The Effect of Meaningful Tasks on Secondary One Students' Mathematics Examination Performance and Engagement

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Abstract

Research has indicated that students who had opportunities to be engaged in meaningful tasks during mathematics lessons achieved higher academic outcomes and had positive attitudes toward mathematics. This study focused on Mathematics lessons with meaningful tasks that created opportunities for cooperative learning involving real and relevant problem solving. In this study, the school developed a framework EASY (Experiencing, Applying and Synergy) to guide the design of meaningful tasks. One project class and one comparison class of Secondary One (Grade 7) Express course students participated in this study, with the project class working on the meaningful tasks. Using a quasi-experimental design, the two groups were compared in the following: engagement level, Mathematics examination scores and perceptions of dimensions such as seeing interconnections between subject matter and contexts (E), assessment to improve learning (A) and relevance of learning content (L). Using standardised mean difference, the results revealed that there was a strong effect in Mathematics examination scores in favour of the project group. In addition, there was also a strong effect observed in the different types of engagement (affective, behavioural and cognitive) with the project group displaying higher scores. With regard to the scales A, E and L, strong effect in favour of the project group was observed. This paper discusses how meaningful tasks have engaged the students. In addition, the teachers' use of information gathered from the meaningful tasks to improve learning will be discussed.

Introduction

In recent years, Singapore students have performed commendably at international comparative studies such as TIMSS and PIRLS. Much as we recognise our strengths in literacy and Mathematics and Science, we continue to strive to level up the attainment of students who are academically challenged in these areas.

The school takes cognizance that a fairly large proportion of primary school students join its secondary one with a weak foundation in Mathematics and struggle in their study of the subject throughout the four to five years in the school. As an early intervention measure, the school introduced a programme in the lower secondary Mathematics curriculum in 2005 with the objective of helping these students gain confidence and interest in Mathematics and to improve their academic results. The main focus of the programme was active learning where the students were involved in student-centered activities that were challenging and fun to them.

As part of the review of this Mathematics intervention programme, the school did an analysis of its internal Final Year Examination results in 2006 and noticed that a class which underwent the programme displayed an improvement from the Mid-year Examinations to the Final Year Examinations. Perception surveys administered to the students also indicated that they learnt better through the programme. However, no evidence was collected to ascertain the effects of the programme with regard to their attitudes in learning. In 2008, the school decided to gather further evidence for a more systematic study and review of the intervention programme.

Literature Review

Research has shown that student engagement is important to student achievement. In particular, studies have shown that there are consistent correlations between engagement and student achievement (Marks, 2000). A meta-synthesis of over 160 studies identified three types of engagement: affective, behavioural and cognitive. (Fredricks, Blumenfeld & Paris, 2004). Affective engagement refers to the emotional reactions and feelings which include interest, boredom, etc. Behavioural engagement refers to observable actions or performance of the students. Cognitive engagement refers to psychological investment in learning and being self-regulating (Ministry of Education, 2008).

In 2005, the Ministry of Education drew up the PETALS™ Framework to guide learning and teaching by paying particular attention to the following dimensions: Pedagogy (P), Experience of Learning (E), Tone of Environment (T), Assessment (A) and Learning Content(L) to produce engaged learning. The interaction among the five dimensions contributed to engaged learning in the classroom. The definitions of the various dimensions are: (a) Pedagogy - a set of strategies that matches the students' learning styles, addresses the students' level of development and taps on their existing knowledge; (b) Experience of Learning - students' thinking are stretched, drawing the interconnection between ideas in their learning and enabling them to be more metacognitive; (c) Tone of Environment - the provision of supportive physical and social-emotional environment; (d) Assessment - assessment to improve learning and assessment to track students' learning; and (e) Learning Content - content that is made relevant and meaningful to the learners (Ministry of Education, 2008).

In line with engaging the students affectively, the school felt that it could start with intrinsic motivation by getting the students to focus on learning goals such as understanding and mastery of mathematical concepts. When students engaged in tasks, they were motivated intrinsically (Lepper, 1988). They tended to exhibit a number of pedagogically desirable behaviours. Research also indicated that success in Mathematics is a powerful influence on the motivation to achieve (Middleton & Spanias, 1999). Further, the use of formative assessment, which focuses on task-centred goals to help students succeed, would raise students' self efficacy and prevent low self-esteem from developing in the first place (Roderick & Engel, 2001, cited in Harlen & Crick, 2003).

Tasks that are meaningful which the children could make sense of what they are learning have been deemed as an important factor that will improve attitude towards mathematics learning. One such meaningful learning experience was described by Donaldson (1978) where the children saw both purpose and relevance in their learning. Middleton and Spanias (1999) suggested the use of ill-structured, real life problem situations in mathematics instruction to uncover important and interesting knowledge which would promote understanding.

In another study by Coltman, Petyaeva and Anghileri (2002) on groups of children aged between 4-6 years old, it was found that introduction of meaningful context led to substantial improvement in post test results as compared to that of the pre test. It was also reported that the experimental group yielded better results with the use of a meaningful task but also with guided feedback from an adult. Guided feedback created opportunities for change and thus allowed students to experience success in the midst of carrying out their tasks. In another study involving academically at-risk students, it was noted that to succeed in mathematics, there was a need to strike a balance between sufficient opportunities for success and tasks that require considerable effort (Woodward & Brown, 2006). Therefore, students might need to experience periodic challenge and even momentary failure to develop higher levels of self-efficacy and task persistence (Bandura, 1986; Middleton & Spanias, 1999; Pajares & Schunk, 2001).

Besides working on meaningful tasks and being given relevant feedback, research has shown that low achieving students who were taught in an active classroom - one that provided students with opportunities in problem solving using real life scenarios and active classroom discussion achieved higher academic outcomes and had more positive attitudes towards mathematics than students in the comparison group (Woodward & Brown, 2006).

Active learning is when students worked in collaboration instead of focusing on the teacher standing in front of the classroom (Crawford & Witte, 1999). To involve students in active learning, five teaching strategies were recommended, namely, relating, experiencing, applying, cooperating and transferring. These strategies, rooted in constructivism, promoted meaningful learning and built on the students' creativity and joyful educational experiences. Such strategies are key elements in the classroom to improve mathematics learning.

This study incorporated these classroom strategies advocated by Crawford and Witte (1999) into the school's 'EASY' (Experiencing , Applying and SYnergy) Framework in designing meaningful tasks for classroom instruction. Students learning in the classroom with meaningful tasks would undergo such learning experiences: activities, games, application of the mathematical concepts through real-life problems or tasks that are relevant to the students and working synergistically with one another through cooperative work.

Encouraged by the above research, this study seeks to find out the effect on the use of meaningful tasks on students' engagement and their performance in Mathematics Examinations, in a classroom of a Singapore school. The specific questions are:

1. Do students who work on meaningful tasks perform better in Mathematics Examinations, compared to students who do not?

2. Are students who work on meaningful tasks more engaged than students who do not?

Method

Participants

The participants in this study were 25 students from one Secondary One (Grade 7) class who underwent lessons using the EASY Framework, where the mode of instruction is more facilitative. Another class of 30 students was used as a comparison group for the study where the teacher used direct instruction. Table 1 below shows the distribution of students involved in this study.

Table 1. Profile of Participants in the study

Class	Group assigned	Number of students	Period of study	Type of Lesson
1E2	Project	25	12 weeks	Meaningful task
1E3	Comparison	30	12 weeks	Direct instructions Demonstrations Drill and practice

Prior to the lessons using the EASY Framework in the project class, a Chi-square analysis on the Mathematics scores from both classes indicated no significant difference between the project group and comparison group. An equivalent group post-test design was carried out to ascertain the impact of meaningful tasks on both the Mathematics achievement scores and students' engagement.

Instruments and Data Collection

For the measurement of students' achievement, the Final Year Examinations drawn up at the school level, was used as a post test. The examination comprised two papers. Paper 1 consisted of questions that were more general but wider in scope while Paper 2 contained questions that were more in depth with an application orientation. The paper assessed students on their understanding and application of concepts and demonstration of Mathematical skills, based on topics taught during the project period.

Student engagement was measured using the PETALS™ Engagement Indicator (PEI) questionnaire which has six scales, namely Pedagogy (P), Experience of Learning (E), Tone of Environment (T), Assessment (A), Learning Content (L) and Engagement (G). The PEI questionnaire was developed by teachers on attachment with the Ministry of Education in 2007. The P, E, T, A, L scales each contain six items. The questionnaire also includes a section with 30 items to measure the three types of engagement: Affective Engagement (A), Behavioral Engagement (B) and Cognitive Engagement(C). Each of the engagement sub-scale contains ten items. Respondents were required to rate the extent to which they agreed with the statements based on an 11-point Likert-type scale. To triangulate the quantitative data collected, qualitative data was collected through interviews with the teacher and the students involved in the project.

Procedure

For the period of 12 weeks, the students from the project class attended lessons which used the activities, problems and lesson materials designed by a group of three teachers. The lessons based on the stages of **E**xperiencing, **A**pplying and working in **SY**nergy, were conducted by the same teacher.

The Mathematics teaching during the intervention period covered three major topics: Arithmetic, Graphing and Mensuration. In a typical lesson, students from the project class experienced the learning through hands-on activities or games that helped them understand the Mathematical concepts taught. These activities were usually based on real-life scenarios that enabled them to appreciate the relevance of the Mathematics concepts taught. Thereafter, the students worked in groups to apply these concepts learned to solve relevant and interesting problems. Both activities and problems allowed active classroom participation and discussion in which students described their problem-solving strategies and obtained immediate feedback from their teacher. An array of mathematical tools and manipulatives, including calculators, notebooks and measuring devices, was used in these lessons. In some topics, problems which were similar to the task designed for application in the classroom were given to students as homework assignments. Finally, these students worked on assignments or tasks which generally contained five to twelve questions that were intended to reinforce the main concepts of the lesson.

The comparison group was taught identical topics based on direct instruction. A typical lesson was taught by a teacher lecturing on a certain Mathematical concept, demonstrating the methods on solving related textbook problems. Like the project group, these students also worked on a set of five to twelve questions to reinforce the main concepts taught.

Data Analysis

The Mathematics Examination scores of the project class and comparison class were compared using standardised mean difference. Likewise, standardised mean difference was used in making comparisons of the engagement scores and the scores of the PETALS^{TM} scales between the project group and the comparison group.

Results and Discussion

Table 2 shows the means, standard deviations and effect sizes of the examination scores after the intervention. The intervention had a moderate effect, in favour of the project group, on the examination scores. The results were encouraging and suggested that the meaningful tasks might have a positive effect on the students' understanding of Mathematics concepts which enabled them to perform better than the comparison group.

Table 2. Mean Comparison on Examination Scores

Measure	Project Group Mean (SD)	Comparison Group Mean (SD)	Effect Size
Examination scores	21.6 (6.38)	18.2 (5.59)	0.61

One of the plausible reasons for the better performance of the project group could be that teaching using the EASY Framework enabled the students to understand the Mathematics concepts better. In the teaching of the topic involving total surface area of three-D objects, students were required to make 3-D shapes by using cardboards. These three-D shapes were dissembled to form nets which students could view them in two dimensions. For example, seeing the two-D form of the cylinder helped students to visualise the total surface area of cylinder as being made up of two circles (base and top areas) and a rectangle (circumference of base x height of cylinder). This allowed students to visualise the formula for computing the total surface area ($2\pi r^2 + 2\pi rh$) and understand and appreciate the formula in a more anchored manner. Thus, the activities planned for the project helped the students to see the linkages between the concepts and the formula, as compared to direct presentation of the formula.

Table 3 shows the means, standard deviations and effect sizes of the PETALS^{TM} dimensions and engagement. There was a strong effect for all the PETALS^{TM} dimensions, in favour of the project class.

Table 3. Mean Comparisons on PETALS™ dimensions and Engagement

Measure	Project Group Mean(SD)	Comparison Group Mean(SD)	Effect Size
Pedagogy (P)	80.3 (14.8)	58.6(18.7)	1.16
Experience of Learning (E)	73.3(17.2)	57.0(19.5)	0.84
Tone of Environment (T)	77.3(14.1)	64.4(15.3)	0.84
Assessment (A)	77.7(14.4)	61.5(18.8)	0.86
Learning Content (L)	75.4 (16.2)	57.5(19.3)	0.92
Engagement (Behavorial)	74.2(17.9)	62.6 (14.0)	0.83
Engagement (Cognitive)	75.7 (17.1)	62.2(12.9)	1.05
Engagement (Affective)	76.2(17.9)	63.4(15.6)	0.82

In general, the results show that students in the project group were better engaged than those from the comparison group. The tasks in these lessons challenged the students and immersed them in active learning. In addition, the structured tasks provided a high level of participation among the students and kept them on-task. The teacher who taught the project group observed a more positive attitude towards learning Mathematics among the students. Beyond the intervention duration, the teacher noted that students remained highly motivated during the Mathematics lessons, suggesting possibly a sustained effect. The following comments were gathered from the teachers who observed the project group and they triangulated with the quantitative findings:

> “Students are highly motivated, eager to learn. The activity is appropriate and engaging.”

> “A very good lesson with students actively engaged throughout the lesson. They asked valid questions to clarify their doubts, were eager to complete their tasks given and discussion were focused on problem solving. Well done!”

Students were asked for their views about their Mathematics lessons taught during the intervention. The students responded positively using adjectives/ terms like ‘fun’, ‘interesting’ and ‘special lessons’. The students also specifically mentioned the meaningful tasks carried out in their lessons, suggesting that these tasks could be a factor which accounted for the increase in interest in the lessons. Some of the students’ comments were:

> “The special activities help us to understand about Mathematics easier than before.”

> "My class is very fun. I enjoy it, so do my friends. We did shopping. It was very fun."

In Table 3, high effect size in favour of the project group was shown in the scales of Pedagogy (P), Learning Content (L) and Assessment (A).

The positive effect on the Pedagogy scale came as no surprise as the teachers who had designed the meaningful tasks had given due consideration to the students' readiness to learn and addressed their different learning styles, as much as possible. The tasks which included games, investigative activities and real life problems motivated the students. The activities, which invoked play while learning mathematics enabled students to learn more readily. Vygotsky (1978), cited in Coltman (2002) also highlighted the role of play in enriching the learning process of young children when he wrote that 'the child moves forward essentially through play activity'. The above results were consistent with the multimodal teaching which advocated leveraging on student's different learning styles to keep them interested in the classroom (Goodlad, 1992).

Students from the project group perceived the lessons to be relevant and authentic, more so than those from the comparison group, as evident by high effect size in the Learning Content scale. These results suggested that the tasks were suitably designed to interest and challenge the students in relating the Mathematical concepts learned to applications in real life. This was evident from the following students' comments:

> "I love my lessons i have during my maths lesson; i make use of the lessons related to my daily life. my teacher will plan some games for my class weekly."

> "The games i had was examples, "battleships", "shopping" etc... "Battleship" teaches me how to plot the points in my graph and i know how to find the gradient of the line after the game."

> "shopping" teaches me how to do shopping next time and it teaches me how to do compound percentage questions. I love my maths lessons."

Besides seeing the relevance of the content, the tasks also stretched the students' understanding and steered them away from "classroom evaluation practices that encourage superficial and rote learning" (p17, Black & Wiliam, 1998).

The high effect size shown in the "Assessment" scale could be due to the constructive feedback given more regularly and effectively by the teacher to the project group. The teacher who was interviewed concurred that feedback given to students helped them to engage their attention. Teacher's feedback also served as interesting input for active discussion among the students themselves in clarifying and enhancing their understanding and learning. The evidence of students' learning from the meaningful tasks informed the teacher in how to adjust her teaching as she goes forward. Some of these assessment practices were aligned with the model advocated by Hattie and Timperley (2007) who identified three major questions on feedback: " Where am I going? How am I going? Where am I going next? According to them, when the discrepancy between what was understood and what was aimed to be understood was minimized, it could increase effort, motivation and engagement. In contrast, less feedback was given to the comparison group, possibly limited by the direct instruction style.

Conclusion

While the use of meaningful tasks seemed to have caused a moderate effect on Mathematics examination scores for the project group, the results showed a large effect on its students' engagement scores. The students' high level of engagement in the project group was similarly explained by the qualitative data gathered from the two teacher-observers and the teacher teaching the project group. The use of meaningful tasks seemed to make the studying of Mathematics more interesting by bringing out the relevance of the Mathematics concepts. It appeared to have helped students understand the use of the concepts in real life situation.

Having the experience of designing meaningful tasks to motivate and support students in their learning, the next step for the school would be to engage students in peer- and self-assessment to investigate their effect on students' learning. Although the use of meaningful tasks had generated positive outcomes in the teaching of Mathematics, it is too premature to generalise the benefits of the intervention given the small sample size of one project group. A further study on a larger scale involving more students and teachers, would be embarked for more conclusive findings on the feasibility on the use of the intervention method.

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