Giving students a voice in science practical assessments

TAN Aik Ling
Phillip A. TOWNDROW
Centre for Research in Pedagogy and Practice, National Institute of Education

ABSTRACT

This paper examines Science Practical Assessment (SPA) in the Singaporean classroom. In contrast to teacher-centric task setting and evaluation, this paper reports findings from a study where a class of students were involved in their own assessments mediated by digital video. Students were recorded during practical work and were then asked to review and edit the footage. Next, they evaluated their own and their classmates' practical skills. These evaluations, scaffolded with a template and facilitated by the teacher, aimed to give the students a voice in presenting what they thought made 'good' science practical skills and practices in the laboratory. They also served as a platform for peer learning and provided a means for the students to be involved in discussing science and science practical skills. Results of this study reveal that students' awareness of acceptable laboratory practices is enhanced through this innovative method of evaluating science practical work.

INTRODUCTION

Scientific inquiry and understanding how scientific inquiry should be carried out in school should occupy a central position in science education (Driver, Leach, Millar & Scott, 1996). School science practical work is seen as an important component of science curricula world-wide as it holds the promise of bridging the gap between theoretical science and the empirical evidence that helps build scientific theories (Hodson, 1990). The teaching and learning of science has tried to mimic what 'real' scientists do. The processes of science, the scientific method, the inquiry process, the content of science and the habits of scientists are all recontextualised in the science curriculum for schools in many parts of the world. It is hence not surprising to find that practical work is very much a characteristic of the science curriculum. Some researchers (Hodson, 1990; Roth, 2002) have claimed that school laboratory activities are ill-conceived, confused and unproductive and that many students learn little about science and do not engage in doing science. School science practical work, with its detailed protocols and instructions, has often degenerated into activities where students merely follow the teachers' instructions with little intellectual input on their part. Is school science practical work really as worthless as these researchers claim? In what ways can education departments enable school science to play a pivotal role in students' learning of science? The answers to these questions are multi-faceted and complex. In this paper, we will examine one attempt by the Ministry of Education in Singapore to improve the procedures of school science assessment and relate this to changes in pedagogical practices that can possibly be introduced to engage students in peer-assessed science practical work.

The Ministry of Education in Singapore is overhauling its science practical assessment practices in schools. Its efforts include examining the role practical work plays in science education and re-evaluating how school science practical work can be made more meaningful and productive for students. In 2003, Science Practical

Assessment (SPA) was trialed in secondary schools and junior colleges. SPA is an attempt to introduce more authentic and consistent assessment into school science practical work. It replaces the one-time practical examination that served the country for many years. The move away from the one-time practical examination that was based solely on what students produced to a more ‘process’ based continuous assessment appears to be supported by Watson and MacRobbie (2004) who argued that traditional assessments of school science practical work tend to concentrate on a written product of an inquiry produced by an individual. As such, the processes of constructing arguments, planning and formulating conclusions are neglected. SPA appears to be a solution to examining the processes rather than just the products of science inquiry.

Although there are several differences between the former one-time practical assessment and SPA, we take this opportunity to highlight a small number of matters concerning assessment and pedagogy.

Instead of individuals sitting for a single practical examination paper, SPA allows for an average grade to be calculated based on multiple assessments. Secondly, the one-time practical examination assessed all science process skills without demarcation. SPA, in contrast, marks out specific process skills, which students can identify and work on improving, should they be weak in any particular area of science practical work.

From the perspective of pedagogy, the one-time practical assessment meant that students worked independently most of the time in the laboratory with little meaningful interaction with their peers. Teachers were seen as the authoritative source of information and hence a very teacher-centric approach was adopted.

For assessment purposes, SPA divides experimental skills and investigations into three key areas:

- Skill 1 – Using and organizing techniques, apparatus and materials; and observing, measuring and recording.
- Skill 2 – Handling experimental observations and data.
- Skill 3 – Planning Investigations. (MOE, 2005)

Student performance in each skill set is measured on a three-point scale ranging from zero to two.

From preliminary observations, SPA appears to serve two key purposes in the reformation of laboratories in Singapore’s schools. First, it provides a common vocabulary for students and teachers to use when talking about science practical skills. Now, teachers and students can freely identify the skills that they are lacking or teachers can communicate to students the types of skills needed to yield desired experimental outcomes. Secondly, based on Bernsteinian ideas (1990), SPA sets out to make pedagogy ‘visible’ for students. They are now presented with descriptors that they can use to investigate how their scientific skills can be improved. They then have the means to know what ‘good’ scientific practical skills are at the different levels. How they bridge the ‘gaps’ between these different levels can either be achieved by the students themselves or through opportunities presented by teachers in the laboratory.

Teachers are trained to be SPA examiners as an essential part of the school-based scheme. They are also taught how to design assessment tasks, craft assessment rubrics, and moderate final grades. Teachers must also communicate the changes in the format of science practical assessment to students and initiate opportunities for these ideas to be trialed. The implementation of SPA has offered an opportunity to re-examine interactions in the science laboratory and to view the teaching and learning of science practical through different lenses.

Having examined the role of science practical work in the larger context of science education, the situation of practical work in Singapore and state of SPA implementation, we deem it necessary and worthwhile to ask the following questions as a way of innovating in the teaching and learning science practical skills:

1. What is the potential of digital video in enhancing the learning of science practical skills?
2. How can the use of digital video support a SPA-infused pedagogy that encourages peer assessment?

In addressing these questions we begin with a review of the literature in the areas of science practical work, peer learning and the use of digital video as a learning tool. The methodology used in this paper is then introduced followed by the presentation of findings and subsequent discussion.

REVIEW OF LITERATURE

Science practical work

For more than a century, laboratory activities have been used in science teaching to support theoretical science instruction (DeBoer, 1991). In promoting science laboratory activities, the rationale for pursuing this form of instruction is sometimes forgotten. There have been calls by Wellington (1998) and Roth (2002) to re-examine the impact and importance of laboratory work in the learning of science. The gap between the theoretical and laboratory aspects of science requires some examination so that it can be understood better.

Tobin (1986) found that laboratory activities were typically viewed as ‘a frill’ by teachers. They did not view them as being conceptually integrated with the science courses they were teaching as a whole. The teachers in Tobin’s study failed to see laboratory activities as opportunities for students to make meanings through scientific inquiry. In another study (Kang & Wallace, 2005) teachers perceived laboratory activities as a means of producing experimental results that would be consistent with canonical science; in other words, laboratory activities were only for verification purposes. Kang and Wallace (2005) found that the teachers they worked with did not consider the laboratory as a place where they could discuss knowledge claims in science and relate these to the evidence that students had collected.

Anecdotal evidence from teachers suggests this is also a popular belief in Singapore where optimal open-ended exploratory laboratory activities appear to be less widely used in the learning of science. Hence the increased importance of studying the impact of SPA in local schools.

Use of digital video

Digital video has been used in classrooms to teach in different disciplines, for example, in the teaching of writing across the curriculum (Scot & Harding, 2004) and in the teaching of science (Yerrick, Ross & Molebash, 2003). Scot and Harding (2004) used digital videos to teach fifth graders researching, brainstorming, webbing, organising and drafting skills by getting them to produce and script their own movie using a digital camera and i-Movie. Yerrick, Ross and Molebash (2003) have also argued that the use of the digital camera in the science classroom can help to solve the issue of access or the lack of assess to science by disadvantaged group of students.

The potential of using the humble digital camera in the classroom is waiting to be discovered. Yerrick, Ross and Molebash (2003) believe that the appropriate use of digital video in the science classroom can enhance certain scientific processes like planning investigations, collecting observation data, controlling variables and also communicating findings from scientific experiments. Digital video invites different forms of engagement and appeals to different learning approaches which implies that a more diverse group of students could be reached when it comes to the learning of science. According to Yerrick, Ross and Molebash (2003), developing and editing scientific digital videos can be highly motivating as it allows students to share their scientific understandings and explanations with one another. The clarification process in a small group can be particularly useful for the learning of science.

The digital camera offers a means of having a permanent record of what goes on in the classroom. Both ‘good’ and ‘bad’ practices can be analyzed, reviewed and critiqued after an event has occurred.

We made use of the digital camera through an intervention that incorporated the potential of a technology-enabled pedagogy to encourage three things in the laboratory: the learning of science practical skills; cooperative learning between the students and communicating science in the classroom.

Cooperative learning

Cooperative learning refers to a variety of teaching methods in which students work in small groups to help one another learn academic content. Typically, in cooperative classrooms, students are expected to help each other, to discuss and argue with each other, to assess each other’s current knowledge and help to fill in gaps in each other’s understandings (Slavin, 1995). According to Slavin (1995) the theoretical underpinnings for cooperative learning lie in motivational and cognitive theories. Rather than a perceived focus on the competitive nature of learning that is typically given in traditional classrooms, cooperative learning can increase motivation by focusing on how personal goals of learning can be achieved if the group is successful. Cognitive theories on the other hand focus on the effects of working together itself. Vygotsky’s (1978) notion of the zone of proximal development is relevant here. Students can solve problems which they are unable to solve on their own with the assistance of more knowledgeable or experienced peers.

With some of the principles of cooperative learning in mind (namely, the motivational factors and the peer support) this project examines the use of peer critique in the classroom to bring about an increase in students’ participation in learning SPA skills.

One of the advantages of using digital video in the learning is that it encourages students to work together in groups and also for the different groups to come together and work as a class. In this way, students are led to take responsibility for their own as well as their peers' progress in the learning of SPA skills.

METHOD

Participants

The study was carried out in an all girls' secondary school in Singapore that admits students with an average *T*-score in the Primary School Leaving Examination. The data for this paper was drawn from a larger study that involved three teachers each specialising in physics, biology and chemistry, respectively.

As a rule of thumb, schools in Singapore teach lower secondary general science as a consolidated subject where physics, biology and chemistry are taught by the same teacher. However, at the study site, subject specialists taught general science on a modular basis in the first year. The researchers followed three 'express' stream classes, comprising an average of forty students, as they moved from one teacher to the next in rotation.

Another difference at the study school site related to the deployment of classrooms. Unlike many schools in Singapore where the students stay put and teachers move from classroom to classroom, the school site functioned on a 'homeroom' system where the students moved to various locations according to their timetabled subjects and lessons.

The biology lessons were conducted in a laboratory equipped with discipline-specific equipment. The laboratory was traditional in design and consisted of five rows of students' workbenches divided into two columns (four students were seated to a bench on wooden stools without a backrest). There was also a row of benches along the side and back walls of the laboratory. The teacher's bench was situated at the front along with the white board, a projection screen, a computer and a visualiser. Each student bench was equipped with four gas outlets and four Bunsen burners. The laboratory was not air-conditioned. The average temperature in the laboratory was 30^oC.

Implementation

Classroom observations were carried out in the first six months of the project, during this period the students were introduced to the idea of SPA and the language used for skills 1 and 2. After six months, the first author and the biology teacher decided that it was timely to allow the students more input in their practical work and they discussed ways in which this could be done. They decided to use digital video as a tool to get the students more involved in the learning process and to 'hear' their views about what constituted 'good' science practical skills.

The following sequence of events was carried out:

1. The teacher designed a practical task which required the students to conduct the Benedict's test, the Iodine test and the Biuret's test. The worksheet and marking rubrics were also designed by the teacher.

2. The students were told that they would be observed as they conducted the practical activity.
3. Two students volunteered to be video recorded.
4. During the practical, two digital video cameras were set up to record the student volunteers throughout the practical.
5. After the practical session, the researcher copied the footage onto a DVD.
6. In the next lesson, the students were briefed and given an instruction sheet (Appendix 1) for the activity. The students were tasked to critique what they saw on the DVD and to state their reasons for their comments.
7. After reviewing the videos, a class discussion was carried out to consolidate the students' learning.

RESULTS

Of the 43 students in the class, the average number of descriptions which were picked up by the students as either 'good' or as areas where there needed to be improvement was 3.7. Typically, the students were able to identify areas where their classmates exhibited 'good' practical skills. And in cases where errors were made, they made suggestions for improvements. The areas that were identified by the students can be broadly categorised as follows:

- General planning in carrying out the practical;
- Working with the Bunsen burner;
- Preparing the sample for experimentation;
- Preparing the water bath and
- Making observations.

Table 1 below illustrates some of the students' comments as they viewed the video clip of their classmates performing the science practical tests.

Table 1: Summary of feedback to students performing practical work. (*All comments were taken directly from students' feedback sheets. No corrections were made to grammatical errors.)*

Category	Feedback
General planning in carrying out the practical	• She keep reading the paper to make sure that she is doing the right thing. She should understand what the paper is saying then start the activity. • She kept her things aside before beginning the experiment.
Working with the Bunsen burner	• She opened the air-hole when she was starting the Bunsen burner. She should close it when she started the Bunsen burner. • She lit the Bunsen burner properly. She did not wait too long after turning the gas on. This prevent accidents from happening in the room.
Preparing the sample for	• Cutting the specimens on the table. She should have used the white tile as base for cutting.

experimentation	
Preparing the water bath	• She should put the beaker of water on top of the tripod stand before turning on the Bunsen burner. • No big bubbles bubbling up when she turned off the Bunsen burner. She should wait for the water to boil before turning off the Bunsen burner. • She wanted to use her hand to take up the test-tube. She should use the tongs. • She pointed the mouth of the test tube from her friends.
Making observations	• She observed the beaker and the experiment well. She did not leave the place unnecessarily. • She pays close attention to the water in the beaker till it boils. She did not leave the beaker unattended. • She recorded the experiment. • When the mixture in the test-tube has turned orange, she took it out and observed it.

The students indicated that they liked this mode of learning because they got to see their friend’s mistakes and learnt from them. Some indicated that they were not able to recognise their own mistakes but others claimed they were able to recognise their errors and correct them. One student indicated that although they gained experience from the mistakes made by others, they tended to laugh at their classmates who made the mistakes. Some indicated that the activity was fun and enjoyable. Beyond the specific practical work that the students were supposed to observe, one student indicated that this pedagogy was relevant to her because it helped in the development of a critical eye for details.

Some of the students’ criticisms of the activity were that only one person’s practical skills were observed at any one time hence the activity might take up too much time if everyone’s work were to be critiqued by the class. The quality of the video was also a cause for concern among the students.

DISCUSSION AND CONCLUSION

The students’ feedback indicated that they understood what was required for SPA skill one (Using and organizing techniques, apparatus and materials; and observing, measuring and recording*)*. Their awareness was shown in their ability to pick out the details of the ‘good’ and ‘inappropriate’ practices of their classmates during the practical work. For example, the suggestion to use the white tile as a cutting base indicated that they knew what was considered safe laboratory practice. This, we argue, demonstrated a strength of SPA as it systematically made visible to the students how and what they needed to be aware of when performing their practical work.

As Yerrick, Ross & Molebash (2003) have argued, the use of the digital video camera to record and play back the video clips was highly motivating. It also allowed the students to share their scientific understandings and explanations with one another. The clarification process in small-group work was shown to be useful in the learning of science. The permanent recording allowed students to revisit the practical and as one student noted, this opportunity allowed her to develop a critical eye for details, one of the key dispositions of a good scientist.

The class critique of the video offered a synergistic environment where the students worked together to improve their science practical skills. As every student in the class performed the same experiment, they could identify with the experiences of their classmates and hence were better placed to relate the skills they observed to their own learning. However, the task could have been better managed in order to eliminate technical issues concerning the clarity and sound quality of the videos.

It is also important to examine the students' level of readiness for group-critique work. For example, some students indicated that they could not help laughing at the mistakes made by their classmates in the video. The group work and principles of cooperative learning used in this classroom practice needs careful planning before it can fulfill the potential that cooperative learning promises.

This study showed that it was possible to examine science practical work from the students' perspective. The students, as learners of science, were able to cast a critical eye towards what were 'good' and 'bad' practical skills in the school science laboratory. We argue that their ability to articulate these moves can form the basis for a deeper understanding of the content of the lower secondary science curriculum.

REFERENCES

Bernstein, B. (1990). *The structuring of pedagogic discourse*. London: Routledge.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice.* New York: Teachers' College.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Philadelphia, PA: Open University Press.

Hodson, D. (1990). A critical look at practical working school science. *School Science Review, 70,* 33-40.

Kang, N. H., & Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education. 89(*1), 140-165.

Roth, W. -M. (2002). Phenomenology, knowledgeability and authentic science. In J. Wallace & W. London (Eds.), *Dilemmas of science teaching: perspectives on problems of science* (pp 42-48). London: Routledge/Falmer.

Scot, T. P., & Harding, D. (2004). Splicing video into the writing process. *Learning & Leading with Technology, 32(*1), 26-31.

Slavin, R. (1995). *Cooperative learning: Theory, research and practice*. Massachusetts: Allyn and Bacon.

Tobin, K. (1986). Secondary school laboratory activities. *International Journal of Science Education*, 8, 199-211.

MOE (2005). *Ministry of Education update of GCE ‘O’ level syllabus for SPA.*

Watson, F. R., & McRobbie, C. (2004). Students’ discussions in practical scientific inquiries. *International Journal of Science Education, 26(*1), 25-45.

Wellington, J. (Ed.). (1998). *Practical work in school science: Which way now?* New York: Routledge.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* M. Cole, V. John-Steiner, S. Scribner and E. Souberman (Eds.). Cambridge, MA: Harvard University Press.

Yerrick, R., Ross, D., & Molebash, P. (2003). Promoting equity with digital video. *Learning & Leading with Technology, 31(*4), 16-19.

Appendix 1

Science Practical Skills

Name : ___________________________(   )   Date: _______________

Class: Secondary 1 (   )

Objectives

This task aims to help you:

1. Develop a critical eye for details during science practical work.
2. Develop your ability to identify good science practical skills and habits in the laboratory and be able to comment on why they are good.
3. Develop your ability to identify poor science practical skills and habits in the laboratory and be able to comment on how they can be improved.

Procedure

1. Get your worksheet, your computer and the video clip ready.
2. Play the video clip and look for good or bad science practical skills.
3. Pause the clip when you come across a relevant segment.
4. Note the time that episode occurs on the clip and then comment on it. (Refer to Pg 2)
5. Start the clip again.
6. Continue until you have completed the clip.
7. You should pick out at least 5 episodes to comment on.

Your reflections

Fill this portion in at the end of the activity.

The good points about this activity were:

1.

2.

The bad points about this activity were:

1.

2.

Data

Complete the table as you watch the video clip. The first one is an example.

Title of Clip: ____

Episode	Time	Description of Skills Exhibited	What should have been done (for bad practices only)
1	**01:23**	• **There was too much water in the water bath as it was boiling too vigorously.**	• **Fill the beaker to only 2/3 its volume.** • **Turn off the Bunsen burner when the water boils.**