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Assessment and Teaching of Mathematics for 21st Century Learning

Objectives of Inquiry

Classroom assessment practices in schools are often influenced by competing views of pedagogical approaches, that is, didactic teaching versus authentic learning. The rapid globalization and the emergence of a knowledge-based economy have created a new technological-communicational reality (Hofman, Alpert, & Schnell, 2007). Its pervasive impact in society includes the digitization of lifestyles, the exponential increase in knowledge and the proliferation of a bewildering array of competing perspectives, alternatives and solutions. The convergence of these societal forces have led Trilling and Fadel (2009, p.21) to suggest a possible formation of a `perfect learning storm' for classroom teaching and assessment. Such quick and monumental changes have confronted teachers with many 'vaguely formulated goals and largely undefined new practices.'(Geijsel & Meijers, 2005).

Teachers are caught in a dilemma between the security of well established traditional practices and the uncertainty of embracing curriculum and assessment innovations and the new reality (Cheng & Walker, 2008). They are unwilling to take on the unfamiliar and yet are afraid to be left behind (Harris, 2001). Educational reforms are often rolled out to manage the effects of globalization and to ride the next wave of innovation and enterprise. Though its ultimate aim is to prepare students to face future challenges, the ensuing restructuring of the educational system has serious ramifications on students, teachers, principals, administrators and the community. Educators may perceive the numerous reforms as unnecessary intrusions that do not address local issues adequately (Fullan, 1991). Teachers are therefore caught in a dilemma between the pull of the familiar and the push for innovation (Walker & Walker, 1998). The formal in the form of didactic teaching seems to have produced academic results. In Singapore, the strong cultural emphasis on didactic pedagogy have consistently help students maintain their top ranking positions in mathematical achievements conducted by Trends in International Mathematics and Science Study (TIMSS). Yet such monologic expository teaching – with its emphasis on drill and practice on basic knowledge and skills – could only prepare students to attain better results in high stakes examinations. Its didactic approach is inadequate in averting the impending `perfect learning storm' as the world today has grown more inter-connected and complex. Twenty-first century learning requires a new set of competencies.

This vision of 21st century skills seems to be diametrically opposed to the drill and practice of traditional assessment mode. It is often centered on the recurring theme of authentic learning and assessment. Situated within the integration of academic disciplines, pedagogies, skills, technologies and community resources (Trilling & Fadel, 2009), this mode of assessment facilitates the incorporation 21st century thinking skills into classroom pedagogical approaches. (Trilling & Fadel, 2009). In Singapore, a new mathematics syllabus that adopts a more eclectic approach to real life problem solving will be implemented with all Grade7cohort from 2011. There is now greater emphasis in the development of 21st century skills and the use of authentic and current materials in the teaching of mathematical concepts. The new syllabus emphasizes a holistic development of concepts, processes, attitudes, skills and meta-cognition in the teaching of mathematical problem solving. It encourages the development of productive habits of mind (Cuoco, Goldenberg, & Mark, 1996), the creation of an organizing taxonomy of mathematical thinking skills (Moseley, et al., 2005), the integration of pedagogies and the usage of technologies for calculations. The applicability of mathematics in many disciplines also fostered new mathematical methods of an inter-disciplinary nature. It takes on diverse roles that require creativity and communication skills within a collaborative work environment. How will these

competing views of pedagogical practices and the diverse assessment modes be synthesized into coherent intellectual demands on students? What are the standards or indicators that could define the quality of classroom teaching and assessment? What should be the goals of classroom assessment practices in Singapore schools?

This study aims to examine the relationships between teacher's assessment practices in mathematics and student's mathematical quality work. The specific objectives of the study are

(a) to reformulate a framework of Intellectual Quality Work (IQW) for mathematics,
(b) to examine the construct validity of the Intellectual Quality Framework (IQF) for both teachers' assignments and associated students' work in mathematics, and
(c) to study the variation of student's mathematical quality work at student level, teacher level and school level.

Conception of Intellectual Quality Framework

The first attempt to build a classification of educational goals began in1948 at an informal meeting of college and university examiners held in Boston. The result was the publication of Bloom's Taxonomy of educational objectives in 1954 (Bloom, 1954). Its impact among educators was extensive and the taxonomy has guided educators in their preparation of classroom experiences for more than half a century. In 1995, a revision to Bloom's Taxonomy was initiated by Lorin Anderson and David Krathwohl. A new taxonomy for learning, teaching and assessing was published in 2001 (Anderson, et al., 2001). This is a two dimensional framework comprising a cognitive process and a knowledge dimension. The former consisted of remember, understand, apply, analyze, evaluate and create. The latter – described by Koh and Luke (2009) as depth of knowledge – starts with factual, followed by conceptual, procedural and finally metacognitive knowledge. The effectiveness of this two-dimensional categorization was described by Erickson's structure of knowledge – an adaptation of Texas Depth & Complexity Model with the revised Bloom's Taxonomy by Anderson and Krathwohl (Erickson, 2007). In another breakthrough study on the US school reform, Newmann suggested the criteria of construction of knowledge, disciplined inquiry and value beyond the school as key indicators of `authentic intellectual work' (Newmann, 1996). This was adapted and expanded by Koh and Luke (2009) in the Singapore Classroom Coding Scheme designed to measure classroom pedagogies (Koh & Luke, 2009). The quality of teachers' assignments or assessment tasks are evaluated by depth of knowledge, knowledge criticism, knowledge manipulation, sustained writing, clarity and organization, connections to the real world beyond the classroom, supportive task framing, student control, and explicit performance standards/marking criteria. Each of these criteria can indicate four levels of complexity. This present study explores the integration of Anderson and Krathwohl's taxonomy with Koh's nine criteria to form an Intellectual Quality Framework (IQF). It can be used to evaluate the Intellectual Quality Works (IQW) of teacher's assignments and the Intellectual Quality Works of student's artifacts. It provides a combination of visual coherence and conceptual congruence in its integrated three-dimensional model. Teachers can therefore be guided by its topographical features in creating authentic intellectual work to meet 21st century expectations in our educational landscape.

Methods

A random stratified sample is obtained from 30 schools (15 primary schools and 15 secondary schools). Subgroups of students taking Mathematics and English from grades 5 and 9 are randomly selected. This sampling method takes into account the diversity of schools types and

the variation in socio-demographic characteristics of the population in Singapore. As the focus is on mathematics, a total of 300 teacher's mathematics assessment tasks and associated 2700 students' work will be collected in 2010. The types of assessment tasks consist of class work, homework, major assignments/projects, and tests. Each teacher is required to submit 3 high-quality, 3 medium-quality, and 3 low-quality student work for each assessment task. Both physical artifacts (e.g. written students' work) and digital artifacts (e.g. oral presentation) on students' work will be videotaped.

To study assessment practices in schools, teachers will have to fill a questionnaire form called the *Coversheet*. It contains open-ended questions and closed-ended questions (i.e. 5-point Likert scale). During the collection of artifacts, a short 15-minute semi-structured interview with teachers will be conducted. The purpose of the interviews is to encourage teachers to elaborate on their answers in the open-ended questions in the *Coversheet*.

Thirty-six experienced/master teachers from non-participating schools will be recruited and trained to use 2 sets of scoring rubrics - one for teacher assignment and another for student work. They are based on a 4-point Likert scale (ranging from 1 = no requirement/no demonstration to 4 = high requirement/high demonstration). To ensure high inter-rater reliability among teachers, an exact agreement of at least 70% must be attained before teachers are asked to score the actual teacher's assessment tasks and students' works.

In this study, quantitative and qualitative analysis will be used. In addition, confirmatory factor analysis and hierarchical linear modeling will be utilized to examine the relationships between teacher's assessment practices in mathematics and student's mathematical quality work. To examine the construct validity of Intellectual Quality Framework (IQF), Mplus version 6 (Muthen, Muthen, & al, 2010) is used to apply confirmatory factor analysis (CFA) in the study. The data of student work have a hierarchical structure in 3 levels: student- (i.e. individual-), teacher- (i.e. classroom-) and school-level. Hence, Hierarchical Linear and Nonlinear Modeling (Bryk & Raudenbush, 2004) is used to 'study the relationships in these 3 levels, incorporating the variability associated with each level of the hierarchy'. HLM is an extension of regression analysis at a hierarchical structure. HLM allows us to investigate the variation of students' quality work at student-level, teacher-level, and school-level in mathematics. Finally, all collected interview data will be transcribed into word documents and can be analyzed using NViVo 8. Such qualitative analysis will provide us with in-depth insights into teachers' perceptions of assessment practices.

Educational Importance

The current classroom assessment in mathematics is confronted with multiple challenges. Teachers must maintain mathematical rigour and standards while at the same time, weave 21st century skills into the newly crafted syllabus to meet 21st century challenges. The limited curriculum and preparation time and the lack of conceptual knowledge of intellectual quality works causes teachers to resort to drill and practice of mathematical concepts. The current study of Intellectual Quality Framework provides a comprehensive examination and identification of essential standards that produces quality achievements. These standards are coherently integrated and educationally contextualized. Teachers can therefore use this framework to evaluate students' artifacts and set appropriate educational objectives to guide them in producing quality assignments.

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