Determinants of Success in Learning Mathematics: A Study of Post-Secondary Students in New Zealand

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In this paper, I report on doctoral research in which I investigated the relationships between student approaches to learning, conceptions of mathematics, mathematical self-efficacy, personal factors and examination results. Using seventy-three post-secondary mathematics students, some pertinent findings were: self-belief in selection processes predicted high examination results; deep approaches and cohesive conceptions correlated positively with examination results; participants with low prior mathematics performed better than individuals with advanced secondary qualifications. These findings could pose practical teaching implications in mathematics education.

Introduction

My study examined the relationships between students' mathematical self-efficacy (MSE), student approaches to learning (SAL), student conceptions of mathematics (SCM), personal factors (age, prior mathematics) and mathematics examination results. This study is important as it serves to highlight personal, affective as well as cognitive determinants that influence mathematical performances of post-secondary mathematics students. It also serves as a conduit for mathematics education researchers and post-secondary mathematics educators to conceptualise student learning and enhance teaching programmes. The key constructs of this study were prior mathematics, age, student approaches to learning, conceptions of mathematics, mathematical self-efficacy, and mathematical performances.

Personal Factors: Prior Mathematics and Age

Prior knowledge is defined as the highest mathematics qualification gained at school. A New Zealand report by Engler (2010) argued that gaining mastery of the skills taught in secondary mathematics could improve advancement in tertiary education. In order to achieve higher levels of university performance, students should achieve a level of understanding that leads to proficiency in the use of those skills and knowledge. As expected, attaining the highest mathematics secondary education (Year 13) is advantageous for future success in tertiary education (Henderson & Broadbridge, 2009).

In particular, young people (15-24 years old) were targeted by the New Zealand Tertiary Education Commission (2013) as a priority group for increasing Science, Technology, Engineering and Mathematics (STEM)-related qualifications. As such, raising mathematics performances of young people could contribute to STEM-related careers in NZ. An empirical study of tertiary students by Carmichael and Taylor (2005) found that while there was no significant difference in mathematical performances of traditional students (18-25 years old), non-traditional students (over 25 years old) could perform better than the younger counterparts due to greater self-efficacy levels. Furthermore, a study by Miller-Reilly (2006) showed that academic support helped non-traditional learners to develop greater confidence in learning mathematics and improved their grades. Non-traditional students tended to have a better academic preparation in foundation studies

2018. In Hunter, J., Perger, P., & Darragh, L. (Eds.). Making waves, opening spaces *(Proceedings of the 41st annual conference of the Mathematics Education Research Group of Australasia)* pp. 575-582. Auckland: MERGA.

(Liston & O'Donoghue, 2010), develop a sense of confidence and enjoyment in learning (Carmichael & Taylor, 2005; Miller-Reilly, 2006) and accept challenges in learning (Forgasz & Leder, 2000). Therefore, non-traditional students could perform better in their studies since they were more mature and committed to learning.

Cognitive Factor: Student Approaches to Learning

SAL, originally coined by Marton and Säljö (1976), refer to co-existence of intention and process of learning. A deep approach involves the motive of intrinsic interest and strategy to maximise meaning, whereas a surface approach to learning is driven by one's fear of failure and a process of rote-learning. An achieving approach or organised effort which overlaps with a deep approach, is driven by one's need for obtaining good grades and how one makes use of space and time to achieve a task. These learning approaches affect the quality of learning outcomes.

Affective Factor: Student Conceptions of Mathematics

Student conception of mathematics, as a form of belief within the affective system, can be described as stable traits and mathematical world views (DeBellis & Goldin, 2006). An international study of 1182 mathematics students by Wood et al. (2012) reported that students at SCM level 1 perceived mathematics to be about numbers and components (53%); at SCM level 2, mathematics is considered to be about modelling and abstraction (34%); and at SCM level 3, mathematics is perceived to be relevant to life (6%). The SCM level 1 as a study of numbers, components or techniques that could be used to solve problems overlaps with 'fragmented conception' of Maths as a set of numbers, rules and formulae which could be applied to solve problems (Crawford, Gordon, Nicholas, & Prosser, 1994). In contrast, cohesive conception, whereby mathematics is a complex logical system which could be used to solve complex problems and provides insights used for understanding the world, was identical in meaning to how mathematical modelling is used to solve real life problems (SCM level 2) and mathematics is applicable in people's lives (SCM level 3). These high level cohesive conceptions tended to be formed by mathematicians, who were familiar with mathematical applications. Moreover, Crawford et al. (1994) reported that fragmented conception was related to a surface approach and unsuccessful outcomes whereas cohesive conception of mathematics corresponded with a deep approach and positive outcomes.

Affective Factor: Mathematical Self-Efficacy

Another construct of this investigation is mathematical self-efficacy. According to Bandura (1997), mathematical self-efficacy is a personal judgement of one's ability to do mathematics. Self-efficacy produces learning outcomes through major processes known as cognitive, motivational and selection processes. Firstly, cognitive processes are described as thinking processes which involves the acquisition, organization and use of information. As a function of self-appraisal of capabilities, goal setting resides in forethought which translates into purposive actions. People with high self-efficacy mediate through cognitive processes by visualising success, which in turn provides cognitive support and guides for attainment. The stronger the self-efficacy, the higher the goals individuals set themselves to attain performances. Secondly, self-efficacy plays a key role in self-regulating motivation. Motivational processes include causal attributions, outcome expectancy, and cognized goals, corresponding with the attribution theory, expectancy-value theory and goal theory. In causal attribution, people with high self-efficacy will attribute poor outcomes to lack of effort whereas those with low self-efficacy attribute failure to low ability. Further, expectancy theory states that people expect their behaviour and actions to bring about valued outcomes. People with high self-efficacy are more likely to persevere and attain successful outcomes. Also, goal setting is governed by the cognitive processes of motivation. Those with strong self-efficacy will endeavour to reach their goals through effort and persistence. Thirdly, driven by selection processes, people are partly the product of their environment because they choose the social and physical environment and types of activities that they judge themselves to be capable of handling. In theory, these metacognitive processes determine self-efficacy and indirectly affects the outcomes of learning.

In metacognitive terms pertaining to self-efficacy, self-belief for self-regulated learning promotes both skill mastery and learning strategies. According to Bandura (1997), self-regulation entails skills and strategies for planning and organizing instructional activities, utilising resources, adjusting one's own motivation and using metacognitive skills to evaluate the adequacy of one's strategies and knowledge. Students who have strong belief in using self-regulation strategies tend to have better mastery of mathematics skills and performances because they develop learning strategies such as, orienting oneself before an assignment, collecting relevant resources, integrating ideas and monitoring progress in learning. As such, these strategies would enable individuals to steer their learning processes, to self-regulate their motivation for learning and amount of effort.

Many researchers have shown that self-efficacy predicts success in mathematics performance (Pajares & Kranzler, 1995; Pajares & Miller, 1994; Skaalvik & Skaavik, 2011).A study of middle and high school mathematics students has found that self-efficacy was a better predictor of mathematics achievement than prior achievement (Skaalvik & Skaavik, 2011). This result was also evident for higher education students of calculus in a study by Hall and Ponton (2005) who found that university calculus students who reported high self-efficacy gained better results than other remedial students who also had low prior experience and/or achievement. Pajares and Kranzler (1995) concluded that students had high self-efficacy because they exhibited more effort and perseverance in challenging problem-solving situations. Although these findings were reported in different educational settings, these studies serve to conceptualise the role of self-efficacy in learning mathematics.

Mathematical Performances

Mathematical performances are measured by mathematics examination scores. The mathematics examination is an appropriate product of learning given that summative assessments fulfil a broad range of learning, ranging from mathematical calculations and comprehension to applications of knowledge in the course learning outcomes. If a student attains 50% marks and above in an examination, it indicates success in the course.

To date, there has been insufficient research in post-secondary education, which relates the constructs of SCM, MSE and SAL to mathematics performances. In order to advance research in student learning within the fields of psychology of learning mathematics and affect, my research questions are as follows:

Q1. What is the relationship between mathematics self-efficacies in five areas (problem-solving, cognitive, motivational, selection processes, and self-regulated learning), deep approaches to learning/organised effort/surface approaches to learning, as well as conceptions levels 1,2 3 in relations to examination results?

Q2.Which factor(s) is/are the most salient predictor(s) of mathematics performances?
Q3.To what extent do age differences, course type and highest level of secondary mathematics determine success in learning mathematics?

Method

Seventy-three (37% of cohort) mathematics students in a New Zealand tertiary institution participated in this study. The sample consisted of males (80%, N=58) and females (20%, N=15). Their ages were 18-25 years old (73%, N=53) and over 25 years old (27%, N=20). Given that some data were missing, at secondary levels, the majority had achieved National Certificate of Educational Achievement (NCEA) Level 3 (30%, N=22) or an overseas qualifications (29%, N=21). Some had completed NCEA Mathematics Level 1 (8%, N=6), NCEA Mathematics Level 2 (15%, N=11) and Mathematics at Cambridge and International Baccalaureate (IB) levels (7%, N=5). The engineering participants were enrolled in Pre-Degree Engineering Mathematics (N=5), Engineering Mathematics 1 at diploma level (N=47) and Engineering Mathematics 2 at degree level (N=6). The business participants were enrolled in Programming Precepts (N=7) and Business Statistical Analysis (N=8).

Using five-point Likert style questionnaires (Likert, 1931), the Refined Self-efficacy Scale (Marat, 2005), Conceptions of Mathematics Form (Wood, Petocz, & Reid, 2012) and the Shortened Experiences of Teaching and Learning Questionnaire (Hounsell et al., 2005) were distributed in March-May. The mathematics examination results were recorded in July. After data collection, the IBM SPSS 22 statistical software was used to carry out correlational studies, multivariate regression and general linear model analyses.

Findings

Q1. Relationships Between Sub-Constructs of MSE, SAL, SCM and Results

Using the categorisations of the strength of correlations (i.e., strong correlations range from R =.7 to .9, moderate to be .4 to .6, weak as ranging from .1 to .3 (Dancey & Reidy, 2004), moderate correlations were found between examination results and self-efficacy in problem-solving and self-efficacy in using motivational, cognitive, selection strategies (see Table 1); deep approaches and organised effort. Weak and positive correlations (two-tail significance) were reported between results and self-belief for self-regulated learning; results and deep approaches; results and Level 2 SCM (see Table 2). The highest mean scores were 'Self-belief in using motivation strategies' (3.66), 'Deep Approaches to Learning' (3.96) and 'Level 1 SCM' (3.98) and 'Level 2 SCM' (3.96).

Table 1
Mean, Standard Deviation and Correlations of MSE and Examination Results (N=73)

	1	2	3	4	5	6
1.Examination results	1					
2.Self-efficacy in solving mathematical problems	.43**	1				
3. Self-belief in using motivation processes	.41**	.65**	1			

4. Self-belief in using cognitive processes	.48**	.77**	.80**	1		
5. Self-belief in using selection processes	.52**	.62**	.73**	.83**	1	
6.Self-belief for self-regulated learning	.39**	.71**	.72**	.86**	.87**	1
Mean	51.08	3.38	3.66	3.38	3.46	3.48
Standard deviation	23.24	0.59	0.69	0.65	0.77	0.67

Table 2
Mean, Standard Deviation and Correlations of SCM, SAL and Examination Results (N=73)

	1	7	8	9	10	11	12
1.Examination results	1						
7. SCM Level 1	0.08	1					
8. SCM Level 2	.23*	.69**	1				
9. SCM Level 3	0.14	.33**	.48**	1			
10.A deep approach	.27*	0.04	0.21	0.23	1		
11.A surface approach	-0.11	-0.16	-.27*	-0.03	-0.12	1	
12. An organised effort	0.16	-0.01	0.02	0.08	.63**	0.14	1
Mean	51.08	3.98	3.96	3.44	3.96	3.16	3.77
Standard deviation	23.24	0.87	0.80	0.87	0.64	0.91	0.91

Notes. **p< 0.01. * p<0.05.

Q2. Factors Predicting Performance

Considering all the predictors (See Table 3), the most significant predictor was self-belief in selection processes given that the regression assumptions were not violated (Hair, Black, Babin, Anderson, & Tatham, 2006). The F ratio of the model mean square to error mean square was 4.702 (df=7, Sign=0.000).The model (Beta=0.589, t=2.413, p=0.000) accounts for 34.7% (R square) of the variation of results.

Table 3
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13345.505	7	1906.501	4.702	.000[b]
	Residual	25141.434	62	405.507		
	Total	38486.939	69			

a. Dependent Variable: Mathematics examination results. b. Predictors: (Constant), Self-belief for self-regulated learning, SCM Level 2, A deep approach, Self-efficacy in solving mathematical problems, Self-belief in using motivation strategies, Self-belief in using selection processes, Self-belief in using cognitive processes.

Q.3 Personal Factors Predicting Performance

53% of the participants (N=73) passed the mathematics examination. A higher percentage (81%; N=24) of traditional students passed the examination compared to non-traditional students (75%; N=15). The average examination scores of those who attained NCEA levels 1, 2 and 3 were 63 marks, 44 marks and 51 marks respectively. Firstly, age differences (18-25 years old and over 25 years old) were not significant factors of examination results (F=2.632, p=.111). Secondly, the univariate variance of analyses showed significant effects (Sign < 0.05) of current mathematics course and mathematics background (Mardia, 1980). The univariate general linear model 2-way ANOVA table showed the F value (3.452) and low significance value (0.014). The estimated marginal means and significant (F=4.002, p=0.007) and pairwise comparisons revealed that participants who were studying Engineering Mathematics 2 (84 marks) and pre-degree Engineering Mathematics (74 marks), had completed mathematics at NCEA level 1 (65 marks), Cambridge and IB (65 marks) and overseas students (68 marks), were more likely to score higher examination marks than those with NCEA Level 2 (47 marks) and Level 3 (50 marks).

Discussion

The correlational analysis showed that examination results were positively associated with high scores in a cohesive conception of mathematics, a deep approach to learning and an organised effort. Firstly, inconsistent with previous literature (Crawford et. al, 1994; Wood et. al, 2012), the participants had high scores in a deep approach, an organised effort and SCM level 2. As mathematics was taught by engineering and business lecturers, their teaching outcomes entailed teaching mathematical procedures as well applications in engineering and business situations. In these courses, the participants were expected to adopt a mathematical belief that mathematics is about modelling mathematical concepts, a cohesive conception which would underpin a deep approach to learning. If the participants were familiar with surface learning, they would carry out procedural calculations and rely on memorisation of facts, which is driven by a fragmented belief about mathematics. Secondly, in line with previous research findings (Crawford et. al, 1994), the sample data revealed positive correlations between high scores in a deep approach and examination results; between high scores in SCM level 2 (or cohesive conceptions) and examinations results. However, the low pass rate in examination suggested that examination results did not reflect the participants' perceived importance of a deep approach and a cohesive conception.

Besides a deep approach to learning, the five domains of self-efficacy correlated positively with strong mathematical performances. Previous literature has also revealed the performance-enhancing role of self-efficacy (Hall & Ponton, 2005; Pajares & Kranzler, 1995; Pajares & Miller, 1994; Skaalvik & Skaavik, 2011). However, my regression data revealed that considering five self-efficacy domains, SAL and SCM sub-constructs, student beliefs in using selection processes were the best predictor of examination results. According to Bandura (1997), individuals develop self-efficacy through the optimal use of resources to accomplish certain tasks. By having strong beliefs about using selection strategies (e.g., time management, effort), individuals can adapt to the teaching and learning environment and are equipped with the necessary means for task completion by developing positive study strategies (e.g. time management, note taking; critical thinking). By gaining more control of one's learning, students develop effective use of self-regulation strategies (e.g. study independently, concentration), which may enable them to make more effort and stimulate their intellectual curiosity in learning tasks.

Another potential determinant of success is prior mathematics background. The univariate data was inconsistent with other studies (Engler, 2010; Henderson & Broadbridge, 2009) as the participants with low mathematics background (NCEA Level 1 Mathematics) scored better than participants with NCEA levels 2 and 3 mathematics qualifications (equivalent to Years 12 and 13). This finding suggested that despite higher secondary qualifications, some participants were less prepared for post-secondary mathematics. Prior to studying a tertiary mathematics course, some participants had completed a refresher mathematics course in order to master basic mathematics skills. Therefore, this finding indicated that participants with the lowest level of secondary mathematics qualifications were likely to succeed in mathematics if they were given early interventions.

Contrary to my expectation, age differences were not a determinant of mathematical success. This result did not match past literature (Forgasz & Leder, 2000, Carmichael & Taylor, 2005; Miller-Reilly, 2006; Liston & O'Donoghue, 2010). This was because the non-traditional participants in the sample were under-represented. While some participants were determined to study mathematics in order to meet their career goals, other participants were easily susceptible to dropping out of the course, which, in turn, could lead to a dramatic reduction of course completion rate. Hence, given this inconsistency, further investigation was warranted to improve generalisability of future research.

Limitations

I found that self-reports of student learning using questionnaires could pose certain limitations even though it was advantageous to gather data efficiently in large lectures. Firstly, the scales could limit the participants to respond according to the fixed categories of key constructs, as established by the researcher. Secondly, reports about student beliefs and learning approaches could be limited by one’s interpretation of the scale and rely on the individual to recall their experience in learning mathematics. Thirdly, at times, self-reports could be self-promoting as participants were keen to over-estimate their judgements of their own capabilities and of deep learning. In order to improve research trustworthiness, these limitations should be taken into account in future quantitative studies.

Conclusion

My research contributes to the field of mathematics education by advancing our understanding of some cognitive, affective, and personal factors that influence success in post-secondary mathematics education. In this study, some key determinants of success were self-beliefs in using selection processes, a deep approach to learning and a cohesive student conception of mathematics whereas age differences and prior mathematics were not. These findings pose further questions about the ways in which mathematics practitioners promote mathematical self-efficacy as well as deep learning strategies for enhancing mathematical achievement of post-secondary students.

Acknowledgements

This doctoral research was supported by Macquarie University Higher Degree Research Office and Faculty of Business and Economics, Australia. I am grateful to

Professor Leigh Wood and her colleagues who provided insight and expertise that greatly assisted the research.

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