STUDENTS' PERCEPTIONS OF WAYS TO LEARN ENGINEERING MATHEMATICS: ARE THESE WAYS CDIO-RELATED?

Low-Ee Huei Wuan

Singapore Polytechnic

Wong Khoon Yoong

National Institute of Education, Nanyang Technological University

ABSTRACT

To promote active learning, lecturers should know how their students learn. With this knowledge, the lecturers can plan lessons that take advantage of the students' learning preferences or challenge learning approaches that are not particularly beneficial. This study examined what students from Singapore Polytechnic reported about how they learned engineering mathematics. A questionnaire consisting of 57 items was designed to cover activities classified under Conscientious Efforts, Metacognition, Involving Others, and Resources. A group of 235 Year 2 Engineering Mathematics (Maths 2) students rated these activities in terms of frequency of use and helpfulness before and after the Maths 2 module. The findings are interpreted in relation to active learning mentioned in Standard 8 of the 12 CDIO Standards. Lecturers may use similar techniques to better understand how their students learn in order to design lessons that take into consideration these ways of learning.

KEYWORDS

Student perceptions, traditional study behaviour, active learning, social dimension of learning, learning resources, engineering mathematics

INTRODUCTION

Research studies, using both qualitative and quantitative methodologies, have built a body of knowledge and theories about learning experiences of students in higher education [1–4]. Lecturers in higher education can improve their teaching through improving students' learning experiences [5]. They can also conduct studies on student learning in order to gain a deeper understanding of the learning experiences of their students, and accordingly to plan pedagogical strategies that will enhance student learning. Hopefully within engineering education, these learning experiences are consistent with Standard 8 (Active Learning) of the *CDIO* (Conceive, Design, Implement, Operate) *Initiative* [6]. This initiative, which has been officially adopted by Singapore Polytechnic since the academic year 2007/08, is a collaborative effort by leading engineering schools in many countries worldwide, to conceive and develop a new vision of engineering education.

The findings to be reported below come from a study that examined the learning experiences of students enrolled in an engineering mathematics module at Singapore Polytechnic (SP). The study was *not* designed to assess CDIO-related learning experiences because it was planned before SP adopted the CDIO Initiative. Nevertheless, the findings suggest several areas that can be further investigated in future implementation of Standard 8 from the perspective of the students rather than faculty members or standards-setters, in particular with respect to active learning of engineering mathematics.

Lecturing is a standard teaching method used very frequently in tertiary institutions, and it has its proponents and opponents among faculty and students [e.g., 7–9]. In a quasi-experimental study involving 578 first year undergraduates, Struyven, Dochy and Janssens [10] randomly assigned these students to five conditions: one lecture-based setting, and four student-activating learning environments based on different assessment modes, namely peer assessment, portfolio assessment, multiple choice examination, and case-based assessment. Students in the lecture condition were quite positive about their learning and out-performed the other student-activating groups. The peer assessment and portfolio assessment groups were more positive than the multiple choice examination and case-based assessment groups, and one reason was that the first two groups tended to receive more prompt feedback. Indeed, the education literature has consistently found that immediate and focussed feedback given by the teachers to the students as well as using feedback from the students has strong effects on learning [11]. Standard 8 has included getting feedback from students about what they are learning as one way to promote active learning.

Research about teaching of tertiary mathematics has offered new possibilities to promote active learning [12]. For example, Ball, Stephenson, Smith, Wood and Coupland [13] created the *MATH* taxonomy and used it to systematically design mathematics tasks for second year undergraduate students. This taxonomy classified tasks into three groups: Group A (factual knowledge, comprehension, and routine use of procedures), Group B (information transfer and applications in new situations) and Group C (justifying and interpreting; implications, conjectures and comparisons; and evaluation). Under this classification, the students were exposed to a variety of mathematical experiences that focussed their attention on different thinking processes. Engaging in tasks that require different levels of complexity is an important form of active learning. Using the *MATH* taxanomy procedure of tasks assignment ensured active engagement by students and gave lecturers the assurance that the skills finally demonstrated by students were learned with good grasp of conceptual understanding by having adopted a deep approach to learning.

Even though the lecturer or teacher may have planned different types of tasks and assessment modes, several researchers [14, 15] have found that school students may not understand the purposes of the learning activities as planned by their teachers. In an investigation conducted by Bell, Crust, Shannon and Swan [14], only two of the 104 British Year 8 pupils recognised the major intended purpose of the calculator activity. A study of Japanese mathematics lessons by Shimizu [15] found that many eighth-grade students did not recognise the climax of the lesson (called “yamaba”) planned by their teachers. We have also found that SP students reported different perceptions about the lectures and tutorials they had attended [16]. These studies highlight the need to learn more about the learning experiences of the students.

Student learning experiences extend beyond what they are engaged in during the formal lessons planned by the teachers. Outside formal hours, students are expected to complete assignments, to revise for upcoming tests, to work with others on projects, to use resources for their learning, and so on. These study behaviours have not been studied with respect to polytechnic students in Singapore. They can contribute to active learning from the students’ perspective. The rest of this paper describes students’ perceptions of how frequently they had used different study behaviours and how helpful they perceived these behaviours to be in learning an engineering mathematics module.

THE STUDY

Participants

The participants were 235 Year 2 Engineering Mathematics students. In May 2007, they answered a questionnaire (called Student Study Questionnaire, SSQ) about their learning experiences of Engineering Mathematics 1 (Maths 1) in the previous academic year. During the months from May to September 2007, they studied Engineering Mathematics 2 (Maths 2) under a combination of lectures, tutorials, problem-based learning, self-study and a week of e-learning. At the end of October, after the examination of Maths 2, the students took SSQ again in relation to their learning experiences of Maths 2. Their two responses to SSQ can be compared to determine any changes to their perceptions of learning mathematics prior to and after working through Maths 2.

Instrument

The Student Study Questionnaire (SSQ) consists of 57 Likert-type items. The items were developed conceptually with references to the literature [e.g., 17 – 21]. These items cover the following four learning dimensions:

1) Conscientious Efforts (CE); these 13 items encompass efforts that are commonly engaged in by conscientious students as well as the motivation for academic achievement, for example, paid attention to lecturer's explanations, completed tutorial exercises assigned by the lecturer, and was punctual for Maths lessons;
2) Metacognition (MC) in terms of taking control over one's thinking and learning; there are 15 items, for example, recognized when to use the appropriate mathematical formula, and planned my schedule for Maths revision;
3) Involving Others (IO); these 15 items describe learning activities that involve direct as well as implied contact with other people, for example, copied my friends' Maths tutorials, approached Maths lecturers even after class, and presented solutions of tutorials to the class;
4) Resources for learning (RE), covering 10 types, such as worked through past year tests and examination papers in Maths, searched for mathematics resources on the internet, and referred to mathematics books from the library.

There were 4 miscellaneous (MS) items, for example, relaxed after completing each tutorial.

Students were asked to respond to each item in terms of

1) frequency of use, i.e., "How often did you learn in this way?" (1 = Not at all; 2 = Occasionally; 3 = Sometimes; 4 = Quite often; 5 = Often; 6 = Always);
2) helpfulness, i.e., "How helpful it was towards learning Maths 1/2?" (1= Waste of time; 2 = Of little help; 3 = Some help; 4 = Quite helpful; 5 = Helpful; 6 = Very helpful).

The even 6-point Likert-type scales were used to avoid neutral responses [22].

FINDINGS AND DISCUSSION

Frequency of use and helpfulness of Maths 2 study behaviours

This section reports on students' responses to Maths 2 only, and these responses will shed some light about how active they were in their study of this module.

In terms of frequency of use, the means of the 57 items ranged from 1.64 to 4.24. On a 6-point scale, these means indicate frequencies of use from occasionally to quite often. Thus, none of the study behaviours was reported to be used very often or always. The standard deviations of these items ranged from 1.11 to 1.67, and these suggest that the students reported varying frequencies of using these study behaviours.

In terms of helpfulness, the means ranged from 2.01 to 4.27, and this gives the impression that some study behaviours were perceived to be of little help while others were quite helpful. However, none of the study behaviours was reported to be helpful or very helpful. The standard deviations ranged from 1.28 to 1.66, suggesting that these study behaviours may be more helpful to some students and less so for others.

The top five items in terms of frequency of use are shown in Table 1, together with their mean scores on helpfulness. They were used quite often and were perceived to be quite helpful. None of them were study behaviours involving others, one on conscientious effort (paid attention to lecturer's explanations), one on metacognition (recognised when to use the appropriate formula), two on resources (took note of lecturer's hints for tests and examination; and worked through past year tests and examination papers in Maths) and the remaining one a miscellaneous item (relaxed after completing each tutorial). This finding is not surprising as these are traditional study behaviours typical of students who focus on getting good grades. What is disconcerting is that the more active study behaviours did not have high enough means to be included.

Table 1
Top five items in terms of frequency of use

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
CE	2	Paid attention to lecturer's explanations.	4.14	1.47	4.27	1.44
MC	26	Recognised when to use the appropriate mathematical formula.	3.90	1.40	4.07	1.44
RE	44	Took note of lecturer's hints for tests and examination.	3.91	1.54	3.80	1.55
RE	46	Worked through past year tests and examination papers in Maths.	4.24	1.67	4.27	1.65
MS	41	Relaxed after completing each tutorial.	3.99	1.57	3.92	1.63

The 15 items in the metacognitive dimension are active learning study behaviours but are only used from occasionally to quite often, as illustrated in Table 2. Thus, ways must be found to inculcate study behaviours that are more closely aligned with active learning under Standard 8.

Table 2
The 15 metacognitive items

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
MC	26	Recognised when to use the appropriate mathematical formula.	3.90	1.40	4.07	1.44
MC	19	Checked my work while doing it.	3.76	1.44	3.70	1.44
MC	23	Analysed mistakes made in solving tutorial problems.	3.71	1.44	3.89	1.43
MC	47	Identified important concepts learnt in Maths.	3.62	1.43	3.80	1.53
MC	33	Was aware of my own thinking during mathematical tasks.	3.57	1.37	3.57	1.45
MC	54	Set personal goals to achieve in Maths.	3.48	1.61	3.52	1.65
MC	5	Was also thinking even though I did not call out the answers to questions asked during lecture.	3.45	1.38	3.52	1.36
MC	9	Made a conscious effort to present mathematical solutions logically.	3.41	1.43	3.50	1.44

MC	57	Planned my own schedule for Maths revision.	3.35	1.64	3.50	1.64
MC	32	Made my own notes in Maths.	3.16	1.53	3.44	1.60
MC	15	Related new concepts taught in Maths to known concepts.	3.06	1.35	3.26	1.42
MC	40	Reviewed my learning after completing each tutorial.	3.06	1.33	3.30	1.41
MC	50	Asked myself a question about the Maths problem/ topic.	3.00	1.39	3.11	1.44
MC	53	Planned the strategies before beginning to solve a problem.	2.98	1.39	3.17	1.46
MC	37	Tried out other possible solutions to a same problem.	2.85	1.30	3.10	1.41
Overall			3.36	1.43	3.50	1.48

The bottom five items in terms of frequency of use are shown in Table 3. The means indicate that they were used only occasionally and even not at all for some students. They were also perceived to be of little help. Lack of use may have led to the low perceived level of helpfulness.

Surprisingly, three of these items were about using technological resources (external links, internet resources, and maths-related software), even though all the students had to own a laptop. From institutional perspective, technological and library resources require substantial funding, and it would be a waste if the students do not use them to enhance their learning of mathematics and other modules. The habit of using relevant resources in learning is essential for lifelong learning as advocated by Standard 8. One suggestion is for the lecturers to require students to use these resources more intensively to complete their assignments.

The remaining item in Table 3 refers to the behaviour of copying their friends' tutorials. Even though this was done occasionally, it was perceived to be of some help (mean close to 3). This behaviour is obviously not aligned with active learning.

Table 3
Bottom five items in terms of frequency of use

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
RE	8	Referred to mathematics books from the library.	1.64	1.11	2.01	1.40
RE	11	Used computer-based programs e.g., Graphmatica and online applets.	1.93	1.26	2.07	1.28
IO	1	Copied my friends' Maths tutorials.	2.04	1.18	2.88	1.61
RE	22	Searched for mathematics resources on the internet.	2.15	1.39	2.31	1.40
RE	18	Visited external links provided by Maths website in Blackboard.	2.18	1.32	2.27	1.31

Changes in study behaviours from Maths 1 to Maths 2

The frequency means of study behaviours for Maths 1 ranged from 1.32 to 4.42, and this range was wider than that for Maths 2 (1.64 to 4.24). The means for Maths 1 were higher than for Maths 2 for 41 of the 57 items. Thus, the students were less frequently engaged in most of these study behaviours when they studied Maths 2 compared to Maths 1.

The (Maths 2 – Maths 1) mean differences were computed, and the top nine items with large differences are reported in Table 4. Five items were about making conscientious efforts, one about metacognition, two about traditional resources, and one miscellaneous. Five of them are traditional behaviours commonly associated with following instructions (pay attention to explanation and hints, complete assigned work, copy solutions, and be punctual). The single metacognitive item (recognise which formula to use) and the item on trying the best to solve a difficult problem were aligned with Standard 8. The students also expressed less frequently looking forward to come to Maths 2 classes compared to previous Maths 1 classes (Q55). The challenge is to devise more diverse active learning activities to entice students to want to come for classes [23].

Table 4
Nine study behaviours with frequency means for Maths 1 higher than for Maths 2

Cat	Q	Ways of learning Maths 1 or Maths 2	Maths 1		Maths 2	
			Mean	SD	Mean	SD
CE	2	Paid attention to lecturer's explanations.	4.67	1.15	4.14	1.47
CE	36	Completed tutorial exercises assigned by the lecturer.	4.39	1.37	3.86	1.51
CE	52	Was punctual for Maths lessons.	4.32	1.36	3.74	1.50
CE	55	Looked forward to coming to class.	3.55	1.49	3.13	1.50
CE	13	Tried my best to solve a difficult problem.	4.33	1.32	3.87	1.50
MC	26	Recognised when to use the appropriate mathematical formula.	4.35	1.22	3.90	1.40
RE	4	Copied solutions from the whiteboard/projection on the screen.	4.07	1.47	3.59	1.53
RE	44	Took note of lecturer's hints for tests and examination.	4.58	1.44	3.91	1.54
MS	41	Relaxed after completing each tutorial.	4.53	1.42	3.99	1.57

Table 5 shows the reverse trend. The frequency means for Maths 1 were lower than those in Maths 2. Most of these items were also of low means, suggesting that the students reported only occasional use. Nevertheless, most of these study behaviours are about active learning consistent with Standard 8, such as using technology resources, being proactive in seeking help, and planning for revision.

Table 5
Eight study behaviours with frequency means for Maths 1 lower than for Maths 2

Cat	Q	Ways of learning Maths 1 or Maths 2	Maths 1		Maths 2	
			Mean	SD	Mean	SD
CE	29	Read through Maths lecture notes before the next lecture.	2.29	1.25	2.59	1.34
MC	57	Planned my own schedule for Maths revision.	3.18	1.58	3.35	1.64
IO	7	Approached Maths lecturers even after class.	1.96	1.10	2.19	1.24
IO	28	Presented solutions of tutorials to the class.	2.38	1.31	2.55	1.28
RE	8	Referred to mathematics books from the library.	1.32	0.87	1.64	1.11
RE	15	Accessed Maths website in Blackboard.	3.33	1.53	3.53	1.48
RE	18	Visited external links provided by Maths website in Blackboard.	2.00	1.24	2.18	1.32
RE	22	Searched for mathematics resources on the internet.	1.88	1.23	2.15	1.39

The lowering of frequency of use of traditional study behaviours reported in Table 4 coupled with the increasing use of more active study behaviours reported in Table 5 suggests a slight but discernable trend toward more active learning as the students progressed from Maths 1 to Maths 2. This is promising but the reported frequencies of use of active learning were still quite low. Other CDIO standards such as curriculum development and the enhancement of faculty teaching skills should be considered in tandem with Standard 8 to promote the acquisition and application of more active study behaviours by the students.

In addition to the above analysis by individual items, it is worthwhile to compare the differences between Maths 1 and Maths 2 by the four dimensions used to create the items. Students' responses under these dimensions show high internal consistency measured by Cronbach's alphas of greater than 0.7, as shown in Table 6. Hence, the mean scores of items for each dimension are computed and these are plotted in Figure 1. It is very striking that in terms of both frequency of use and helpfulness for Maths 1 and Maths 2, the trends were consistent in the order: Conscientious effort > Metacognition > Involving Others > Resources. The social dimension of learning as measured by the items under Involving

Others was not reported in the earlier tables because these items had intermediate means between the higher and lowers values.

Table 6
Cronbach's alphas of dimensions of study behaviours

	Maths 1		Maths 2	
	Frequency of use	Helpfulness	Frequency of use	Helpfulness
Conscientious effort (CE)	0.87	0.88	0.92	0.93
Metacognition (MC)	0.87	0.88	0.92	0.93
Involving Others (IO)	0.82	0.84	0.88	0.90
Resources (RE)	0.74	0.79	0.77	0.79

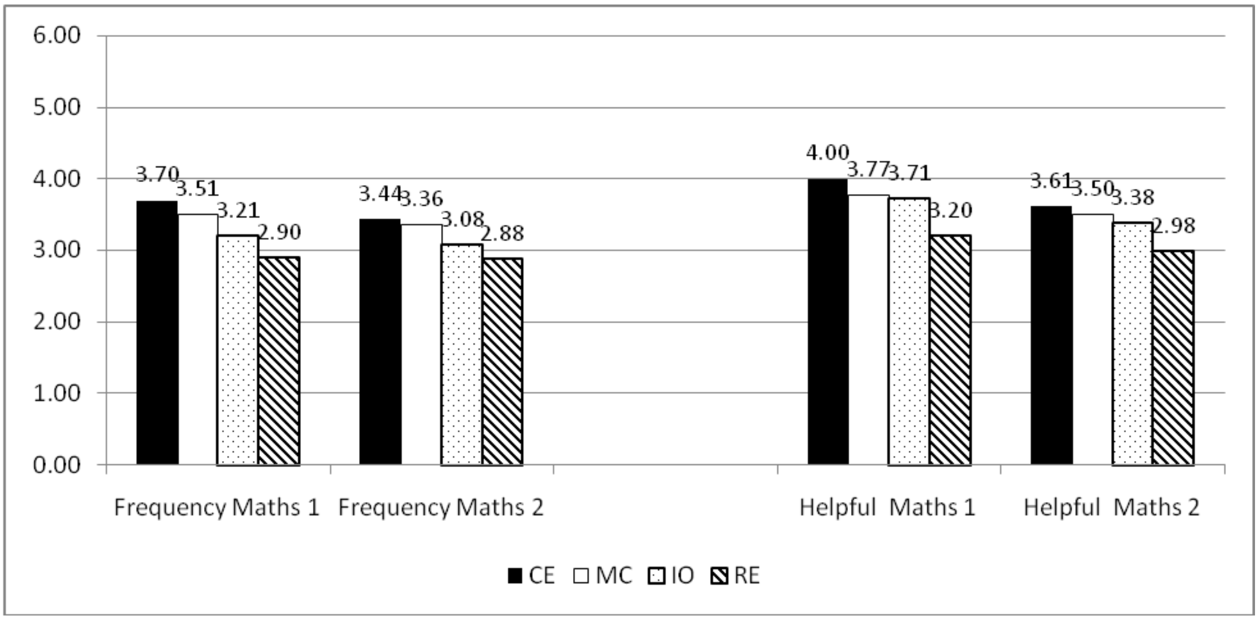

Figure 1. Frequency and helpfulness of Maths 1 and Maths 2 study behaviours

CONCLUDING REMARKS

This study provided empirical data about the learning experiences reported by local polytechnic students on Engineering Mathematics. These students generally made use of traditional study behaviours often related to the transmission mode of learning, believing that these behaviours will help them to learn the module. They became slightly more metacognitive in the later module, but this change was not yet strong. Interactions with others during learning were not common, and the use of technology resources and library books was quite rare. This broad picture of how polytechnic students learn mathematics is not surprising, especially when considered in terms of the objective of doing well in traditional assessment.

However, the implementation of the CDIO Initiative requires re-thinking of the learning experiences provided by the faculty to the students, beginning with enriching the curriculum with more experiential, industry-related tasks. For mathematics modules, this should include showing students how to solve real problems taken from modules outside of mathematics by using standard mathematics procedures as well as modelling using technology. This will sensitise the students to the need to exploit appropriate resources in their learning.

Standards 2 and 3 of the CDIO Initiative emphasise teamwork and communication skills. More modules at SP should provide learning activities that involve other partners. The above findings about Involving others and the study by Struyven, Dochy and Janssens [10] suggest that students at polytechnic may prefer direct instruction to the more interactive modes of learning. It is not a straightforward case of catering to their preferred learning style because what they prefer may not be optimal. Indeed, the working environment of the 21st century requires team work, and students who have not learned this social style of learning need to be properly inducted to acquire the necessary skills. For effective implementation, however, care must be taken so that students who are familiar with the traditional transmission mode of learning will have time to adapt to the new learning strategies [24]. These new activities need to be infused slowly to give students lead time to familiarise themselves with a learning approach that is not their usual practice. These activities need also be introduced explicitly so that students will perceive the efforts made by their lecturers [14, 15], and to appreciate the helpfulness of these study behaviours.

Teaching staff should be encouraged to conduct action research about their teaching practices as part of Standard 10 of the CDIO Initiative. One feasible area of action research is to gather data on student learning in order to better match the planned learning experiences to student preferences of learning [14, 15], and to challenge learning approaches that are not particularly beneficial.

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Biographical Information

Low-Ee Huei Wuan is a Senior Lecturer at the Department of Mathematics and Science, currently on secondment as an Education Advisor at the Department of Educational Development at Singapore Polytechnic, Singapore. She is also a Ph.D. candidate at the

National Institute of Education, Nanyang Technological University, Singapore. Her PhD research project studies various aspects of student learning experiences in- and out- of classroom, throughout a semester at the polytechnic. She has been serving the local community of mathematics educators as the Vice President of the Association of Mathematics Educators since 2002, and was founding member of the organising committee for the series of yearly Mathematics Teachers Conference since its inception in 2005. She has also organised many enrichment talks and workshops for local mathematics educators.

Wong Khoon Yoong is an Associate Professor in Mathematics Education and Head of Mathematics and Mathematics Education Academic Group at the National Institute of Education, Nanyang Technological University, Singapore. His current research focuses on comparative study of mathematics curriculum, multi-modal teaching strategy, learning difficulties in mathematics, problem solving heuristics, Logo and ICT, and mathematics teacher education. He is currently the principal investigator for the Singapore team in the IEA study on Teacher Education Study: Mathematics (TEDS-M). He has also published work in general education about pupils' discipline problems, teacher concerns, and career choice of pupils. His professional education experience spans five countries, namely Australia, Brunei Darussalam, Malaysia, the Philippines, and Singapore.

Corresponding authors

Mrs Low-Ee Huei Wuan
Singapore Polytechnic
500 Dover Road
Singapore 139651
65-6772-1730
lowhw@sp.edu.sg

Dr. Wong Khoon Yoong
Mathematics & Mathematics Education Academic Group
National Institute of Education
Nanyang Technological University
1 Nanyang Walk
Singapore 637616
65-6790-3927
khoonyoong.wong@nie.edu.sg