of difficulty. The test contained a larger than usual number of items at levels 5 and 6 in order to facilitate measurement of persistence and to reflect the fact that the participants in this study were older than those involved in PISA and had (in general) achieved a higher level of mathematical attainment. The particular PISA items used are listed in Table 2. Students were given 30 minutes to complete the test, as is the practice in PISA assessments.

Item	Level	Subdomain	Competency
Walking 1	5	Change & Relationships	Reproduction
Walking 2	6	Change & Relationships	Connections
Apples	6	Change & Relationships	Reflection
Continent Area	6	Space & Shape	Connections
Exchange Rate 1	1	Quantity	Reproduction
Exchange Rate 2	2	Quantity	Reproduction
Exchange Rate 3	4	Quantity	Reflection
Test Scores	5	Uncertainty	Connections
Carpenter	6	Space & Shape	Connections
Earthquake	4	Uncertainty	Reflection

Table 2: PISA items used

Students were also asked to rate their confidence in performing different types of mathematical tasks, correspoinding to the processes involved in solving these PISA questions (see Cleary, Breen and O'Shea (2010) for further details).

Analysis and results

Rasch analysis and self-report persistence measure

Rasch analysis is a means of constructing an objective fundamental measurement scale from a set of observations of ordered categorical responses (to assessment items or rating-scale items). The scale produced is an interval one centred at 0 (Bond and Fox 2007). Analysis of the responses to the Persistence items in this study resulted in 40% of students being awarded negative Persistence scores. Following the assumption that useful measurement involves the consideration of a single trait or construct at a time (i.e. assumption of unidimensionality), the Rasch model incorporates a quality control mechanism using error estimates and fit statistics to verify this. Fit statistics for the Persistence scale here indicate that all items are contributing to the measurement. Moreover, the person reliability of the scale was found to be 0.7, while the item reliability was 0.98. (Supporting evidence of reliability was provided by a Cronbach's alpha measure of 0.732.) Furthermore, the model facilitated the production of an item-person map which determined that the range of trait levels observed matched well with the range of participants, ensuring the appropriateness of the instrument for the sample.

Behavioural measure

Overall there was a wide spread of results on the PISA style test of 10 questions. In particular, not one of the 182 students had all 10 questions correct, and at the other end of the scale nearly 9% of the students got fewer than 3 correct. In PISA, scores are assigned to six literacy levels to distinguish between different levels of proficiency. For a description of these six levels see OECD (2009, 122). For example, at level 1 students can carry out routine procedures when given direct instructions, while at level 6 students display deep understanding of the subject and are creative problem solvers. Participants' scores on the PISA-style test were converted to the scale used by PISA - the range of these scores was from 199 to 783, with an average of 588.12, indicating an average literacy level of 4 (OECD 2009).

To measure persistence, the number of questions, and in particular, the number of level 5 and 6 questions, each student attempted was recorded. The table below shows that all participants attempted at least one level 6 question. In fact almost 87% of students attempted at least three of these four questions.

No of Level 6 questions attempted	Frequency	Percentage
1	4	2.2
2	20	11.0
3	56	30.8
4	102	56.0
Total	182	100

Table 3: Number of level 6 questions

The most difficult question for this group of students was the level 6 question labeled Continent Area: 37% of students made no attempt, a further 16% were awarded no credit for their attempts and only 7% scored full marks.

Comparison of Measures

Correlations were computed between the self-report Persistence measure constructed using Rasch analysis and the behavioural persistence measures mentioned above. Results are shown in Table 4.

	PISA score	Total of number of questions attempted	Number of Level 6 questions attempted
Correlation coefficient	0.314	0.195	0.187
Significance Level	0.01	0.01	0.05

Table 4: Comparison of self-report and behavioural measures

In order to allow further comparison of results by means of chi-squared tests the self-report Persistence scores were recategorised into low, moderate and high levels of persistence using the 33rd and 67th percentiles. Students with high persistence were more likely to have

- achieved highest literacy levels (5 and 6) on the PISA-style test: 61% of those showing high persistence achieved literacy level 5 or 6 compared with 43.4% of those displaying low persistence (p=0.002);

- attempted all level 6 questions: 69.5% of students with high persistence compared with 45.3% of those exhibiting low persistence (p=0.083);

- attempted the most difficult question on Area: 74.6% of students in the high persistence category compared with 54.7% of those in the low persistence category (p=0.069).

Discussion

While the correlation coefficients computed between the self-report Persistence measure and behavioural measures used are statistically significant, they are not as strong as might be expected. The sample was also divided by gender and no significant differences were observed between male and female subgroups. The correlations between self-reporting and behavioural measures might be improved if students had been allowed more time to complete the PISA-style test or if students had greater incentive to persist on the test.

At first it may seem that many students have a very false impression of their own levels of persistence, deeming themselves more persistent than is merited. In fact the self-reporting items resulted in a wide range of persistence scores being awarded, with 40% of the sample being awarded negative scores. An anomaly arises in the students' responses to the self-efficacy items related to the mathematical tasks presented. The majority of students were very confident in their abilities to successfully complete the tasks involved in the level 6 items: such as, to compute the perimeter and area of 2-dimensional shapes, to make use of quadratic functions, and to explain in writing a simple mathematical concept that they understand. But the number of students failing to persist with the corresponding PISA items did not appear to reflect these levels of confidence.

It may be that the tasks were so far removed from students' usual experience of mathematical tasks at school that they did not recognise them as being within their capabilities. There is some evidence that in post-primary schools in Ireland a procedural rather than conceptual or problem-solving approach prevails in the teaching of mathematics, and that teaching for examinations is an overriding preoccupation (Lyons et al. 2003). Moreover, while the Mathematics syllabus for the senior cycle of post-primary school includes in its list of objectives that students should be able to analyse information presented in unfamiliar contexts and should be able to create mathematics for themselves, supporting, communicating and explaining their findings, it is acknowledged that the formal written state examinations taken by students at the end of post-primary do not assess these objectives. It may be that this system contributed not only to the students' behaviour when presented with the mathematical tasks from PISA but also to their view of what was expected of them in attempting the tasks.

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