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Scaffolding to Support Better Achievement in Mathematics

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Abstract

According to the National Science Education Standards, teachers should emphasize students' interests, needs, experiences, inquiry, collaboration and understanding in their classrooms. One of the characteristics of inquiry is using scaffolding. Because of the benefits, it is important to investigate the effect of scaffolding on achievement in mathematics. Based on some relevant previous studies, scaffolding can be used to support better achievement in mathematics. In scaffolding, teacher's guidance decreases gradually and student's autonomy increases gradually. By giving guidance, teacher revises student's misconceptions; while by giving autonomy, teacher supports student's motivation in learning. Minimizing misconceptions and maximizing motivation can lead students to better achievement in mathematics. Many studies in this paper emphasize the importance of teachers' contribution in giving scaffolding to their students. Further research should be conducted to investigate the role of other people surrounding the students, such as parent and peer, in supporting effective scaffolding.

Keywords: scaffolding, achievement in mathematics, misconceptions, motivation

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INTRODUCTION

According to the National Science Education Standards, teachers should emphasize students' interests, needs, experiences, inquiry, collaboration and understanding in their class-rooms. The National Educational Technology Standards (NETS) indicate, "The most effective learning environments meld traditional and new approaches to facilitate learning of relevant content while addressing individual needs" (Butler & Lumpe, 2008). Therefore, the concept of learning goes beyond the traditional knowledge of the past. Instead, the standards focus more on developing the teacher and student's ability to construct new knowledge from their own inquiry, collaboration and experiences. One of the characteristics of inquiry is using scaffolding.

It is over 25 years since Wood, Bruner and Ross (1976) introduced the idea of "scaffolding" to represent the way children's learning can be supported. This idea has enduring attraction in the way it emphasizes the intent to support a sound foundation with increasing independence for the learner as understanding becomes more secure. It has relation with the widely accepted notion in teaching of construction and the constructivist paradigm for learning.

Scaffolding is a widely used educational practice in which directed instruction gradually decreases as students' competence increases, resulting in increased independent learning. In the beginning, teacher still give guidance for students to avoid them from misconceptions. Teacher stops giving help when students can learn by themselves. Students are given opportunity to have autonomy in learning. In this case, teacher facilitates intrinsic motivation by emphasizing students' autonomy and providing optimal challenges for them.

In learning mathematics, students should be given the opportunity to communicate mathematically, reasoning mathematically, develop self-confidence to solve mathematics problems through scaffolding (Johnson and Johnson, 1990). Because of the benefits, it is important to investigate the effect of scaffolding on achievement in mathematics. The question in this essay is whether scaffolding can support better achievement in mathematics? Some relevant studies will be described to find the answer.

DISCUSSION

Scaffolding

Scaffold Instruction

Scaffold instruction is the systematic sequencing of prompted content, materials, tasks, teacher and peer support to optimize learning (Dickson, Chard, & Simmons, 1993). Scaffolding provides students with the help they need and allows them to complete a task with assistance before they are able to complete it independently (Pearson in Larkin, 2001). The goal of scaffolding is to support students until they can apply the new skills and strategies by themselves. This means a gradual decrease in supports and a gradual increase in student responsibility. The responsibility for learning shifts from the teacher to the student.

In other words, scaffold instruction means that teachers make sure that their students have the necessary support to complete a task successfully. When learning something new or difficult, students may need more assistance; and as they begin to demonstrate task mastery, the support is removed gradually. Through appropriately scaffold instruction, students accept more responsibility for their learning and become more independent learners. As a student performs tasks with less and less teacher assistance, he gains more self-confidence and is more likely to take risks.

Hogan and Pressley (Larkin, 2001) listed eight essential elements of scaffold instruction, those are pre-engagement with the learners and curriculum; establishing a shared goal; actively diagnosing the understandings and needs of the learners; providing tailored assistance; maintaining pursuit of the goal; giving feedback; controlling for frustration and risk; and assisting internalization, independence, and generalization to other contexts. Teachers need not follow these elements in lockstep succession, but use them as general guidelines for dynamic and flexible scaffolding.

Guidelines for Effective Scaffolding

According to Pressley, effective scaffolding requires that teachers are cognizant of what students already know (background or prior knowledge), the students' misconceptions, and the students' current zone of proximal development, for examples which competencies are developing and which are beyond student's level of functioning (Larkin, 2001). Teachers should begin with what students can do to make them believe with their ability. It can motivate students intrinsically.

Effective scaffolding means that teachers need to listen and watch for clues from their students as to when teacher assistance is needed or is not needed. Obviously, teachers do not want students to fail, but they should not allow students to become too dependent on them. As special education teacher noted, achieving independence is different for individual students. Some students may be at identical skill levels, but emotionally may be at different levels regarding the amount of frustration they can tolerate. Students may not be able to apart from teacher assistance at the same time. In other words, some students will need more teacher support while learning to perform a task; others will demonstrate task mastery more quickly. Teachers need to help his students gradually move from teacher assistance to students' independence as they demonstrate command of the task or activity. Teachers should know when it is time to stop.

The Use of Scaffolding in Inquiry Learning

All learning involves knowledge construction in one form or another; it is therefore a constructivist process. The question of what sorts of instructional practices are likely to promote such knowledge construction is at the core of the argument presented by Kirschner, Sweller, & Clark (2006). The authors loosely define minimally guided instruction as a learning context in which "learners, rather than being presented with essential information, must discover or construct essential information for them". They conversely define direct guidance instruction as "providing information that fully explains the concepts and procedures that students are required to learn." In their argument, Kirschner et al. contrast minimally guided instructional approaches with approaches that provide direct instructional guidance and assert that minimally guided instructional approaches are ineffective and inefficient.

In fact, inquiry learning is not minimally guided instructional approaches but rather provide extensive scaffolding and guidance to facilitate students learning. Scaffold inquiry presents learners with opportunities to engage in complex tasks that would otherwise be beyond their current abilities. Scaffolding makes the learning more tractable for students by changing complex and difficult tasks in ways that make these tasks accessible, manageable, and within students' zone of proximal development.

The zone of proximal development (ZPD) is the difference between the learner's capacity to solve problems on his own and his capacity to solve them with assistance (Vygotsky, 1978). In other words, the actual developmental level refers to all the functions and activities that a learner can perform independently. On the other hand, the ZPD includes all the functions and activities that a learner can perform only with the assistance of someone else. The person in this scaffolding process, providing non-intrusive intervention, could be an adult, such as a teacher or parent, or another peer who has already mastered that particular function.

Scaffolding is conceived as a key element of cognitive apprenticeship, whereby students become increasingly accomplished problem-solvers given structure and guidance from mentors who scaffold students through coaching, task structuring, and hints, without explicitly giving students the final answers. An important feature of scaffolding is that it supports students' learning of both how to do the task as well as why the task should be done that way (Hmelo-Silver, Duncan, & Chinn, 2006).

Inquiry learning situates learning in complex tasks. Such task require scaffolding to help students engage in sense making, managing their investigations and problem-solving processes, and encouraging students to articulate their thinking and reflect on their learning (Quintana, Reiser, Davis, Krajcik, Fretz, & Duncan, 2004). Teachers play a significant role in scaffolding mindful and productive engagement with the task, tools, and peers. They guide students in the learning process, pushing them to think deeply, and model the kinds of questions that students need to be asking themselves, thus forming a cognitive apprenticeship.

Scaffolds that Embed Expert Guidance

In many teaching learning processes, expert information and guidance are sometimes offered directly to the learners. Schwartz and Bransford showed that providing explanations when needed can be a very effective form of scaffolding. They presented some students with a lecture on memory after they had tried to explain the pattern of results in data from real memory experiments. Other students received the lecture without having engaged in the inquiry activity (Hmelo-Silver et al., 2006).

The students who received the lecture after trying to explain the data learned much more from the lecture. In the context of students trying to explain data, the lecture provided scaffolding that helped students make sense of the data, and hence was more meaningful than the same lecture presented not as scaffolding for inquiry but as direct instruction. Meaningful learning can bring students to the right basic concept so that can avoid them from misconceptions.

Scaffolds that Reduce Cognitive Load

Scaffolding can guide instruction and decrease cognitive load by structuring a task in ways that allow the learner to focus on aspects of the task that are relevant to the learning goals. For example, scaffolding can reduce cognitive load by automating the generation of data representations, labor intensive calculations, or storing information. By structuring the tasks and the available functionality, scaffolding can restrict the options that are available to the learner at any point in time to make the task accessible and manageable (Quintana et al., 2004).

Tasks can affect learners' motivation. According to Wigfield and Eccles (Hmelo-Silver et al., 2006), many theories suggest that the strength of students' motivation in a particular situation is determined by both students' expectation that they can succeed and the value of that success for them. Students' beliefs about the value of a task seem to predict the choices they make. Efficacy expectations predict achievement in doing the task - how well the students actually perform.

Misconceptions

The Role of Misconceptions in Constructivism

Revising misconceptions is important aspect within the constructivist view of the development of learning. Misconceptions should be seen as not only an inevitable and integral part of learning but also as a valuable source of information about the learning process. In fact, Resnick et al. in Kembitzky (2009) argued that consistent misconceptions are active knowledge constructions and therefore indicate the presence rather than the absence of learning. According to Tirosh, cognitive development theories view individuals' efforts to resolve inconsistencies in their thinking as an essential and vital part of their construction of concepts (Kembitzky, 2009).

Within the students, a state of cognitive conflict is reached and a misconception is born, although not necessarily in that order. Until the students reach that state of conflict, they are not aware that they even have a misconception. Without intervention, this misconception will become stronger and more difficult to correct over time. Within the constructivist frameworks of Bruner and Vygotsky, intervention needs to come in through two pathways, the teacher and the student. One without the other will not necessarily create a situation where the student is able to understand his misconception. Without the student reaching that state of conflict, the instruction by the teacher will have little to no impact on the student. Without the teacher helping to scaffold the instruction and find the student's ZPD, the student will have difficulty understanding their misconception on their own (Kembitzky, 2009).

Misconceptions in Mathematics

A misconception is a line of thinking that causes a series of errors all resulting from an incorrect underlying premise, rather than sporadic, unconnected and nonsystematic errors (Nesher, 1987). The role that misconceptions play in the construction of students' mathematical development is an area that has received a great deal of attention. Misconceptions are caused by using wrong generalization of everyday experiences, using the correct rule at the wrong situation, using superficial analysis of situation and giving too concrete meaning to the mathematical symbol.

One of the best-known misconceptions in mathematics called "illusion of linearity". Linearity (or proportionality) is, from a long way back, a key concept in mathematics and science education from elementary school to university. Both from a psychological and a mathematical point of view, the idea of linearity comes first. Rouche in De Bock, Van Dooren, Janssens, & Verschaffel (2002) argued that because of their simplicity, linear functions immediately appear in human's mind. However, the reinforcement of linearity at numerous occasions in school mathematics, along with its intrinsic simplicity and self-evidence, may lead to a tendency in students, and even in adults, to see and apply the linear model everywhere. ''Linearity is such a suggestive property of relations that one readily yields to the seduction to deal with each numerical relation as though it were linear'' (Freudenthal, 1983). The misuse of linearity in non-linear situations sometimes referred to as the "illusion of linearity" is a classical misconception.

Design of Learning Environment to Minimize Students' Misconceptions

Currently, the widely accepted view in the research community on learning and instruction is that students are not ''empty vessels'' when considering scientific or mathematical knowledge. Rather, they have already constructed a common-sense understanding of the world based on their experiences from everyday life and prior schooling (Mason in Van Dooren, De Bock, Hessels, Janssens, & Verschaffel, 2004). This prior knowledge base interacts with new information students are confronted with. Especially, when that knowledge base is incompatible with new learning contents, classroom learning requires a significant reorganization of students' existing knowledge base, which is called conceptual change. The conceptual change theory (CCT) focuses on knowledge acquisition in specific domains where prior conceptions interact with the new, intended knowledge. It describes learning as a process that requires significant reorganization of existing knowledge structures (Vosniadou, 2003).

The design of learning environment based on CCT in order to maximize the chance of obtaining conceptual change in the students consists of being informed about students' prior knowledge, students' misconceptions and their origin; explicitly addressing students' preconceptions during instruction; supporting students' metaconceptual awareness (awareness of their beliefs and possible inconsistencies in them) and metacognition (monitoring their learning and problem-solving processes) in order to bring conceptual change in the conscious control of the learners; facilitating motivation source such as providing meaningful learning experiences and involving them in learning activities; facilitating appropriate mathematical models and related external representations to clarify aspects of an explanation that are not apparent when the explanation is given in a purely linguistic or symbolic way (Vosniadou, 2003).

Motivation

Motivation within Self-Determination Theory

Self-Determination Theory or SDT is a theory of motivation, but combines traditional empirical methods and a theory that deals with people's internal resources for motivation (Deci & Ryan, 1991). SDT proposes that people's psychological needs are the basis for their motivation. In particular, the needs for autonomy, competence, and relatedness are believed essential for enhancing motivation. The need for autonomy is the need to engage in self-directed behavior. The need for competence is the need to experience satisfaction in improving one's abilities. The need for relatedness is the need to feel related to significant others. Consequently, people engage in behaviors to support these needs.

SDT postulates that self-determined or autonomous motivation is related to positive academic and emotional outcomes, including school achievement, whereas non-self determined motivation is related to negative outcomes (Deci & Ryan, 1991). Evidence exists to support this idea. For example, some researchers have found that more self-determined motivation was related to better academic performance, lower dropout (Vallerand, Fortier, & Guay, 1997), better ability to cope with failures, and higher quality learning (Deci & Ryan, 1991). Other researchers have found that non-self determined motivation was related to higher dropout, less interest, less value, and less effort toward achievement (Vallerand et al., 1997).

Motivation in Mathematics

It has been suggested that because mathematics is perceived to be more difficult and to demand more effort than many other school subjects, it necessitates a strong degree of intrinsic motivation (Gottfried in Aunola, Leskinen, & Nurmi, 2006). Research carried out so far has shown that various motivational constructs, such as intrinsic motivation, perceptions of mathematics usefulness, and positive attitudes and interest towards mathematics are associated with high performance in mathematics (Aunola et al., 2006).

The findings provide some insight into how educators may begin to increase the content area interest of students. In particular, those findings suggest that teachers should seek to foster an autonomy supportive climate, not only in the interests of fostering positive mathematics self-concept, but also because autonomy support directly affected mathematics achievement. One must recognize that autonomy promoting activities may be useful educational activities that directly affect mathematics achievement by increasing subject matter knowledge.

Some Factors that Affect Motivation to Learn

Teachers are concerned about developing a particular kind of motivation in their learners, the motivation to learn. Brophy in Woolfolk (2008) described the motivation to learn as a student tendency to find academic activities meaningful and worthwhile and to try to derive the intended academic benefits from them. Motivation to learn involves more than intending to learn, it includes the quality of the learner's mental efforts.

Some factors that affect motivation to learn are the classroom or learning area must be fairly organized and free constant interruptions and disruptions; the teacher needs to be patient and supportive to avoid embarrassing learners for mistakes; the work must be challenging but reasonable; the learning tasks should be authentic; and the autonomy learners are allowed in working (Stipek in Woolfolk, 2008).

Achievement in Mathematics

At present, mathematics is widely used in various fields and covering a wide range of activities. However, the decline in mathematics achievement is of concern. Among the reasons of the decline in mathematics achievement in schools is because students consider mathematics as a difficult and boring subject. The phenomenon of frustration among teachers and students need to be overcome in order to achieve excellence in mathematics. Therefore, teachers should take note of the needs of individual students (Zakaria, Chin, & Daud, 2010). The individual needs of students should be treated accordingly so that the teaching and learning is effective.

According to Crocker, achievements are reinforced when teachers use substantial emphasis on academic instruction and pupils' engagement in academic tasks; whole class instruction; effective question answer and seat work practices; minimal disruptive behavior; and prompt feedback to pupils. Clarke argued that successful teachers engage in and focus on pupils' thinking in a whole class activity. In the interaction with pupils, teachers use questions in order to challenge the children's thinking and reasoning. They do not give the right answers immediately, instead they encourage pupils to describe their ideas about mathematics independently and encourage them to listen and evaluate their classmates' reflections and ideas (Samuelssons & Granstrom, 2007).

In order to enhance mathematics achievements, the teacher's role is crucial, not as the repository of knowledge, but as the one who initiates and guides the students in community practices. Maximizing the effectiveness of these classrooms through their transformation into environments of inquiry requires that the teacher take on the role of "facilitator" and not "transmitter of knowledge" (Cross, 2008). In so doing, students' collaborative engagement in argumentation around mathematical ideas and concepts is continuously scaffold by the teacher, guiding the students towards expertise.

CONCLUSION

This essay started with the question whether scaffolding can support better achievement in mathematics? Based on some relevant studies that were described above, scaffolding can be used to support better achievement in mathematics. In scaffolding, teacher's guidance decreases gradually and student's autonomy increases gradually. By giving guidance, teacher revises student's misconceptions; while by giving autonomy, teacher supports student's motivation in learning. Minimizing misconceptions and maximizing motivation can lead students to better achievement in mathematics.

Furthermore, misconceptions can be used to stimulate and support mathematical inquiry in the classroom. With respect to cognitive development, it will promote positive changes in students' previous misconceptions and misunderstandings with mathematical concepts. When students are asked to explain, define, and describe concepts and procedures in their own words, they are cognitively engaged in creating personally meaningful conceptions of the content. If students are taught to face their misconceptions as learning opportunities rather than reminders of their inabilities, then they are more confident about their mathematical learning and contributions.

In scaffolding, teacher will know when to intervene and when to allow students to struggle. Teacher must allow students to realize their errors and wrestle with the concepts as they work with their way to deeper understanding. It seems that a teaching intervention aiming at the intended conceptual change should elicit more purposeful learning. It is initiated by intrinsically motivated learners under their conscious control.

Moreover, teacher has contribution in helping students develop these motivational resources by providing autonomy supportive classrooms, which support students' needs for self-determination. Teacher's support of autonomy significantly improves mathematics performance. Such autonomy promoting changes could positively affect students' mathematics self-concept, thus directly and indirectly increasing mathematics achievement.

Many studies in this paper emphasize the importance of teachers' contribution in giving scaffolding to their students. However, the role of other people surrounding the students, such as parent and peer, in improving scaffolding can not be overlooked. Further research should be conducted to investigate the effect of involving parent and peer in supporting effective scaffolding.

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