<table>
<thead>
<tr>
<th>Title</th>
<th>Using scaffolding strategies for improving student science practical skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Au Sau Kheng and Tan Kok Siang</td>
</tr>
<tr>
<td>Source</td>
<td>12\textsuperscript{th} Hawaii International Conference on Education, Honolulu, Hawaii, 5-8 January 2014</td>
</tr>
</tbody>
</table>

This document may be used for private study or research purpose only. This document or any part of it may not be duplicated and/or distributed without permission of the copyright owner.

The Singapore Copyright Act applies to the use of this document.
Using Scaffolding Strategies for Improving Student Science Practical Skills

Au Sau Kheng

National Institute of Education, Singapore
au_sau_kheng@moe.gov.sg

Tan Kok Siang

National Institute of Education, Singapore
koksiang.tan @ nie.edu.sg

Abstract: Learning in the 21st century is focused on information management and students are expected to be developed as inquiry learners instead of just knowledge gatherers. As inquiry learners, they have to be observant, for example when conducting experiments in the laboratory, and to make use of information to solve or complete science-related problems or tasks. Traditionally, science practical skills are assessed through single-session laboratory-based examinations and students are prepared through drill-and-practice strategies. However, school systems around the world today have chosen to adopt course-based science practical assessment which assesses students on their abilities to identify and select appropriate hands-on skills when conducting laboratory experiments. Thus, there is a need to help students prepare for this change in practical assessment format and one established way is the use of scaffolding strategies. Although scaffolding is a tried and tested method to help students master new knowledge and skills in many school subjects, its effectiveness in school science practical work has not been thoroughly investigated. This paper reports some of the current work done in Singapore schools where the use of scaffolding strategies in preparing students for school-based practical assessment is being studied. The findings from these studies are significantly positive and do indicate the potential of scaffolding strategies in helping students become more motivated and skillful in science practical work.

Keywords: science, practical, skills, assessment, scaffolding, strategies
1 Introduction

In recent years, assessment of students' science practical work in Singapore has been reforming to focus on the course-based development of science practical skills (over two years) instead of assessing the end-product of learning in the form of a submitted laboratory report over one assessment sitting in the usual end-of-course science practical examinations. Teachers usually prepare their students to sit for the practical examinations through a series of drill-and-practice science practical sessions. In 2006, the practical examination was replaced by the School-based Practical Assessment (or SPA) for students offering sciences as subjects in the Singapore-Cambridge General Certificate of Examination (or GCE). Students' proficiencies in science practical skills are now assessed through performing a series of experimental tasks over a two-year period for the 16-year olds (equivalent to the middle school students) sitting for the GCE Ordinary Level examination, and the 18 year-olds (equivalent to high school or college pre-university students) sitting for the GCE Advanced Level examination. Unlike practical examinations, in which students were drilled to perfect specific practical skills like those in qualitative analysis (identification of ions in unknown chemical samples) or volumetric analysis (using titration techniques to find out concentrations, in moles per litre, of unknown aqueous solutions of acids or alkalis), SPA requires students to be proficient in an array of science practical skills.

Given the broader range of skills in SPA (compared to those assessed in practical examination) it is no longer effective to train students to be competent in practical skills through drill-and-practice methods. To help students prepare for the assessment of practical skills, one established way is the use of scaffolding strategies. Although scaffolding is a tried and tested method to help students master new knowledge and skills in many school subjects, its effectiveness in school science practical work has not been thoroughly investigated. This paper is a report of a few current Singapore studies on the use of scaffolding strategies in preparing students for school-based practical assessment.

2 What is Scaffolding

The idea of scaffolding to support learning was introduced more than three decades ago by Wood, Bruner and Ross (1976). The original notion of scaffolding was applied to interactions between an expert and a learner, the former was usually a teacher or a parent who provided the help needed to move the learner forward (Wood et al., 1976). In essence, it was a one-on-one interaction where the expert, being the knowledgeable and skillful one, provided just enough support the learner needed to complete an activity or task successfully. The interaction between them allowed the expert to monitor the learner's progress and provide the appropriate support. The support was then removed once the learner was in control of her/his learning. In an education context, instructional scaffolding is known to enable a child or a novice to solve a problem, carry out a task, or achieve a goal that s/he cannot accomplish on her/his own (Wood et al., 1976). The support can progressively "fade" away when there is no longer a need for it. This fading of the support, one of the key theoretical features of scaffolding, enables the learner to be responsible for her/his learning.
Over the past 35 years, the concept of scaffolding has been widely used as a metaphor to support teaching and learning. This metaphor was used to describe the support provided by parents, teachers and mentors to assist the learners to learn new concepts, master skills or raise levels of understanding. This term describes the nature of an essential support that provides temporary assistance to enable the learner to advance to the next level in knowledge and understanding (Maybin, Mercer & Stierer, 1992).

Another notion of scaffolding is “distributed scaffolding”, a term coined by Puntembekar and Kolodner (1998; in press), and it refers to instructional designs that sequence and integrate a variety of social and material supports (cited in Tabak, 2004). In this context, scaffolding refers to the titrated supports that enable learners to engage in learning through activity, such as “doing and talking science”. It helps learners perform tasks that are outside their independent reach and consequently develop the skills necessary for completing such tasks independently (Rogoff, 1990; Wertsch, 1979; Wood, Bruner, & Ross, 1976; cited in Tabak, 2004). In short, it is a collection of materials and social supports that enable learners to learn discipline such as science by “doing science”.

Tabak (2004) described distributed scaffolding (Puntembekar & Kolodner, 1998) as an emerging approach in the design of supports for rich learning environments that are intended to help students develop disciplinary ways of knowing, doing, and communicating. In this scaffolded environment, multiple forms of support are provided through different means to address the complex and diverse learning needs of the learners. It is the metaphor that made the multiple supports explicit, in contrast to the original conception of scaffolding in relation to parent-child interactions, where there is just a single means of support. Her framework formalised distributed scaffolding and delineated the different forms or patterns that the scaffolding can take and the functions that these different patterns perform. Distributed scaffolding is envisaged in different ways and differentiated scaffolds, redundant scaffolds and synergistic scaffolds are the three complementary patterns associated to it.

Redundant scaffolds have been explicitly identified as a design strategy for distributed scaffolding. It involves different means of support that target the same need but are enacted at different points in time in the curriculum to provide titrated levels of support (Puntembekar & Kolodner, 2005). As a result of the difference in student competencies, there is a need for different types and levels of support to meet the particular learning needs.

When scaffolding is provided in multiple formats, there are more chances for students to notice and take advantages of the environment’s affordances (cited in Puntembekar & Kolodner, 2005). Providing good and effective scaffolding may mean that a learner is provided with support that can enable him or her to function independently. The best scaffoldings are the ones that can be faded because the learner will eventually (through the scaffoldings) internalise the processes s/he is being helped to accomplish (Rogoff, 1990; cited in Puntembekar & Hubscner, 2005). Tabak (2004) argues that the tasks in these contexts are more complex and extend over longer periods of time than the tasks depicted in the classical examples of scaffolding. As such, scaffolding needs to
change accordingly over time in response to the changing needs of students and the curriculum.

Studies have also shown that question prompts, a type of instructional supports, can effectively promote students’ knowledge integration (Davis & Linn, 2000). Different question prompts may serve different needs and purposes for students. Davis and Linn (2000) also studied the effects of guided questions on metacognition skills, knowledge integration, and problem-solving. Also, reflective prompts were used to support knowledge integration and encourage reflection at a level that students did not generally consider. This paper documents an initial effort to apply scaffolding in the learning of school science, especially how it can be used in the laboratory to help students learn chemistry practical skills.

3 Scaffolding in the Recent Years

In terms of learning, teachers are responsible for providing the scaffolding for classroom instruction. Scaffolding used in the classroom is only a temporary support which has to be removed when learners are able to independently demonstrate their competence and articulate knowledge without the support. To distinguish scaffolding from just mere help given by a teacher to accomplish a task, there should be some evidences that the teacher has intention for the learner to develop a specific skill, learn a specific concept or achieve a particular level of understanding. There should also be evidences indicating how the teacher could monitor a learner’s success in a task or on how the teacher intends to measure the learner’s increased competence or improved level of understanding of a specific learning activity (Maybin, Mercer, & Stierer, 1992).

Many of these evidences are reported by researchers and educators in their studies using various forms of scaffolding or scaffolding experiences or environments. As a result of the frequent use of this metaphor in the teaching and learning, it has been redefined and re-interpreted in relation to the learners’ needs in these studies. However, the main idea of it being a form of support for learners’ attempts to achieve specific learning goals under a wide range of learning environments remains unchanged. Also, its popularity in classroom instruction suggests that teachers do believe it contributes to effective classroom instruction and the beneficial effects on school curriculum. Few teachers and educators would have any dispute over the importance of scaffolding in their own learning environments. Despite the many changes and adaptations, most forms of scaffolding, if not all, still align with Wood's idea of providing a just-in-time learning opportunity to help the learner complete the task and reach the goal per se (Wood et al., 1976).

This paper aims to (i) present the various forms of scaffolds and scaffolding strategies that have been used in classrooms to help students learn curriculum-assessed practical skills, and (ii) share recent experiences on the use of scaffolds in science education in some studies conducted in Singapore schools, including some of the outcomes from these recent studies in which scaffolding were used to support learners as they learn laboratory experimental skills in the chemistry laboratory.
4 Recent Studies on Scaffolding in Singapore Schools

Unlike the wide ranging literature on scaffolding that generally helps students learn in school, there are fewer studies involving the use of scaffolding to help students learn science practical skills in the school laboratory. Two recent studies in Singapore schools on the effectiveness of using scaffolding in school science laboratory (Au, 2009; Au & Tan, 2010) had shown that this is a potential area for more extensive and intensive research to be done. The two studies investigated the effectiveness of scaffolds in laboratory as a means for teachers to help students learn and master curriculum-assessed chemistry practical skills. The focus of both studies was on the types of scaffolds provided during chemistry laboratory practical lessons. Both adopted the concept of distributed scaffolding, an emerging practice among researchers interested in supporting science learning (Raes et al., 2011; Puntambekar & Kolodner, 2005) and others such as in history (Li & Lim, 2008). This concept involves developing ways of knowing, doing, and communicating and entails a large assortment of learning or support needs (Tabak, 2004). The different types of scaffolds used in her study are teacher support, procedural facilitation (a pedagogical technique used in the study of Scardamalia and Bereiter, 1985, cited in Pea, 2004), prompts and questions, and reflection prompts (Davis, 2003). Some of these scaffolds are used as redundant scaffolds. Redundant scaffold is one of the three patterns of distributed scaffolding. As a result of the difference in student competencies, there is a need for different types of support in the chemistry laboratory to meet the particular learning needs. Redundant scaffolds provide the multiple scaffolds for the same needs to the students who may have missed opportunities to benefit from a particular scaffold (for example, missing out parts of the teacher’s verbal instructions in the laboratory) and to some others who may need more support to perform the tasks (Tabak, 2004).

Similarly, all students performing science practical tasks in the laboratory can also benefit from both redundant and multiple scaffolds. The different types of scaffolds supporting the same learning needs were incorporated at different points in the curricular materials used in the studies. Thus the multiple supports used allowed students to receive more assistance to complete a task. Initial findings of an earlier study on two classes of grade 9 chemistry students (Au, 2009) indicated that students who had been through scaffolded lessons performed better than those who did not. These findings suggest that scaffolds may enhance student performance in chemistry laboratory and the students can function independently when the support is removed (faded).

A survey was conducted with the two classes of 63 students performing a set of experiments with scaffolds (S1-S6) provided to learn six common skills (Au & Tan, 2010). The findings of the survey conducted indicate that a large number of students in both classes viewed scaffolds that were provided in the scaffold environments of chemistry laboratory were helpful in supporting the learning of practical skills and useful for reflection on skills performed. This is observed in the comparable number of “Strongly Agree, SA” and “Agree, A” responses from both classes. Table 1 shows the percentage range of responses for both classes.
Table 1: Percentage of responses to Scaffolds S1 – S6

<table>
<thead>
<tr>
<th>Class</th>
<th>% Responded (SA &amp; A)</th>
<th>SA (%)</th>
<th>A (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (33)</td>
<td>85 – 97</td>
<td>42 – 49</td>
<td>33 – 51</td>
</tr>
<tr>
<td>II (30)</td>
<td>87 – 93</td>
<td>60 – 73</td>
<td>20 – 33</td>
</tr>
</tbody>
</table>

The percentage response to SA in Table 1 indicates that class II students have a higher percentage response than class I. This finding may indicate that a greater number of class II students find scaffolding helpful in the chemistry laboratory. A larger number of SA responses from class II may be attributed to students’ experiences in both no scaffold and scaffold environments for the chemistry laboratory. Class II students were not provided with scaffolds in the first round of the study but after the second round with scaffolds, more students of the class could make a distinct comparison between scaffold and no scaffold laboratory environments.

An extension of the research on distributed scaffolding followed after the earlier studies. The project was conducted with two classes of Secondary 3-4 (Grade 9-10) students (n=73) over a 2-year chemistry curriculum. This project probed the effectiveness of distributed scaffolding in the curricular materials for the Grades 9-10 chemistry laboratory. In this extended study, multiple supports were provided to scaffold the learning of practical skills with the end goal being the completion of the chemistry experiments safely using the appropriate laboratory techniques. The multiple supports provided involved guiding questions and reflective prompts (Davis & Linn, 2000) and instructions which are procedural and direct in nature.

The extension project involved the “non-scaffolded” class and the “scaffolded” class. Each class carried out 11 chemistry experiments over a 12-month period. Each experiment was a one-hour long and was designed to be aligned to the formal chemistry curriculum schedule. Only the intervention class was given chemistry laboratory materials supported by distributed scaffolding instructions or notes. After carrying out a series of five to six experiments (non-scaffolded or scaffolded) the classes sat for a one-hour chemistry laboratory (non-scaffolded) test. For the scaffolded classes, the scaffolds were deliberately and gradually removed over the series of five to six experiments until they sat for the final chemistry laboratory (non-scaffolded) test. This tapering off of scaffolds aligns with the fading feature of scaffolding.

A t-test analysis was done on the total of the two test scores of the two classes. The t-test results and the related descriptive statistics are summarised in Table 2.

Table 2: Summary of t-test results for the scores of no-scaffold class and scaffold class

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of students</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-scaffold</td>
<td>34</td>
<td>13.18</td>
<td>2.33</td>
<td>-3.94</td>
<td>.000</td>
<td>0.93</td>
</tr>
<tr>
<td>Scaffold</td>
<td>39</td>
<td>15.03</td>
<td>1.55</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean score of the scaffold class (M = 15.03, SD = 1.55) is significantly higher (t = -3.94, df = 56, two-tailed p = .000) than that of the no-scaffold class (M = 13.18, SD = 2.33). The effect size, estimated with Cohen’s d was .93. The findings show that a scaf-
folding environment can enhance the learning of practical skills in chemistry laboratory and that scaffolding has a large effect ($ES = 0.93$) on the performance of practical work in the laboratory.

5 Implications and Conclusion

The findings of the Singapore studies on the use of scaffolds in practical work have important implications on student learning of chemistry laboratory skills in school. For example, the different types of support did help students improve in their performance in chemistry laboratory tasks. These supports would be especially helpful in large classes where the teacher may not be able to effectively provide individual attention to the students. Scaffolds, like those in the worksheets used in the studies or presented visually next to instruments in the laboratory, may be effective supports to assist students in the learning and mastery of practical skills. Also, by providing different multiple scaffolds in chemistry laboratory students’ learning of practical skills can be better enhanced because students have indicated that the scaffolds were helpful in their learning process. The Singapore studies have also provided new insights into how scaffolded learning environments can help improve student learning of laboratory skills. The scaffolded chemistry laboratory environment has enabled us to explore the use of different and multiple scaffolds as another teaching and learning approach to learn science practical skills in school chemistry. Nevertheless, more investigation on scaffolding the laboratory for learning science practical skills have to be done in chemistry classes before the essential features of scaffolding in the laboratory setting may be more convincingly identified.
6 References


