

# Integrating new assessment strategies into mathematics classrooms: What have we learned from a CRPP mathematics assessment project?

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## Abstract

A major research project on mathematics assessment has been carried out by the Centre for Research in Pedagogy and Practice (CRPP), National Institute of Education, Nanyang Technological University. The project involves more than 30 classes from eight primary and eight secondary schools in Singapore and the intervention is implemented over three semesters: in Primary 3 to Primary 4 and Secondary 1 to Secondary 2. In this paper, we will first give an overview of the project, including its aims, conceptual framework, research methodology and instruments, the implementation process and then share initial findings we have obtained, issues encountered and experiences we have learned from the project.

## Introduction

Educational researchers and practitioners have in recent years paid increasing attention to the importance of new assessment (or the so-called alternative assessment) strategies in mathematics instruction to better reflect the desired educational goals and values in education (e.g., Niss, 1993, National Council of Teachers of Mathematics, 1995). In 2002, the Curriculum Planning and Development Division of the Singapore Ministry of Education (MOE) drafted a set of guidelines for the assessment of mathematics in primary and lower secondary school levels. Therein are suggestions for using alternative assessments. In 2004, these drafts were later finalised as the *Assessment Guides to Primary Mathematics* (MOE, 2004a) and *Assessment Guides to Lower Secondary Mathematics* (MOE, 2004b). The implementation of these assessment strategies, elsewhere and especially in Singapore, seeks as much research-based support as it could garner (Fan & Yeo, 2000; Fan, 2002; Yazilah & Fan, 2002), for the consequential high-stake impact that assessment has on many local student's future. A major research project (called Mathematics Assessment Project or MAP) on the "newer" mathematics assessment strategies has been carried out under the Centre for Research in Pedagogy and Practice (CRPP), National Institute of Education, Nanyang Technological University. The project involves more than 30 classes in eight primary and eight secondary schools in Singapore and its intervention is implemented over three semesters from Primary 3 to Primary 4 and from Secondary 1 to Secondary 2. In this paper, we will first give an overview of the project including its aims, conceptual framework, research methodology and instruments, and the implementation process, and then share some initial findings we have obtained, issues we have encountered and experiences we have learned from the project.

Traditionally, the term "assessment" in the educational context refers mainly to the written test or examination, regardless of whether the tests or examinations were set by teachers or external examining agencies. Fan's (2002) research on and experience with in-service teachers in Singapore reveals the profound effect of this conception of assessment on many teachers' classroom practice. The large numbers of "assessment" books that are readily available in Singapore to students (or their parents) to provide more practice on the written test further promulgate the notion of assessment as marks and grades for the individual student's achievement on written tests.

Recent waves of reform in mathematics education, especially in the United States of America, cast the notion of assessment in broader terms. Assessment should beyond the focus on the end product of student achievement in written tests to include the how, what and why in assessing the students in the service of authentic learning. The National Council of Teachers of Mathematics offers, in its *Assessment Standards for School Mathematics*, a definition of assessment that has since been commonly cited: "[Assessment] is the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward mathematics and of making inferences from that evidence for a variety of purposes" (NCTM, 1995, p.3). An important aspect of learning that is highlighted within this broader conception of assessment is "disposition". According to the *Standards*, disposition refers to the interest and appreciation students show for mathematics, the tendency with which students think, act and react positively toward mathematics – with confidence, curiosity, perseverance,

flexibility, inventiveness and reflectivity in doing mathematics. The traditional assessment modes are inadequate to the assisting instruction that helps develop these dispositions in students.

To Fan (2003), the traditional assessment may be characterized as time-limited (i.e., to be completed in a block of time), tool-limited (i.e., restricted to paper-and-pencil) and venue-limited (i.e., held at a specified place like an examination hall), with a predominant concern on marks, grades, student academic achievement on knowledge of the mathematics content and problem-solution methods taught in schools is inadequate in meeting the expanded role of assessment, namely, in promoting genuine learning. Fan (2003) argues that teachers using alternative assessment approaches would utilize a variety of ways to obtain assessment evidence to assist student learning, and are not restricted to the written tests and contrived or idealised tasks.

The two *Assessment Guides* produced locally (MOE, 2004a, 2004b) recognizes the role of assessment methods other than the so-called traditional written tests. The *Guides* point out that assessment should be “an integral component of the teaching and learning process” whose main purpose is to “improve the teaching and learning of mathematics” (MOE, 2004a, p.7), and offers a generous selection of “alternative assessment” methods, such as journal writing, classroom observation with teacher-pupil conferencing, portfolios and self-assessment. Locally, the broader role of assessment may serve better the primary aim of the Singapore mathematics curriculum (MOE, 2001), which is to enable students to develop their ability to solve mathematics problems. To this end, the curriculum identifies five essential components - concepts, skills, processes, attitudes and metacognition - that would support the development of mathematical problem solving ability. Whereas the traditional assessment may have catered well with teaching for the first two components, it is the newer assessment strategies that may be more appropriate in meeting instruction for the last three components.

#### Mathematics Assessment Project (MAP)

The Mathematics Assessment Project (MAP) asks two broad research questions:

1. What are the effects of using “alternative” assessment approaches in mathematics on students’ achievement – cognitive and affective?
2. How should the new assessment strategies be effectively embedded in classroom practice?

The four “new” assessment approaches investigated in MAP were:

- Project-based assessment
- Communication-based assessment: Written (journal-writing) and oral (presentations)
- Performance-based assessment
- Student self-assessment

The selection of the four types is based on the following two concerns: (1) these strategies are better defined in research community compared to others, and (2) these strategies have more relevance to Singapore’s educational system.

The first strategy is project assessment. In fact, in recent years, the Ministry of Education (MOE) has emphasized it in classroom practices across many subjects, including mathematics. A project is a task or a series of tasks for students to carry out, which often includes some or all of the following processes: gathering data, observing, looking for references, identifying, measuring, analyzing, determining patterns and/or relationships, graphing, written/oral communicating, etc. It is believed that project assessment can better assess students in cognitive domain, particularly students’ problem solving ability and creative thinking skills. In this project, several types of project tasks are conceptualized: guided projects, independent projects, extended projects, mini-projects, contextualized projects, non-contextualized projects, interdisciplinary projects, mathematical projects, group projects, and individual projects. The setting of various kinds of projects is convenient for teachers to make better decisions to cater for students with different abilities.

The second strategy is performance tasks, which are believed to be helpful in developing students’ problem solving abilities and higher-order thinking. The authenticity and openness are the most important features of the performance tasks used in this project. According to the National Council of Teachers of Mathematics (NCTM, 1995), authenticity is the degree to which activities are faithful, comprehensive representations of the contexts and complexity found in important, real-life performances of adults that are non-routine yet meaningful and engaging for students. The openness includes two aspects – various avenues of access, which allow students at many levels of understanding to begin working on the problems, and multiple acceptable answers to problems.

The third strategy focuses on the communication aspect in students' learning, including written communication (through mainly journal writing tasks) and oral communication (through mainly oral presentation tasks). Developing students' communication skills is highly valued in the knowledge-based society and is explicitly listed as one objective in Singapore mathematics syllabus. Through students' writing, teachers can obtain useful information about students, not only in cognitive domain but also affective domain, which is hardly assessed by traditional assessment. Through oral presentation, students can have opportunities to tell both teachers and their fellow students (whole class or small groups) what they have learnt, which are useful for teachers to assess students' performance or achievement and for students themselves to reflect their own learning.

The fourth strategy is student self-assessment, including student self-constructed assessment, which asks students to take more responsibilities and have more self-reflection. It is believed that Singaporean students need improvement in this area compared to their Western peers. In this form of assessment, students assess themselves. Self-assessment is conducted by students but instructed (designed and supervised) by teachers and intended to serve the purpose of teachers' assessment. Student self-assessment could be further divided into three sub-types: self-evaluation, self-reflection, and self-construction (for test or just problem-posing). This strategy is another one that could be used to assess students' affective domain.

### Research Design and Procedure

#### *Population and sample*

Each of these four alternative assessment approaches was tried out in 8 secondary and 8 primary schools with their students from Secondary 1 and Primary 3, respectively. These grade levels were selected to avoid the streaming schools may have for their students. Also, Secondary 1 students are in the transition period from primary to secondary education and so may be more willing to try the new assessment strategies in their learning; and the Primary 3 pupils should be becoming familiar enough with the traditional assessment modes after two years of schooling and may be young enough to accept most learning strategies. Indeed, it is about this age that primary pupils may take to thinking and learning to learn (Nisbet & Shucksmith, 1984).

Altogether, 55 mathematics teachers and 2323 students participated in the project. The schools were selected based in a stratified random sample from of from the population. At the primary level, four schools were selected from School Cohort I, consisting of all 9 schools with top-level performance as identified by the Ministry of Education, and the other four from School Cohort II, the remaining schools. Similarly, at the secondary level, four high-performing school were selected from School Cohort I consisting of the fifty best performing schools in the previous two years of GCE 'O' Level Examinations and the other four schools from Cohort II, the remaining schools.

The selected schools were then requested to nominate two high-performing classes and two non-high-performing classes for the project intervention, as well as a comparison class. The criteria used were, for the Primary 3 classes, the pupils' performance in the Primary 2 examinations, and for the Secondary 1, according to course types - Special, Express, and Normal - which are indicative of their O-level performance to a good extent.

Each of the sample schools are randomly assigned to one new assessment strategy, listed as follows. Table 1 and Table 2 below show the details of the participating schools.

Table 1. *Numbers of Participating Students*

	Primary School								Secondary School								Total
	I				II				I				II				
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
HP																	
Int.	40	42	76	82	--	40	41	--	38	40	40	40	40	38	40	41	638
Com.	40	40	39	41	--	40	39	--	40	38	40	39	40	39	40	41	556
LP																	
Int.	40	36	--	--	79	40	31	78	40	40	42	41	40	39	40	39	625
Com.	40	36	--	--	76	40	--	39	39	41	--	39	39	39	39	37	504
Total	160	154	115	123	155	160	111	117	157	159	122	159	159	155	159	158	2323

Note. 1. HP stands for "high performing classes", whereas LP stands for "low performing classes"; 2. Int. stands for "intervention classes" and Com. stands for "comparison classes".

Table 2. *Assignment of Schools to Assessment Strategies*

	Primary Schools	Secondary Schools
Performance Assessment	A, E	I, M
Communication	B, F	J, N
Project Work	C, G	K, O
Self-assessment	D, H	L, P

### *Instruments*

Three main instruments are used by MAP: questionnaires, “new strategy task” tests, and “new strategy” interventions.

### *Questionnaire*

The questionnaire survey, administered to the students, consists of a set four questionnaires: (a) pre-survey (primary school version), (b) pre-survey (secondary school version), (c) post-survey (primary school version), and (d) post-survey (secondary school version). The pre-survey is administered before the intervention, whereas the post-survey will be used at the end of the project. Both questionnaires use the Likert-type scale. The main purpose of the four questionnaires is to find out students’ attitude towards mathematics and mathematics learning and their experience with the new assessment strategies in the daily lesson.

The pre-survey consists of two parts. The first part focuses on students’ perceptions about the subject of mathematics and the value of mathematics learning. In particular, four aspects are included: general view towards mathematics and mathematics learning, the anxiety level in mathematics learning, students’ perceptions of their own performance in mathematics, and students’ beliefs about the usefulness of mathematics. The only difference between the primary version and secondary version lies in the number of questions (Primary: 14; Secondary: 22) and the phrasing of some questions in the consideration of students’ comprehension abilities. For both school levels, a nine-point scale ranging from “disagree totally” to “agree totally” is used for this part. It is believed that such a design is easier for researchers to detect possible changes in students’ attitudes before and after intervention.

The second part of survey in both versions are the same, a total of six questions, which intend to measure students’ experience with the new assessment strategies in their previous mathematics learning. More specifically, one of the questions, including four sub-questions, asks students’ experience with writing and speaking mathematics, two questions are about students’ experience with self-reflection and self-construction, one question talks about the experience with real-life problems, and the other two questions are related to problems having various ways to solve or multiple correct answers.

A total of 79 primary three students selected from the population but not the sample took a pilot version of the survey, in which both two-point-scale and nine-point-scale Likert scale were used. The pilot survey shows that the questionnaire could be completed within 15 minutes with and without teachers’ assistance (with reading the items). Overall, students had no difficulty in answering the questionnaires with both scales. For some phrasing which some students had problems in understanding, a modification was made in the final version of the survey. A reliability test was done for the first part of questionnaire. To enhance the reliable level, four questions in the pilot version were finally removed.

Similarly, a pilot survey conducted at the secondary level with 65 students from two schools from the population but not the sample participated in the survey. Two questions were finally removed from the pilot version in order to enhance the reliable level and the phrasing of some questions was modified so as to make the questions more understandable to the students.

### *“New strategy task” test*

The “new strategy task” test consists of four versions of the four types of new assessment strategies as described in previous section. Similar to the questionnaire survey, the test also includes a pre- and post- intervention version. Research sub-teams (one team for each of the four new strategies) designed their own tests which were then critiqued by the entire research team before sending them for a pilot-test. The purpose of the pre-test is to obtain baseline measures on how well the students perform on the new types of tasks so that researchers could understand better about the students’ entry level as well as benefit from them in the designing subsequent interventions.

Four classes of Primary 3 students from one school took the pilot tests. In each class, the students were given one version of tests in a counter-balanced fashion. The tests lasted about 20 minutes. This was followed by a 10-

minute question-and-answer session. The pilot test revealed the test questions to be new to majority of the students. Some questions were rephrased to remove the language demands for primary pupils. Similarly, the “new strategy task” tests at the secondary level were piloted with five classes from two schools. The analysis of secondary students’ work revealed that they were not familiar with these new types of “assessment” questions. Some students also pointed out that they had difficulty in understanding certain questions and corresponding modifications were made in the final version of the tests.

#### *“New strategy” intervention*

The main intention of the project is to integrate new assessment strategies into the teachers’ daily mathematics lessons. Therefore, when designing interventions, each research sub-team worked the new assessment tasks into each school’s Schemes of Work. The Scheme of Work is a school-based document that spells out the syllabus to be covered for each term. The two intervention classes in the participating schools are at different performance levels and so different versions of the assessment tasks had to be prepared so as to match the students’ ability. Before the implementation of the new strategies, the researchers worked with the participating teachers to confirm the appropriateness of the assessment tasks. The MAP team organised a one-day workshop to prepare the participating teachers (and their HODs, Vice-Principals, or Principals where they could make it) for the integration of new assessment strategies into their daily teaching. The workshop consisted of an overall presentation by the principal investigator, and in-depth sub-team meetings on the details each of the individual assessment strategies.

#### Data collection

The pre-survey was conducted in the 16 sample schools in January-February 2004 with a response rate being 97.6% for the primary school survey and 97.6% for the secondary school survey. The “new strategy task” pre-tests were conducted in the schools in March-April 2004. The high response rate might be expected from such a school-backed research project.

The date of actual commencement of intervention were different across schools – between early April and end May - because each intervention had to be aligned with a school’s scheme of work, the time of the first intervention and the number of interventions being done so far are different across schools. The number of interventions for the first half school year (end May 2004) varies from one to four. The respective sub-teams collected the students’ works for documentation and analysis at end of each intervention. With the participating teachers’ agreement, the researchers observed in a non-participatory manner the classroom implementation of the assessment strategy and made field-notes. Also, where agreeable to the participating teacher, the implementations were video-taped. Thus far, 13 schools were observed and 8 video-taped.

#### Preliminary Data Analysis

The data from the pre-survey were analyzed using qualitative methods to obtain an idea of how the students view mathematics learning and their experiences with traditional education strategies. The analysis also compared the intervention classes and comparison classes on the different aspects of their mathematics learning.

Students’ work in the “new-strategy task” pre-tests were assessed by the individual sub-teams, e.g., using rubrics. An analysis of students’ work was done to obtain a sense of the students’ ability in solving these “new-strategy” tasks before the intervention. The analysis also explored possible differences between experimental classes and control classes.

Two types of data are collected from the interventions. The data from the researcher’s classroom observations were mainly used to monitor whether teachers were beginning to or have fully implemented the new assessment strategy and whether the students are adapting to learning in such a teaching mode. The researchers would use this information for post-lesson discussions with the teachers and for improving on the design of the subsequent tasks. The other set of data came from the students’ performance in either written or oral formats. These would be analyzed in both quantitative and qualitative ways to track students’ learning progress through the whole intervention programme.

#### Preliminary Results and Comments

This section highlights some preliminary results from the pre-survey findings and field notes on the interventions.

### *Pre-survey*

The pre-survey consists of two parts: (A) students' attitude towards mathematics and mathematics learning, and (B) students' experiences with new assessment strategies before the intervention.

For the questions in part A, they could be further classified into four sub-categories: general view, anxiety, performance, and belief. A reliability test of the questions in part A for both school levels yields Cronbach's alpha reliabilities from 0.37 to 0.89. All the low alpha reliabilities came from the primary school survey. The low reliability estimates may indicate that primary students are more malleable to changes in attitudinal dimension. The low values could be due to the fewer number of questions used in the primary school survey than the secondary.

In general, about 80% of primary students found mathematics interesting and learning mathematics enjoyable, while secondary students view mathematics and mathematics learning in a relatively negative way. Compared to the primary students, around 17% more of secondary students claimed that mathematics was hard for them (primary: 37%, secondary: 54%). Consistently, more primary than secondary students expressed that they like to study mathematics.

The survey also reveals that primary students are less anxious than the secondary students toward mathematics. About 20% of primary students reported that they felt scare or nervous about doing mathematics. The results are highly related to students' perception about their performance in mathematics. For instance, nearly 90% of the primary students believe that they can learn mathematics well, whereas about 77% of the secondary students have similar view. While 80% of the primary students claim that they can get good grades in mathematics, about 61% of the secondary students claim so.

Regarding the beliefs of mathematics, students at both school levels claim that mathematics is useful (primary: 87%, secondary: 91%). However, it is also found that only 64% of the secondary students believe that they will use mathematics a lot as an adult (this question is not included in the primary school survey).

Since the pre-survey is to investigate students' attitude toward mathematics before the intervention, which is regarded as a baseline measurement, an examination of the equivalence between intervention classes and comparison classes at the same performance level is necessary. The results show that in most schools, there are no significant differences between intervention classes and comparison classes on the majority of questions in the first part of the questionnaires at both primary level (86%) and secondary level (90%).

Are these shifts in student attitude, belief and anxiety towards mathematics as result of their classroom's experiences with mathematics learning in general and how they were assessed in particular? If so, there are all the more reasons to look into these experiences.

Part B of the pre-survey investigates students' experience with new assessment strategies before the intervention. It was found that nearly half of the primary and secondary students have "never" or "rarely" been requested to explain in writing or verbally, their mathematical ideas or work. In fact, about 76% of the primary students and 93% of the secondary students claimed that their teachers "never" or "rarely" asked them to write down their feeling about mathematics.

The preliminary analysis also reveals that students at both levels did not have many opportunities to make up their own mathematics questions. In particular, about 44% of the primary pupils and 55% of the secondary students reported that they "never" did so. Students were also seldom asked to think about the reasons for their solving mathematics problems.

About 22% of the secondary students and 15% of the primary pupils reported that they did not solve any mathematics problems that were amenable to multiple solutions in the last school year. Nearly 50% of the secondary students claimed that at least half of the mathematics questions they did last year had nothing related to real world. On the other hand, the pre-survey shows that primary pupils to have had more experience with real-world problems.

The majority of the question items in Part B held no significant differences between intervention and comparison classes for school levels in most schools (primary: 79%, secondary: 87%).

These preliminary findings suggest that the students experiences with the alternative forms of assessment to be limited, with the exception of perhaps, working on problems amenable to multiple solution methods. The MAP is thus timely and relevant.

#### *Field notes*

Overall, the participating teachers were very positive and receptive towards the project. Many of them believed that the new strategies would benefit their teaching. Moreover, the strategies that the project introduced are generally new to both teachers and students. One common comment, not unexpectedly here and elsewhere, was that the implementation of the strategies was very time consuming. Some teachers worried that they might not have enough time and energy to implement them. The pressure to make sure that their students could get good results is those teachers' another important concern. The daily heavy workload was also one factor that brings difficulties to teachers' integration of new strategies into regular teaching. In view of the fact that tasks were designed to be aligned with their scheme of work (of course, there is the possibility that the tasks were not appropriate) the MAP sees these teachers' concern to be a point of concern, which it tries to understand by purposefully attempting the integration or infusion of the strategies into the daily lesson. Would not these alternative assessment strategies result in no less student achievement and take no more time?

Regarding video-taping the intervention lessons, different teachers reacted to it differently. Some teachers were very keen on the idea as they would like to discuss their teaching with researchers. At the other end, some teachers were remained uncomfortable with the idea of an observer in their classes, despite assurances that the observation was solely on how the pupils reacted to the new strategies and not on the evaluation of the teaching. However, these teachers did agree to look out for the pupils' reaction to the tasks and to make notes on the researchers' behalf. It is part of MAP's to find out the conditions under which the integration of the new strategies would be successful and teacher-factor is one of them.

The initial set of assessment tasks was crafted by the researchers. Ideally, the teachers were to design subsequent ones to match their students' ability and school's scheme of work. However, the teachers needed more assistance than expected with crafting the assessment tasks for the performance assessment, project work and oral communication assessment. The teachers working with student self-assessment strategy or with the journal writing (part of the communication assessment strategy) were able to design the tasks to meet their needs. Not unexpectedly, it is clear that time, experience, and knowledge are important factors to consider for successful implementation of the new assessment strategies. It indicates that not only students need time to be used to the new strategies, teachers also need to learn how to integrate the new strategies into regular teaching to enhance the effectiveness of teaching and learning. MAP seeks to understand mechanics behind these factors.

#### *Lessons learned*

The project met with some difficulties in the initial stage of implementation. First, most of the teachers commented that they were already heavily loaded with their school work in addition to other educational initiatives their school is committed. They found it hard to carve out time to execute the intervention tasks the researchers had prepared for them as they found it a challenge even to cover the syllabus according to the schedule mapped out by the Scheme of Work. The teachers prioritised, and the MAP interventions were placed lower. In discussing with some of these teachers it appears that their other commitment are to projects that are sanctioned centre-to-periphery whereas, on an ethical basis, the MAP was presented as participatory, wherein teachers could opt not to collaborate.

Some schools are concerned with the academic performance of their students. The schools are worried that the intervention may affect their academic performance. The teachers also felt the need to do many other things to meet this expectation. For instance, the schools were assigned much homework which the teachers must mark and return in time. Participation in the MAP meant that the teachers and students will have assignments over and above the assigned ones. As such, for successfully implementation of an external project, the research team has to work hard at convincing and assuring schools of the benefits of the project. This was evident from the boosts in teacher interventions after each of the continual assurance talks by the principal investigator.

Keeping regular contact with the teachers to monitor the project and to render them assistance are very important. MAP realised that it is vital that the teachers and researchers to meet occasionally, and if possible, frequently, so as to maintain an amicable yet professional working relationship. However, to find time convenient for both the researchers and teachers to meet is not easy. A teacher's professional life is surprisingly very busy; they go on course for training, they supervise students' camps, just to mention a few. The situation was not helped when a 5-day work week was implemented in schools soon after the commencement of MAP.

The classroom is still very much one of a closed, personal space. Teaching is indeed very personal. One of the research questions is to find out how to use the intervention tasks effectively in the classrooms and so observations or video-tapes these interventions lessons will be an invaluable source of data. However, some teachers were strongly against the idea “someone” else in the classroom. Indeed, in this case, even the head of department respected the teachers’ wish not to be “watched” at all. The fact that other teachers could be persuaded by the researchers to allow video-taping or observations of their lessons goes to show that trust in the researcher may be an important success factor for closer collaboration with an external research project.

Some operational issues include streaming of students at Primary 3 and Secondary 1. Whereas some schools could keep the classes intact, others had to re-organise the classes due to some unforeseen reasons or new administrative policies. Such is the reality facing a research project that span a year and a half of the school calendar.

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