The Quality of Teachers' Assessment Tasks and Student Work in the Singapore Science Classrooms

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Abstract

This study examined the quality of teachers' assessment tasks and associated student work in the Singapore Science classrooms. Using the authentic intellectual quality framework, two sets of standards and scoring rubrics were developed for the training of teachers to judge the quality of teachers' science assessment tasks and student work. The samples of teachers' assessment tasks and student work were collected from 30 elementary schools and 29 high schools. The results show that the teachers' assessment tasks at both grade levels did not demand high authentic intellectual performance from students. As a result, student work did not demonstrate high authentic intellectual quality. The findings suggest the need for improving teachers' assessment literacy in science through professional development in authentic assessments.

The Quality of Teachers' Assessment Tasks and Student Work in the Singapore Science Classrooms

Singapore, a tiny island nation located at the southern tip of the Malaysian peninsula, was a British colony until gaining independence in 1965. Because it has little land and few natural resources, Singapore has capitalized on its technological and entrepreneurial approaches to become economically and politically successful at the international level. Science literacy has always been considered important and plays a significant role in driving Singapore's technological and economic developments. In the Singapore education system, Science is introduced formally at grade 3 and it remains a core subject area throughout a child's ten years of compulsory education from the elementary to high school levels. The science education aims at equipping individuals with the skills, processes, and attitudes needed to acquire knowledge about the natural world as well as producing competent individuals in research and development in the various scientific disciplines.

In the international tests, Singapore students in grades 4 and 8 ranked first in the science achievement test of the 2003 Trends in International Mathematics and Science Study (TIMSS). Although students have performed very well in science, the Ministry of Education (MOE) has constantly reviewed and improved the science curriculum so that students can be exposed to instruction and assessment that focus more on promoting their higher-order thinking and real-world problem solving skills. These two skills are essential for preparing highly qualified knowledge workers to meet the needs of the 21st century knowledge-based economy (Hargreaves, 2003).

The current framework of the Singapore Science Curriculum is centered on *Science as an Inquiry*. It focuses on the acquisition of general inquiry processes and science process skills which scientists use to make sense of the natural environment. Many researchers have found that inquiry-based instruction is effective in fostering science literacy and understanding of science processes (Lindberg, 1990), vocabulary knowledge and conceptual understanding (Lloyd & Contreras, 1985, 1987), critical thinking (Narode & Associates, 1987), positive attitudes toward science (Kyle & Associates, 1985; Rakow, 1986), and higher achievement on tests of procedural knowledge (Glasson, 1989). Inquiry-based instruction also stimulates students' thinking and engages students in authentic investigations to satisfy curiosities to make learning more meaningful (Hawkins, & Pea 1987; Krajcik, 2001; Krajcik, Marx, Blumenfeld, Soloway, & Fishman, 2000; Shepard, 2000; Stanbridge, 1990). With the major recent curricular revisions such as *infusing thinking skills* and the *Science Practical Assessment* (SPA), Singaporean science teachers are strongly encouraged to use the inquiry-based instruction and performance-based assessments in their science classrooms. This will ensure that curriculum goals can be met through these authentic learning experiences as students construct meaningful, broadly applicable, well-structured, information-rich knowledge, skills, and affective domain attributes.

Inquiry-based instruction is contrasted with conventional didactic teaching and reflects the social-constructivist or student-centered model of teaching and learning. From the social-constructivist perspective, classroom learning should be authentic and connected to the world outside of school. This will not only make learning more interesting and motivating to students but also to develop their abilities to use knowledge in real-world settings. In addition to the development of higher-order intellectual abilities, classroom learning environment should foster the development of important dispositions, such as students' persistence in solving complex problems (Shepard, 2000).

Previous research has shown that when teachers assigned more intellectually demanding assignments or assessment tasks, students were able to demonstrate more complex intellectual performance in their work (Bryk, Nagaoka, & Newmann, 2000; Clare & Aschbacher, 2001; Luke, Matters, Herschell, Grace, Barrett, and Land, 2000; Matsumura, 2003; Newmann and associates, 1996). Newmann et al. (1996) and Bryk et al. (2000) examined the intellectual quality of teachers' assignments in mathematics and writing at grades 3, 6, and 8 in Chicago schools. They found that students who received assignments requiring more challenging intellectual work achieved greater than average gains on the Iowa Tests of Basic Skills in reading and mathematics, and demonstrated higher performance in reading, mathematics, and writing on Illinois Goals Assessment Program. In addition, there was a strong relationship between the quality of teacher assignments and the quality of student work, that is, teachers who assigned higher intellectually demanding tasks were more likely to get higher authentic intellectual work from students. Similarly, Luke et al. (2000) have found that students' performance in Australian schools was dependent upon what was asked of them in the teachers' assessment tasks. In the Clare and Aschbacher (2001) and the Matsumura (2003) studies, the quality of the teacher assignments was found to be statistically significantly associated with the quality of classroom instruction and the quality of student work in language arts.

In Singapore, the MOE introduced the initiative 'Teach Less Learn More' in 2004 to encourage teachers to use more varied and engaging instructional strategies and assessment methods to make learning more meaningful for students. It is felt that classroom instruction and assessment should go beyond 'spoon-feeding' students to acquire basic knowledge and skills to do well only in high-stakes examinations. Instead, students should be actively engaged in collaborative hands-on and minds-on learning activities through authentic tasks that emphasize higher-order thinking and real-world problem-solving.

Although many new initiatives have been introduced into the Singapore Science Curriculum, little is known about teachers' instructional and assessment practices in the current science classrooms. This study investigated the extent to which Singaporean Science teachers made authentic intellectual demands on students in their day-to-day classroom assignments. The specific objectives of the inquiry were (a) to describe the patterns of science teachers' assessment practices in grades 5 and 9 classrooms, (b) to examine the quality of science teachers' assessment tasks, and (c) to examine the quality of student work in response to the teachers' assessment tasks in science.

Theoretical Framework

According to Newmann and Associates (1996), there are three criteria for authentic intellectual work: construction of knowledge; disciplined inquiry; and value beyond school. It is believed that students gain a deeper understanding of subject matter when they actively construct knowledge in contexts that they find meaningful and motivating. If teachers were to aim for high authentic intellectual performance, then they would need to create assessment tasks that provide authentic learning experiences for students. In this way, students could become active learners, capable of solving complex problems and constructing meaning that is grounded in real-world experience.

In this study, nine standards were used to evaluate the quality of the teachers' assessment tasks: *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.* Likewise, six standards were used to examine the quality of student work: *depth of knowledge, knowledge criticism, knowledge manipulation, sustained writing, quality of student writing/answers, and connections to the real world beyond the classroom.*

Under *depth of knowledge*, we conceptualized three types of knowledge: factual knowledge, procedural knowledge, and advanced concepts based on revised Bloom's knowledge taxonomy (Anderson & Krathwohl, 2001). Higher-order thinking is captured by two standards, namely *knowledge criticism* and *knowledge manipulation*. *Knowledge criticism* is exemplified by tasks that ask students to compare and contrast different sources of information and to critique knowledge whereas *knowledge manipulation* is exemplified by tasks that demand students to organize, analyze, interpret, synthesize, and evaluate information; to apply knowledge and skills; and to construct new meaning or knowledge. In line with Newmann et al.'s authentic intellectual framework, *sustained writing* and *connections to the real world beyond the classroom* were also included. The aforementioned standards also apply to the evaluation of the quality of student work.

We contend that teacher's *supportive task framing* will result in higher intellectual quality in student work. Teacher's scaffolding of an assignment task can provide some structure and guidance to assist students in completing a complex task (Nitko, 2004). Teachers must be able to diagnose students' current understandings so that they can provide task scaffolding that build upon these understandings. *Task clarity and organization, student control, and explicit performance standards/marking criteria* are conceptualized based on Marzano's (1992) learning-centered instruction. The incorporation of these standards into the classroom assessment provides students with opportunities to engage in independent learning and critical thinking.

These standards were used to develop two scoring rubrics manuals: one for assessing the authentic intellectual quality of teachers' assessment tasks and the other for assessing the authentic intellectual quality of student work.

Methods

Samples

The samples of teachers' science assessment tasks and associated student work were collected from 59 Singapore schools (30 elementary schools and 29 high schools) in 2004 and 2005. All the teachers' assessment tasks and samples of student work were embedded within the classrooms where observation and coding of the quality of instruction had taken place. The types of assessment tasks included daily class work, homework assignments, major assignments/projects, and teacher-made tests. Each teacher was asked to submit four high-quality, four medium-quality, and four low-quality student work in relation to each of the aforementioned types of assessment tasks.

Scoring of Teachers' Assessment Tasks and Student Work

To determine the authentic intellectual quality of teachers' assessment tasks and student work, a panel of experienced science teachers teaching grades 5 and 9 were trained to use the two scoring rubrics to evaluate the quality of teachers' assessment tasks and student work. All standards were scored on 4-point scales (ranging from 1 = no requirement/no demonstration to 4 = high requirement/high level). High inter-rater reliability (percent of exact agreement ≥ 70%) was achieved by training the teachers to use the scoring rubrics during the teacher moderation sessions.

Teachers' Self-Report Data

A brief questionnaire was written to measure the teachers' assessment practices. This study only reported the results of the teachers' rationales for setting assessment tasks (7 items). The response format was based on a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree. The values of Cronbach's alpha at grade 5 and grade 9 were .60 and .84, respectively. This indicates that the teachers' self-report data have good reliability.

Results and Discussions

Table 1 shows that the majority of the student work collected at grades 5 and 9 were class work and homework, which consisted mainly of lower-order thinking drilland-practice worksheets or routine exercises from the textbooks and workbooks. Teacher-made tests were mainly summative tests (e.g., class tests and topical tests). The number of high intellectually demanding project-based work and other forms of alternative assessments was relatively low.

As can be seen in Table 2, the most commonly used item types were short-answer items, fill-in-the-blanks, and true-and-false items. Comparatively, extended-response items were less frequently used by the science teachers. There were a large number of mixed format items at grade 5, which comprised of multiple-choice items, fill-in-the-blanks, and short-answers items. Assessment tasks that required the use of illustrations and graphic organizers were more evident at grade 5 than grade 9. Although science experiments were included in the science lessons, the student work indicated that these experiments were usually demonstrated by the teachers due to limited curriculum time. When the experiments were expected to be performed by the students, they were only asked to carefully follow a set of preordained experimental procedures dictated by the teachers in order to arrive at the expected results or observations. Students were seldom asked to design their own investigations. In-depth discussions and critique of experimental results were not highly evident in the work produced by the students.

Table 3 summarized the self-report results of the teachers' rationales for setting assessment tasks. Most of the teachers reported that the rationale for setting assessment tasks was because they wanted to prepare students for high-stakes examinations and that the assessment was required by the syllabus or their heads of department. Not many teachers had attributed the rationale for setting assessment tasks to professional development.

The results of the quality of teachers' assessment tasks and student work were presented in Tables 4 and 5, respectively. Majority of the teachers' assessment tasks and student work demonstrated a substantial level of reproduction of factual and procedure knowledge, with limited application of advanced concepts and making connection to the real world beyond the classroom. The teachers' assessment tasks did not provide ample opportunities for students to compare and contrast information or to critique knowledge. Teachers' task framing focused on content and procedural scaffolding, As a result, student work did not demonstrate a high level of knowledge criticism. Both teachers' assessment tasks and student work demonstrated a moderately high level of knowledge manipulation in terms of organizing, interpreting, analyzing, synthesizing and evaluating information. There was little evidence that students could go beyond the application of knowledge and skills or problem-solving to a higher cognitive level of constructing knowledge new to them. One main reason was likely due to the limited number of science teaching periods and having the need to complete the syllabus, thus it left little time for teachers to allow students to explore the content topics more thoroughly and to develop deep understanding of subject matter knowledge and application of problem-solving skills in performance-based tasks.

We found that most of the student work produced at grades 5 and 9 did not demonstrate sustained writing. This might be due to the fact that only short, precise answers are usually required in the conventional paper-and-pencil tests as long as students can use the correct key words or phrases in their answers. Sustained writing with the use of labeled diagrams, scientific drawings, tables, charts, and other graphical representations seem to be more evident in science project work and essay writing but these types of student work were not evident in the artifacts we collected from the Singapore science classrooms. In addition, students were not given enough choice over the task parameters (e.g., length of answers, use of alternative procedures, use of tools and resources). Teachers had also seldom informed students about performance expectations.

Educational Implications

The current Singapore classroom instructional and assessment practices have not reflected the new curriculum goals. Science teaching and learning in the Singapore classrooms still require students to regurgitate and memorize discrete bits of basic facts to a great extent so that students can perform well in high-stakes examinations. Due to limited curriculum and lesson preparation time and inadequate teaching and assessment competency in science (especially for generalist elementary science teachers), many teachers resort to lecture-style of teaching with limited open-ended questionings and frequent teacher-demonstrated experiments. It is imperative for the ministry and school administrators to realize that in the absence of significant changes designed to provide teachers with better support for inquiry teaching, true inquiry-based instruction is probably not a realistic option for many science teachers.

Similarly, it is essential for science teachers to understand and be convinced that science cannot be learnt effectively merely by rote-learning without letting the students going through the process of thinking, exploring and reflecting in performance-based assessments. The findings set the stage for intervention plans of redesigning the classroom teaching and assessment methods. It is important for science teachers to be competent in designing authentic intellectual quality tasks and using performance-based assessments to allow ample opportunities for the students to demonstrate inquiry-based problem-solving, creative, and critical thinking skills.

When teachers analyze their own assessment tasks and student work, they are engaged in a reflective process which allows them to look more closely at the quality of an assessment task and its impact on the quality of student work. This is a useful strategy for both pre-service and in-service teacher training programs to help teachers improve their own classroom instructional and assessment practices. For science teachers who are not confident in using alternative assessment or are inadequately-trained in developing and interpreting results of alternative assessments, professional development workshops and on-going collaborative collegial support within and outside schools are effective ways to help them improve their science assessment literacy.

Table 1

Types of Student Work by Grade Level

	Types of Student Work							
	Class work		*Homework*		*Major Assignment/ Project*		*Test*	
Subject Area	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*
Science	328	264	133	39	7	3	49	37

Table 2

Types of Item Formats used by the Science Teachers

	Types of Item Formats									
	Fill-in-the-blanks		*Short Answers*		*Extended Responses*		*Mixed Item Formats*		*Illustrations*	
Subject Area	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*	*Grade 5*	*Grade 9*
Science	58	68	68	172	5	51	248	75	92	-

Table 3

Teachers' Rationales for Setting Assessment Tasks

Statement	*Grade 5* *n = 36*		*Grade 9* *n = 19*	
	Mean	*SD*	*Mean*	*SD*
This assignment …				
will prepare students for the examination	3.78	1.20	4.47	.61
is required by the syllabus	3.69	1.45	4.26	.81
is required by my department head	3.44	1.28	3.32	1.06
gives my students something to do	3.42	1.23	3.26	1.24
was suggested in a professional development session	3.11	1.09	2.79	1.44
is included in the class textbook	2.78	1.42	2.74	1.15
is not really necessary at all	1.89	1.06	1.58	.51

Note. n = number of teachers.

Table 4

Mean Score Differences of the Quality of Grade 5 and Grade 9 Science Teachers' Assessment Tasks

	Grade 5	*Grade 9*
	n = 45	*n = 43*
	Mean	*Mean*
Standard	*(SD)*	*(SD)*
Depth of Knowledge:		
Factual Knowledge	3.02	2.70
	(.87)	(.80)
Procedural Knowledge	2.04	2.12
	(1.11)	(.82)
Advanced Concepts	1.80	1.51
	(.76)	(.67)
Knowledge Criticism:		
Presentation of Knowledge as Given	2.96	3.37
	(.77)	(.62)
Compare and Contrast Knowledge	2.36	1.70
	(.65)	(.67)
Critique of Knowledge	1.80	1.14
	(.73)	(.47)
Knowledge Manipulation:		
Reproduction	2.49	3.30
	(.82)	(.71)
Organization, Interpretation, or Evaluation of Information	2.64	2.00
	(.68)	(.72)
Application/Problem-Solving	2.42	1.84
	(.75)	(.69)
Generation/ Construction of Knowledge New to Students	1.71	1.12
	(.63)	(.32)
Sustained Writing	2.02	2.33
	(1.08)	(.94)
Connections to the Real World beyond the Classroom	2.18	1.40
	(.98)	(.73)
Supportive Task Framing:		
Structure of the Task	2.09	1.84
	(.95)	(.65)

Content Scaffolding	2.82	2.63
	(.81)	(.90)
Procedural Scaffolding	2.24	2.09
	(.91)	(1.00)
Strategy Scaffolding	1.00	1.09
	(.00)	(.29)
Clarity and Organization	3.56	3.53
	(.79)	(.59)
Learner Support:		
Student Control	1.62	1.33
	(.75)	(.47)
Explicit Performance Standards/Marking Criteria	1.11	1.74
	(.38)	(.90)

Table 5

Mean Score Differences of the Quality of Grade 5 and Grade 9 Science Student Work

	Grade 5	*Grade 9*
	n = 517	*n = 343*
	Mean	*Mean*
Standard	*(SD)*	*(SD)*
Depth of Knowledge:		
Factual Knowledge	2.91	2.37
	(.80)	(.65)
Procedural Knowledge	2.03	1.63
	(.86)	(.71)
Advanced Concepts	1.63	1.19
	(.62)	(.46)
Knowledge Criticism:		
Presentation of Knowledge as Given	2.71	3.47
	(.67)	(.56)
Compare and Contrast Knowledge	2.29	1.57
	(.73)	(.55)
Critique of Knowledge	1.66	1.03
	(.62)	(.18)

Knowledge Manipulation:		
Reproduction	2.32	3.44
	(.57)	(.57)
Organization, Interpretation, or Evaluation of Information	2.52	1.87
	(.63)	(.64)
Application/Problem-Solving	2.17	1.61
	(.70)	(.61)
Generation/ Construction of Knowledge New to Students	1.74	1.08
	(.57)	(.27)
Sustained Writing	2.02	2.02
	(1.06)	(.91)
Quality of Student Writing/Answers	3.03	2.51
	(.86)	(.90)
Connections to the Real World beyond the Classroom	1.94	1.42
	(.82)	(.68)

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