What is in the Metaphor of Scaffolding?

by

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ABSTRACT

The Vygotskian idea that the intra-individual skills of a learner have their origin in the inter-individual activity had shaped the concept of scaffolding in the context of adult-child interaction from the 1970s. This paper reports the findings of a research project on scaffolding as a teaching strategy. Scaffolding consists largely of questioning, but also includes body language, encouraging comments and active listening. A four-stage lesson plan was proposed to realize the scaffolding lessons – whole-class discussion, group work, reporting back and summing up. In these lessons, students were always encouraged to explain and justify their solutions. The teacher-student and student-student interactions were taken into consideration when devising new instructions and tendering scaffolding tailored to the needs of students. Hence it played different roles such as clarifying doubts, inviting responses, focusing on task, reinforcing important facts and evaluating students' works. Initially, students were passive and their responses were confined to brief phrases or single disconnected sentences. Eventually, they became actively involved and improved in articulating their solutions.

INTRODUCTION

The 21st century is characterized by advances in knowledge and technology. These advances call for a revamp in mathematics education which emphasizes on creative methods in the teaching and learning of mathematics that can foster problem-solving skills, higher-order thinking skills, independent learning, team work and communication skills. The mathematics of yesterday will not suffice for this knowledge-based era.

Educators have been actively engaged in research on mathematics education. The findings are disseminated to schools that aid the effective teaching of mathematics. It is hoped that students will be engaged in more meaningful learning and the various skills mentioned above will be cultivated in students.

Even though educators report much progress on students' performance, mathematics still seems to be one of the difficult subjects for school students. Von Glaserfeld (1995) says that '[Educators] have noticed that many students were quite able to learn the necessary formulas and apply them to the limited range of textbook and test situations, but when faced with novel problems, they fell short and showed that they were far from having understood the relevant concepts and conceptual relations' (p. 20). Lau et al (2003) find that the problem-solving ability of students decline drastically as the level of difficulty of mathematics problem increases.

A study entitled "Scaffolding as a teaching strategy to enhance mathematics learning in the classroom" was started in January 2004 to investigate the potentials of scaffolding to deliver the emphases of mathematics education of the 21^{st} century. This paper not only presents the theoretical rationale and the importance of scaffolding to the teaching and learning process of mathematics, also reports some of the findings of the above study.

LITERATURE REVIEW

Why do people do Mathematics? It is paradoxical in that it is both a means to achieve goals and an activity in its own right. In 'developed' countries, almost everybody knows that it is an important body of knowledge. There are a great number of professions such as engineering, medicine, accountancy and so on that cannot be exercised without some knowledge of mathematics. But there are some who still consider mathematicians to be custodians of a fund of formulas and the work of mathematicians as limited to passing on the legacy of past centuries. The following are two different but interesting views on mathematics education.

(1) 'To teach mathematics as a separate discipline is a perversion, a corruption and a distortion of true knowledge.' (Kline, 1973, p 145)
(2) 'Mathematics is a subject reserved for the elite, who should study symbolic aspects of number and space, preferably from a textbook in order to later serve the needs of industry and technology.' (Dengate & Lerman, 1995, p. 28)

What should schools offer to their students in mathematics? It is hard to formulate a single answer. For the purpose of this paper, we will discuss constructivism as the learning philosophy and scaffolding as the teaching strategy having the potential to deliver the emphases of mathematics education of the 21^{st} century.

Constructivism

The traditional approach to the teaching and learning of mathematics such as "drill and practice" is criticized for its assumption that students are passive learners. Its scope is limited to receiving, storing and retrieving information. A theory of learning called constructivism was shaped from the early 1980s, and owes its debt to Piaget's Developmental Psychology and the Vygotskian School of Learning. The following two key hypotheses are the bases of constructivism:

(1) 'Knowledge is actively constructed by the cognizing subject, not passively received from the environment.
(2) Coming to know is an adaptive process that organizes one's experiential world; it does not discover an independent, pre-existing world outside the mind of the knower.' (Kilpatrick, 1987, p. 7)

These principles are becoming popular with many mathematics educators when we think about listening to students and their mathematical learning. It implies that learning has to do with more than what is experienced through the senses. It has to do with what is going on inside the cognizing subject. Lerman (1983) describes an example where students were asked to find a fraction between 1/2 and 3/4. One of the students gave 2/3 as an answer. The student insisted that this solution was correct and easy to find and refused to accept another way of getting a solution since 2 is between 1 and 3 and 3 between 2 and 4, which is true. The teacher then asked the student another question, that is, find a fraction between 1/2 and 1/3. This time, the student was unable to reason out a solution using the above method, since there is no whole number between 1 and 1 or 2 and 3. Therefore, students learn the concept not because their teacher tells them that this is the usual way everyone tackles such a problem, but because the conception that they had before could not produce an expected result. '[Students] will accept new ideas only when their old ideas do not work or are inefficient. Furthermore, ideas are not isolated in memory but are organized and associated with the natural language that one uses and the situations one has encountered in the past.' (NCTM, 1989, p. 10)

Constructivism is increasingly being criticized for its limitations as a learning theory. Those educators who adhere to the Vygotskian School of Learning suggest social constructivism as a possible extension of constructivism by incorporating "intersubjectivity", which views mathematics learning as both a collective human activity and an individual constructive activity. Confrey (1990) says that: '... the constructive process is subject to social influences. We do not think in isolation; our choice of problem, the language in which we cast the problem, our method of examining a problem, our choice of resource to solve the problem, and our acceptance of a level of rigor for a solution are all both social and individual processes.' (p. 110) These influences shape one's constructions. In other words, there are two faces of mathematics. These are mathematics in students' heads and mathematics in the students' environment. The main concern of social constructivists is how to account for mathematics learning in the students' environment.

Since constructivism is a way of thinking about knowledge and the act of knowing, what are its implications for mathematics education? The following list, which should by no means be treated as complete, contains a few, but important implications.

(1) Learners should not be treated as 'empty vessels' or 'blank slates'. They are thinking beings.
(2) Knowledge cannot be literally transmitted.
(3) Knowledge is growing.
(4) Learners make sense of new information from their prior knowledge.
(5) It advocates learning with understanding.
(6) It claims that learning is like an experiment, which proceeds not along a fixed, preconceived plan, but along a plan invented step by step according to what the learner says or does.
(7) It encourages dialogue, communication and reflection.

Scaffolding

If constructivism is adopted as a learning philosophy for mathematics education, what should be the teaching method? Scaffolding can be one of the answers. The Vygotskian School of thought probably has the most profound influence on the formation of the concept of scaffolding.

Vygotsky emphasizes concept formation as a major issue in the cognitive development of a child. The process of concept formation should be studied by referring to the means by which the operation is accomplished, including the use of tools, the mobilization of the appropriate means, and the means by which people learn to organize and direct their behaviour. Based on this, Vygotsky (1978) conceptualizes the idea of the Zone of Proximal Development. He says that children who by themselves are able to perform a task at a particular cognitive level, in cooperation with others and with adults will be able to perform at a higher level, and this difference between the two levels is the child's "Zone of Proximal Development". He suggests taking note of this capability of a child when designing instruction. He also claims that: 'Every function in the child's cultural development appears twice, on two levels. First on the social, and later on the psychological level; first, between people as an interpsychological category and then inside the child as an intrapsychological category.' (p. 128) The process by which inter becomes intra is called internalization and involves more than the endowment of the child and more than the child can accomplish on his or her own, but it occurs within the child's Zone of Proximal Development. Hence the cognitive development in a child is social, which involves another person and the society as a whole. In other words, social interaction taking the form of dialogue or exchange of cues or gestures plays an important role in concept formation. It also forms the backbone for educators in formulating the concept of scaffolding.

Wood, Bruner and Ross (1976) introduced the word scaffolding for the first time in their article 'The Role of Tutoring in Problem Solving'. They believe that the acquisition of skills by a child is an activity in which the readily relevant skills are combined and 'bent' into 'higher skills' to meet new, more complex task requirements. This activity can only be successful through the intervention of a tutor, which will result in much more than just modeling and imitation. 'More often than not, it involves a kind of "scaffolding" process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted effort. This scaffolding consists essentially of the adult "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence. The task thus proceeds to a successful conclusion. We assume, however, that the process can potentially achieve much more for the learner than an assisted completion of the task. It may result, eventually, in development of task competency by the learner at a pace that would far outstrip his unassisted efforts.' (p. 90)

Greenfield (1984) defines the scaffold for building construction as follow: 'The scaffold, as it is known in building construction, has five characteristics: It provides a support; it functions as a tool; it extends the range of a worker; it allows the worker to accomplish the task not otherwise possible; and it is used selectively to aid the worker where needed.' (p. 118) Based on this definition, she puts forward the following idea of the scaffolding process in a learning situation: '… the teacher's selective intervention provides a supportive tool for the learner, which extends his or her skills, thereby allowing the learner successfully to accomplish a task not otherwise possible. Put another way, the teacher structures an interaction by building on what he or she knows the learner can do. Scaffolding thus closes the gap between task requirement and the skill level of the learner.' (p. 118)

The common interactions in scaffolding have been highlighted as: Focusing on a gap to bridge in a child's skills to accomplish a task; Extending by raising the skill level: asking questions like 'What else will you (would you, could you) do?' when the teacher is satisfied with the performance of the child; Refocusing by encouraging clarification and justification by asking questions like ‘Is this what you are trying to say (do, write) or is it something else?’ when the teacher is confused or unclear about what the child is doing or saying; and Redirecting by offering new resources if there is a mismatch between the child’s intent and the message or in the expectations which the teacher holds for the child (Cambourne, 1988). In line with this, scaffolding can be classified as: Level E: Teacher modeling – A teacher models the complete problem-solving process by verbal explanations; Level D: Inviting student performance – Teacher modeling with some students’ participation; Level C: Specific cueing – Cues given on specific elements of problem-solving strategy; Level B: Strategy cueing – Cues given on general strategies; and Level A: General cues like ‘What can you do now?’ (Beed, Hawkins & Roller, 1991). Lau (1998) suggests that scaffolding can only be successful if the task in hand is meaningful and challenging, students participate actively in tackling the task and the scaffold is tailored to the needs of students.

METHODOLOGY

The study entitled “Scaffolding as a teaching strategy to enhance mathematics learning in the classroom” is predominantly qualitative. The methodology is formulated by incorporating features such as natural setting, human instrument, qualitative method, purposive sampling, inductive data analysis, emergent design, negotiated outcomes, case study, idiographic interpretation, and special criteria for trustworthiness of constructivist paradigm and the spiral nature, interventional and group work of action research (Lincoln & Guba, 1985, Kemmis & McTaggart, 1988). Two teachers from a secondary school accepted the invitation to participate in this study. Both teachers are qualified teachers and have many years’ experience in teaching secondary school mathematics. We decided to conduct this research on two classes of Form Four students of age 16 years old in the school.

The fieldwork for this research consisted of observing the teachers and students in the classroom and discussing the work with the participating teachers. Three formal methods of data collection were used: video recording of the lessons, running records of observations and discussions in the classroom and taping of the interviews with teachers and students. These tapes were transcribed and the transcriptions consisted of the time for the sections, the sequential conversation of the participants and non-verbal events, which could assist in interpreting the interactions between the participants.

The critical determinants identified for successful scaffolding for this research are ‘activity’, ‘scaffolding’ and ‘student achievement’. These determinants are further divided into themes as shown in table 1.

This study entails the development of a framework that represents something of an amalgamation of the work of educators such as Schoenfeld (1983), and Cobb and Whitenack (1996). There are three phases in the analysis of the data: initial analysis, episode-by-episode analysis and comparative analysis. Initial analyses – The researchers and the participating teachers identified the three critical determinants and the different themes. Episode-by-episode analysis – An interpretative stance guided these analyses. The transcriptions of the videotapes and audiotapes and the running records of the observations are the sources of the episodes for interpretations. The analysis of each episode was guided by the themes. Comparative analysis – The last phase of this analysis involves a meta-analysis of the selected episodes and their interpretations to develop an overview of the progress on the various themes that occurred during this research in chronological order. These chronological analyses, which feature the progress made by the human instruments of this research served as the bases for the case studies in the report.

FINDINGS

For the purpose of this paper, we will present some of the findings on ‘scaffolding’ and ‘student achievement’.

Scaffolding

An important feature of scaffolding lessons is that it is student centered. In order to encourage active involvement from students, the role played by the teacher shifts from ‘the so called sage on the stage’ for the traditional chalk and talk lessons to ‘the guide by the side’ for scaffolding lessons. The findings indicate that the scaffolds, mostly in the form of questions, from the teachers can play different roles such as ‘clarifying’, ‘inviting’, ‘focusing’, ‘reinforcing’ and ‘evaluating’. Table 2 contains some of these questions frequently posed by the teachers according to the above roles. Clarifying – The teachers posed the questions playing this role mostly during the first part of a scaffolding lesson, that is, whole-class discussion. The main aim was to get the students to understand the activity thoroughly and to generate possible strategies for a solution. Inviting – These questions were posed to students at different parts of a lesson aiming to further clarify the activity or to get students to justify their solutions. Focusing – These questions were posed mostly during group work, the second part of a scaffolding lesson, to get students to move on-task. Reinforcing – These questions were posed throughout the lesson to emphasize important features of the activity. Evaluating – These questions were posed mostly at the last two parts of a scaffolding lesson, reporting back and summing up, to legitimize students’ solutions.

Student Achievement

At the beginning of this study, students were quite reluctant to express their thinking to others and their responses were confined to ‘brief phrases’ or ‘single disconnected sentences’. This placed the teachers under the obligation of approaching the students’ solutions in a non-evaluative way and to refrain from imposing their ways of tackling the problem on the students. As the students realized that their explanations or solutions were respected and accepted, reciprocal obligations and expectations were negotiated implicitly during these lessons. The responses from students slowly evolved to explanations which ‘made sense’ to anybody.

At the latter part of this study, students began to challenge the arguments from their teachers and their peers frequently. They put forward questions like: What does it mean by …? How about …? How do you get …? Are … and … the same? Can we use …? Why must we …? These show that some of the scaffolding questions posed to students by their teachers had been internalized and had become the students’ stock of tools for questioning.

DISCUSSIONS AND CONCLUSIONS

Figure 1 illustrates the dependence of students’ success in mathematics learning on the three aspects of activity, scaffolding and classroom context.

By activity, we mean the rich problems posed to students in a scaffolding lesson that is related to students' prior knowledge, promote discussions and must be challenging. For scaffolding, we are considering the nature of the social and mathematical interaction between students and their teacher. Finally, the classroom context refers to the concept of the teaching and learning of mathematics, group work and the role of the teacher.

In this study, we proposed a four-phase lesson plan for teachers delivering scaffolding lessons so that their objectives could be realized: whole-class discussion, group work, reporting back and summing up. During the whole-class discussion, the teachers scaffolded students to understand a problem and to come up with possible heuristics and strategies for a solution. Group work provided a chance for students to solve a problem themselves through active discussion and individual effort. The teachers moved around the class acting as facilitators providing the 'right' scaffold to their work. At the reporting-back phase, students were given an opportunity to explain and justify their solutions to the class. By doing so, not only were students made aware of different choices of strategies to solve a problem, but they were also scaffolded to verbalize their thinking effectively. Finally, the teachers summed up the lesson by actively discussing all solutions, providing scaffolds to justify the legitimacy of each solution, introducing new symbols and mathematical language, and extending the problem to new problems.

Students benefited greatly from these scaffolding lessons. They changed from passive learners to active participants. Their responses made sense. Some of the scaffolds from their teachers were internalized and became their stock of tools for questioning. When they started questioning, they were in fact engaged in higher-order thinking.

The continuous constructions and transformations of the teaching and learning process motivated the teachers to carefully consider the appropriate classroom context required of a scaffolding lesson. First, they reconceptualized the teaching and learning process of mathematics as a social process of negotiation rather than imposition. Second, group work was another strategy that helped implement scaffolding successfully. Last but not least, they acted as facilitators in the development of the students' mathematical constructions rather than the sole source of mathematical knowledge.

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APPENDICES

Figure 1: The interdependence of activity, scaffolding and context for successful learning

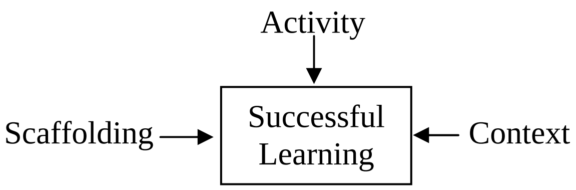

Table 1: Determinants and themes

Determinant	Theme
Activity	1. Challenging 2. Related to prior knowledge 3. Promote discussion
Scaffolding	1. Roles of scaffolding 2. Tailor to the needs 3. Taking students' perspectives 4. Developmental
Student achievement	1. Active learning 2. Communication skills

Table 2: Roles and questions of scaffolding

Role	Question
Clarifying	Do we need to find …? Why is it …?
Inviting	Where did you get this? Who can tell me what is …?
Focusing	What is the question really wanted? Do we find … or …?
Reinforcing	What does it mean by …? Is it possible …?
Evaluating	Is this solution correct? Is there any other answer?