

**Improving Mathematics Teaching and Learning through Effective Classroom  
Assessment: Experiences and Perspectives from Singapore Schools**

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# **Improving Mathematics Teaching and Learning through Effective Classroom Assessment: Experiences and Perspectives from Singapore Schools\***

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During the last decades, the importance of assessment in mathematics education has received much attention from policy makers, mathematics education researchers, and mathematics teachers, among others, in many countries (e.g., see Niss, 1993, Webb & Coxford, 1993, National Council of Teachers of Mathematics (NCTM), 1995). In particular, relatively new assessment (or the so-called alternative assessment) concepts and strategies have been widely advocated by educational reformers and increasingly used by practitioners in classroom practices. In Singapore, those newer strategies have also received mounting attention in the mathematics education community (e.g., see Fan & Yeo, 2000; Seto, 2002, Yazilah & Fan, 2002). In 2002, the Ministry of Education of Singapore issued a draft version of assessment guidelines for mathematics instruction at primary and lower secondary school levels respectively, which were later developed into its official documents, *Assessment Guides to Primary School Mathematics* and *Assessment Guides to Lower Secondary Mathematics*, published in 2004 (MOE, 2004a, 2004b). Currently, there are 16 primary and secondary schools participating in a nationwide research project, Mathematics Assessment Project (MAP), under the Center for Research in Pedagogy and Practice (CRPP) of the National Institute of Education of Singapore, integrating new assessment strategies into mathematics classrooms.

This paper mainly draws on my experiences of offering in-service training in assessment and alternative assessment at university level and some research work (including the MAP) I have been involved in recent years concerning the implementation of new assessment strategies in Singapore schools, and presents my personal perspectives on relevant issues on assessment. The paper below is mainly in three sections. In the first section, taking a broad view I will share with the readers my understanding of the concepts of assessment and alternative assessment. In the second section, I will analyze the rationale for using alternative assessment strategies in teachers' classroom instruction, and explain why the newer assessment strategies are often more effective in mathematics teaching and learning. In the last section, I will discuss relevant issues and make

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suggestions on how to implement alternative assessment strategies in classrooms. A few concluding remarks will be made at the end of this paper.

### **Concept of Assessment and Alternative Assessment**

It is interesting to notice that in the recent Tenth International Congress on Mathematical Education (ICME-10), two terms “internal assessment” and “external assessment” were employed to distinguish assessment themes. Internal assessment was basically used to refer to classroom assessment, which is “in the hands of the teacher with the constraints imposed upon teachers and schools by externally sanctioned forms of assessment”, while external assessment includes “all kinds of testing and assessment that is done because of external obligations from a school district, or from the state or federal government” (Stephens, 2004). Nevertheless, traditionally the concept of assessment was largely equated with written tests/examinations, as evidenced, for example, in an early book, *The Theory and Practice of Teaching* (Bayles, 1950), no matter they are internal ones carried out by teachers or external tests conducted by test agencies or educational authorities. Based on findings from an action research on Singapore teachers who participated in an in-service training in alternative assessment, this conception still exerts profound influence on many teachers’ cognition and practices in their classroom teaching (Fan, 2002). Under this traditional and narrower conception, what students are assessed are purely their academic achievement, including mainly their knowledge on topics well defined in the syllabus or textbooks and skills on solving routine and conventional problems; how students are assessed are dominantly through administering time-limited (in a block of time), tool-limited (paper-and-pencil and/or with calculators), and venue-limited (often within classrooms) tests; and the underlying reason for conducting such assessment is to mark and grade students’ learning results for reporting or selecting purposes. In fact, the practices of written examinations can be traced back in China at latest to the beginning of Tang Dynasty (the 7th century) in its well-established state examination system (e.g., see Siu, 2004) and in the US to the 1840s when the Boston public schools began to institute the first uniform written examinations across schools (e.g., see Tyack, 1974).

The newer and broader concept of assessment in mathematics education goes much beyond just being written test not only in how students are assessed, but also in what and why they are assessed. According to *Assessment Standards for School Mathematics* issued by NCTM, 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). Under this concept, assessment means both teachers’ gathering information and making inferences for various purposes, and should cover both cognitive and affective domains in students’ achievements and performances. Similarly, Singapore MOE’s *Assessment Guides* (MOE, 2004a, 2004b) emphasized that assessment is “more than tests, rubrics and giving marks”, and it should be “an integral component of the teaching and learning process” and the main purpose is to “improve the teaching and learning of mathematics” (e.g., see MOE, 2004a, p.7; also see MOE, 2001, p.18).

The NCTM's definition mentioned above includes both the so-called internal assessment and external assessment, and Singapore's MOE's description is largely similar but more focus is, though implicitly, on internal assessment or classroom assessment. One indicator for such a difference is the fact that not all external assessments mainly serve the purpose of improving the teaching and learning of mathematics, instead they often serve the purpose of measuring students' academic performances for certifying their attainments and/or selecting them for placement in streaming or entering a higher level of education. It seems clear that traditionally policy makers, educational administrators, and the general public, especially in China and other Asian countries, pay much more attention to external examinations such as O-level/HKCEE and A-level/HKALE tests in Singapore and Hong Kong, and college entrance examinations in China and Japan, since they are usually of high-stakes and highly publicized. On the other hand, people tend to underestimate or ignore the importance and issues of internal assessment in mathematics classroom, which is, however, in general more relevant to mathematics teaching and learning for students. Below I shall mainly restrict the theme of my discussion to internal or classroom assessment.

It should be noted that the traditional concept of assessment as written test (regardless it is internal or external) virtually excludes students' "disposition", which NCTM's *Standards* interpreted as students' interest in and appreciation for mathematics, tendency to think and act in positive ways, and confidence, curiosity, perseverance, flexibility, inventiveness, and reflectivity in doing mathematics (NCTM, 1995). In addition, it is clear that students' disposition to be assessed should be not only about mathematics itself as a discipline, but also about mathematics teaching and learning. Furthermore, what are assessed should include not only students' learning results, but also students' learning process, that is, how they learn.

The main features of the traditional and new concepts of classroom assessment can be generally summarized as below (See Table 1).

**Table 1**

Comparing the main features of the traditional and new concepts of assessment

<b>Mathematics assessment</b>	<b>Traditional concept</b>	<b>New concept</b>
What (content)	Cognitive domain (mainly knowledge and skill), and the results of learning	Both cognitive and affective domains (knowledge, skill, ability and disposition), and both the results and process of learning
Where (location)	Within classrooms	Within and/or outside classrooms
When (time)	During class for a block of time (e.g., one class period)	During and/or after class. It could be days, weeks, months, or even years.
How (method)	Conventional way (paper-and pencil or written test)	Both conventional and alternative ways
Why (purpose)	Single (most important: grading and reporting students' learning results)	Multiple (most important: improving teaching and learning)

The development of the concept of alternative assessment can be roughly traced through three stages, though some so-called novel assessment techniques, for examples, classroom observation, oral discussion, and student interviews, have been discussed since as early as the 1940s (e.g., see Lambdin, 1993). In the 1970s, education reformers particularly in the United States begun to see more the inadequacy of purely employing standardized tests, which dominantly used multiple-choice-questions, to assess students' learning, and they suggested a number of alternatives to standardized tests. The then recommended list included the so-called performance contract (or contract grading), classroom observation, and interviews, etc. In this stage, researchers also treated teacher-developed test as an alternative to the standardized ones, which were the main target of criticism for assessment reform (e.g., see Quinto & McKenna, 1977).

In the 1980s, much attention was shifted to internal assessment or teachers' classroom assessment, and alternative assessment was meant to be different from traditional paper-and-pencil tests. In 1989, NCTM issued an influential document, *Curriculum And Evaluation Standards For School Mathematics*, in which the recommended list of possible assessment methods, in addition to written and standardized achievement tests, include classroom observation, oral questioning, focused written tasks and journals, class presentations, group work and projects, student interviews, extended problem solving projects, among others (NCTM, 1989).

In the last decade, the list of alternative assessment has been further expanded. In particular, mathematics educators have demonstrated more interest in internal assessment with the purpose of improving teaching and learning in classrooms. Many have focused more on directly exploring new ways to assess students' learning, less on the relative meaning of "alternatives"; this could be partially seen from the fact we now see that people increasingly use a more neutral term "new assessment" instead of "alternative assessment" in describing their assessment concept and practice, and in some extreme cases, people even argued that the labels "traditional" and "alternative" are meaningless (Romagnano & Long, 2001).

Although researchers and educators have different views about alternative assessment and there exists no single universal definition of alternative assessment, people generally agree that alternative assessment is different from traditional paper-and-pencil or written tests, and it can include any type of assessment in which students create a response to a question or task rather than simply recall an answer from memory or choose a response from a given list as typically seen in traditional multiple-choice, true/false, or matching test items. Moreover, in alternative assessment, the tasks are expected to be consistent with curriculum goals and often embedded in real-world situations, and teachers need to employ a variety of ways or procedures for observing, collecting, and evaluating evidence on students' learning.

According to Hatfield, Edwards, and Bitter (1997, p.107), alternative assessment usually has one or more of the following characteristics: (1). Students perform, create, and produce (procedures, answers, or even questions); (2). Tasks require problem solving or

higher-order thinking; (3). Problems are contextualized; (4). Tasks are often time-consuming and need days to complete; and (5). Scoring rubrics or scoring guides are required. Nevertheless, it is not difficult to note that those characteristics are mainly applicable to assessment tasks in cognitive domain rather than affective domain.

In recent years, the concept of alternative assessment in mathematics has been generally used to include the following specific techniques in classroom assessment (though these techniques might be termed by different people slightly differently): performance-based assessment, authentic assessment, portfolio assessment, journal writing, project assessment, oral presentation, student interview, classroom observation, student self-assessment, among others. Those specific ways of assessment have been better defined and increasingly used in practices. In this sense, the general label “alternative assessment” is still meaningful to reflect the difference of these new ways of assessment from the paper-and-pencil test, though it appears now clear that some kinds of test items in the traditional written test can also to a degree reflect and accommodate certain ideas of the so-called “alternative assessment”. Therefore, in terms of the content of assessment, the distinction between traditional assessment and alternative assessment has been somehow blurred.

### **Rationale for Alternative Assessment**

Why is alternative assessment needed in classroom practice? There are mainly three related reasons. The first is that the traditional paper-and-pencil test has its own limitations. The second is that new educational goals and values have been developed over the last decades. The third, following the second reason, is a reflection of the development of the new conception of pedagogy and assessment.

Regarding assessing students’ learning of mathematics, undoubtedly the traditional written classroom test has its own advantages; however, it also has serious inadequacies, which become more evident under the new paradigms of educational goals and values. Table 2 presents an overview of the relative advantages and disadvantages of using traditional paper-and-pencil tests in classroom assessment.

Because of its advantages, it is clear that the paper-and-pencil test should and can still play an important role in teachers’ daily practice in assessing students, and because of its limitations, new ways of assessment are needed to compensate for what the traditional written test cannot achieve.

There is no doubt that the ultimate reason for teachers’ teaching practices is to help students achieve the educational goals. Assessment as a tool and as an activity in teaching is no exception. In Singapore, as in many other countries, the goals of education have undergone significant changes for the last decades along with the rapid economic and social development and change. Developing students’ problem solving ability and higher-order thinking, interpersonal and cooperative skills, oral and written communication skills, among other objectives, have been increasingly valued in education. Those changes must be reflected into classroom practice, and teachers need to measure how

their students achieve and make progress against those important goals. As the traditional written test largely cannot serve this aspect, there is necessity to introduce new assessment strategies to better reflect the changed goals.

**Table 2**

Advantages and disadvantages of traditional paper-and-pencil tests in classroom assessment

Advantages	Disadvantages
1. Good coverage in content.	1. Exclude affective domain.
2. Good for testing factual knowledge and specific skills.	2. Often test what is easy to test, not what is important to test.
3. Easy to design.	3. Emphasize more on memorization, less on understanding.
4. Easy to administer.	4. Emphasize more on lower level skills, less on higher-order skills and abilities.
5. Easy to mark and grade.	5. Often test what students don't know, not what they do know.
6. More objective.	6. Students might have test anxiety which will affect their performance in test.
7. Easy to analyze and report.	7. Emphasize more on the product, less on the process of learning.
8. Well established.	8. Could be destructive, making students dislike mathematics and learning.
9. Well accepted.	9. Hard to be an integral part of the teaching and learning process.

Note: The advantages of the written test listed in the table are more evident when they are used in external assessments with a large population of students for achieving certain uniformity/equity, efficiency in testing and consistency of the results.

In mathematics subject, according to the well-known pentagon curriculum framework in Singapore's mathematics syllabus (MOE, 2001), the primary aim of mathematics curriculum is to enable students to develop their ability to solve mathematical problems. Around the center are five components: concepts, skills, processes, attitudes, and metacognition. Moreover, the syllabus clearly stated that "teachers should assess different aspects of thinking, learning and behavior", which include mental calculation, mathematical communication, practical uses of mathematics, investigative work, problem solving, critical thinking, creative work, and use of information technology. Given those broad objectives and contents in mathematics and the inadequacies of traditional written test discussed above, there is much realistic reason to employ new approaches in order to align the methods and tasks for assessing students' learning with the curriculum's goals, objectives, and content, and thus effectively provide useful information to both teachers

and students for the improvement of teaching and learning in mathematics classrooms (also, see NCTM, 1989; 2000)

Alternative assessment can be also viewed as a reflection of the new developed conception of pedagogy and assessment. For the last decades, people have gained much knowledge about the importance of students' affect (e.g., attitude and interest), of the ways of students' learning (e.g., cooperative learning and constructivism learning), and of teachers' monitoring students' learning behavior and process (e.g., their learning habit and their thinking process) in improving student's learning of mathematics. Correspondingly, the concept of assessment has expanded to include both students' cognitive and affective domain, and both the results and process of students' learning, as mentioned earlier. Under such new development, the traditional paper-and-pencil test becomes in many senses ineffective and even irrelevant, therefore different methods are needed to provide effective tools for classroom assessment.

In short, the alternative assessment techniques in mathematics are developed to more effectively reflect the new shifted values and desired goals and objectives in mathematics instruction, and are a reflection of the new developed conception of pedagogy and assessment.

### **Issues on Implementing Alternative Assessment**

There have been quite a number of literatures available concerning the implementation of new assessment concept and techniques in classrooms, particularly in the US and some other western countries (e.g., see Kulm, 1994; Berenson & Glenda, 1995; Clarke, 1997; Hargreaves, Earl, & Schmidt, 2002).

In Singapore, the MOE has made much effort in promoting the use of project work to develop students' problem solving ability and other desirable skills. According to the MOE, a school-based trial carried out in all junior colleges and centralized institutes has affirmed that project work is a valuable learning activity, though it was found that teachers and students needed more time than originally scheduled to be familiar with the processes involved in project work. As a result, it was decided that project work would be included as part of student assessment package (external assessment) for admission into local universities from 2005 instead of 2004 as recommended earlier (MOE, 2001).

For the last few years, the National Institution of Education has offered an in-service training module, in which alternative assessment is a key component, to local primary mathematics teachers. The main objective of the in-service module is to help teachers keep abreast of the new development in assessment and be equipped with necessary knowledge and skills for implementing a variety of alternative assessment methods in their teaching (also see Fan, 2002). So far, more than 100 teachers have participated in the training in six intakes, and all of them were required in the module to design, implement, and analyze an alternative assessment task in the class they were teaching. Various ways of doing alternative assessment were employed by those in-service teachers

in an authentic way, including project work, journal writing, interview, oral presentation, performance tasks, student self-assessment, and classroom observation.

Some more structured research work, though in small-scale, in this area in Singapore educational settings can be found in Seto (2002) on oral presentation with Primary 4 students in a neighborhood school, Yazilah and Fan (2002) on journal writing with Primary 5 students in a high-performing school, and Yeo and Fan (2003) on journal writing in junior college classrooms, among others.

Since the end of 2003, a team consisting mainly of university professors and researchers, educational administrators and school teachers have been conducting a major research project, Mathematics Assessment Project (MAP), as mentioned earlier. Four types of new assessment strategies: project-based assessment, performance-based assessment, communication-tasks-based assessment (on both written and oral communications tasks), and student self-assessment, have been implemented in more than 50 mathematics classrooms in 16 schools including both primary and secondary schools and high performing and non-performing schools, involving a total of 55 mathematics teachers and more than 2300 students. The implementation will last for about one year and a half, and the purpose is to investigate the influence of those assessment strategies on students' learning of mathematics in both academic and affective domains and to explore the effective ways of implementing those strategies into mathematics classrooms.

The results from those in-service teachers' experiences, the small-scale studies, and the ongoing MAP project, have been quite consistent and overall very positive. It proved that alternative assessment is within teachers' ability to grasp and implement, and both teachers and students benefited from those new ways of assessment in a variety of ways. It can effectively overcome the weakness of traditional paper-and-pencil tests as described earlier in Table 2. In addition, it was found that alternative assessment can not only help students develop their problem solving ability and higher-order thinking skills and foster positive dispositions toward mathematics learning, but also help students improve their achievement measured using conventional written tests, which is particularly notable in Seto's study (also see Nirmala, 2002).

On the other hand, it should be pointed out that, compared with the traditional teacher-made test, alternative assessment also presents practical challenges for teachers and students. The main problems or challenges found can be generally described in the following four aspects. Some relevant suggestions are given accordingly.

**1. Time-consuming.** Designing, administering, evaluating, and reporting alternative assessment are often time-consuming. It requires not only teachers' innovation and creativity, but more importantly their determination and persistence. In addition, doing or preparing for alternative assessment tasks, such as project work, journal writing, and oral presentation, could be also time-consuming for students. Therefore, teachers should be cautious in deciding the frequency of using such tasks. It could be unrealistic or even counterproductive for teachers and students to implement too many different ways of alternative assessment or use a single way too frequently in a short period of time. The

ideal situation would be that teachers integrate alternative assessment into their instructional practice so as to avoid disrupting the process of teaching and learning or imposing unnecessarily additional work on both teachers themselves and students.

**2. Difficulty getting started.** Teachers and students often have substantial difficulty at the beginning and need time to be familiar with the new approaches to assessment, which seems particularly to be a challenge in an educational environment like Singapore, where there is usually a great pressure for teachers and students to target teaching and learning activities closely to the preparation for external assessments such as PSLE (Primary School Leaving Examination) and O-level tests. Hence, it is often necessary that teachers start using alternative assessment methods gradually and carefully. The MAP has found it is feasible to start implementing these new assessment methods at an early grade level, that is, when the students do not have immediate pressure at the end of the school year for passing external assessments. More importantly, it is also essential that enough guidance be given to students at the initial stage of the implementation.

**3. Lack of resources.** Teachers have found that not many resources are available in this area, and in particular, the current textbooks do not well reflect alternative assessment concept and contents. Nevertheless, it should be pointed out that the amount of resources, especially online resources, in supporting using alternative assessment grows very rapidly. In addition, it would be helpful if teachers can have more exchanges with their colleagues and be provided with more professional development opportunities in this area such as participating in seminars, workshops, and in-service training courses. In fact, the MAP is also intended to develop relevant teaching resources for classroom use in this area.

**4. Less well accepted.** That is particularly true at the beginning of implementing alternative assessment in a class. Being familiar with doing paper-and-pencil work, students can question why they need to work on new types of tasks, and parents can doubt if the teachers' evaluation of their children's work is fair, valid, and reliable. In this regard, it is important for teachers themselves to establish a broader and newer mindset about assessment and make clear to students and sometimes even parents that the main purpose of using those new assessment strategies and tasks is not for teachers to grade and report students' learning results, but for them to more effectively collect information about teaching and learning in the classroom, and therefore make informed decisions to improve teaching and learning of mathematics.

To make alternative assessment successful, I believe it is also vital that teachers realize that different alternative assessment methods serve different purposes. It would be naive to think that there is a single best way, be it the traditional written test or a new alternative method, that can serve all the purposes of mathematical instruction. Table 3 is an outline of some connections between different alternative assessment methods and different purposes of assessment they can reasonably serve.

By the way, in terms of research, researchers have also explored relevant theoretical as well as technical issues concerning the use of alternative assessment particularly in large-scale assessment, such as those about validity, reliability, equity, objectivity, and

generalizability (e.g., see Ruthven, 1994; Phillips, 1996; Herman & Klein, 1996; Hargreaves, Earl, & Schmidt, 2002). Nevertheless, it is beyond the intention of this article to discuss those issues.

**Table 3**

Alternative assessment methods and different purposes of assessment

<b>Alternative method</b>	<b>What can be better assessed</b>
Performance-based assessment	Cognitive domain, particularly students' higher-order thinking process and problem solving ability.
Authentic assessment	Cognitive domain, particularly real-life problem solving ability.
Portfolio assessment	Both cognitive and affective domains, particularly the development of students' learning over a period of time or represented in a variety of aspects.
Journal writing	Both cognitive and affective domains, particularly students' deep thinking and written communication skills, and their disposition concerning learning of mathematics.
Project assessment	Cognitive domain, particularly students' problem solving ability and creative thinking skills.
Oral presentation	Cognitive domain, particularly students' organizational and oral communication skills
Student interview	Both cognitive and affective domains, particularly for getting information from a few particular students
Classroom observation	Affective domain, particularly students' learning behaviors in classroom.
Student self-assessment	Both cognitive and affective domains, particularly students' disposition toward learning of mathematics, and their involvement in learning process, e.g., doing group activity.
Student-constructed assessment	Cognitive domain, particularly at the evaluation level in Bloom's taxonomy of educational objectives in cognitive domain.

### **Concluding Remarks**

It seems clear to me that there are two basic principles relevant to the theme of this article for teachers' classroom assessment. First, teachers' classroom assessment must serve the purpose of improving teaching and learning; and second, classroom assessment must be an integral part of instructional practice. In a sense, these two principles largely reflect the distinction between internal assessment and external assessment. Given those two principles and the limitations of the traditional paper-and-pencil assessment, it is quite natural to see the necessity and values of employing new ways of assessing students in mathematics instruction.

In short, although the traditional assessment still has its own advantages and values to offer and hence we should improve rather than abolish it, the so-called alternative assessment does show us new hope and give us new tools in our teaching practices. It can help us make assessment more consistent with educational goals and curriculum objectives, more constructive in promoting students' learning, and more integral as a part in the process of teaching and learning, though how much it can be helpful depends on how we can implement it effectively.

Finally, I believe that the integration of new types of assessment methods into mathematics classroom should, in a large sense, precede the use of them in external assessments. In other words, the reform in international assessment should correspondingly lead to the reform in external assessment, not the other way around. By this way, desirable reforms in the high-stake external assessment can be better accepted and implemented.

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