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Scaffolding Strategies Applied by Student Teachers to Teach Mathematics

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Abstract: Scaffolding is a teaching strategy that provides individualized support based on the learner's Zone of the Proximal Development (Chang, Sung & Chen, 2002). In scaffolding instruction, another, more knowledgeable individual, provides scaffolds or supports to facilitate the learner's development. Roehler & Cantlon (1997) identified five different strategies in instructional scaffolding: the modeling of desired behaviors, the offering of explanations, inviting students to participate, verifying and clarifying student understandings, and inviting students to contribute clues. In this research, the aim has been to analyze student teachers' scaffolding strategies as they have been applied to the teaching of mathematics. The research was conducted with thirteen student teachers in their fourth year of study in Bachelor of Education (Classroom Teacher) Programs. Nine student teachers worked with two fifth grader learners, while the other four worked with three. In order to determine the participant students, a geometry test relating to the first unit of the fifth grade mathematics curriculum was administered. The student teachers worked on a one-to-one basis with students who were having difficulty in geometry and this scaffolding process was recorded. According to the results; *inviting student participation* was found to be the most commonly used scaffolding strategy. The least common were *inviting students to contribute clues* and the *modeling of desired behaviors*. While the majority of student teachers had similar tendencies, certain others had different inclinations. However, the reasons for their preferences in using these scaffolding strategies were not clear.

Keywords: Scaffolding, mathematics education, student teacher

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Introduction

The concept of scaffolding, which was introduced by Wood, Bruner & Ross, (1976, in Anghileri, 2006) , is grounded in the developmental theories of Vygotsky. Vygotsky (1978) stated 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 variation between the two levels is the child's "Zone of Proximal Development".

Scaffolding is a support strategy for children's convergent development areas. It is based on controlled support offered by an able adult to amend the cognitive difficulty faced by children when they cannot solve problems with their existing level of development. It is important for such support to be temporary. As children's skills advance with the support, scaffolding subsides and children are eventually able to perform on their own (Chang, Sung, & Chen, 2002).

Collins, Brown and Newman (1989) describe scaffolding as: "a kind of cooperative problem-solving effort by teachers and students in which the express intention is for the students to assume as much of the task on his own as possible, as soon as possible."

Wood, Bruner and Ross (1976, in Anghileri, 2006) define it as the controlling of the features of a task, that are initially above the capacity of a learner, by another person (such as teacher, a skilled adult or a peer) and thus directing the child's attention to these features so that they can complete the task within the limits of their skills. The features of the task are stressed in order to direct the child's attention to task-related goals and maintain this attention throughout the task. When children have complete control over the task, they will take more responsibility to complete it and reciprocity will be achieved (Roehler & Cantlon, 1997).

The concept of scaffolding is used to define and explain the role of adults - or more able peers - in supporting children's learning and development. Although it does not offer precise clues as to how the instructional process will occur, it does offer an understanding of the interaction between adults and children (Stone, 1998). The construction model of the epistemic student – that is, the student as constructor of knowledge – is one of the most fundamental teacher activities, as identified by Steffe (1993) (in Holton & Clake, 2006).

To implement scaffolding succesfully, teachers must first determine the differences between what each student can accomplish independently and what he or she can accomplish with guidance, i.e. the student's zone of proximal development (Gaskin et al., 1997). In order to achieve this, the principles of scaffolding should be followed: a) maintaining a fine balance between challenging and supporting the student, b) using appropriate scaffolding forms (permanent, temporary), c) modeling favorable personality traits and behaviors (experimentation, avoiding judgment, openness...), d) providing the most appropriate environment, e) responding and giving feedback to students regarding their questions and comments so that they can be responsible for their own learning.

In the scaffolding literature, the six key functions determined by Wood, Bruner and Ross (1976) (in Anghileri, 2006) are prominent. These are:

- Recruitment: enlisting the learner's interest and adherence to the requirements of the task,
- Reduction in the degree of freedom: simplifying the task so that feedback is regulated to a level that may be used for correction,
- Maintenance: keeping the learner in pursuit of a particular objective,
- Marking: accentuating and interpreting discrepancies,
- Control: responding to the learner's emotional states,
- Demonstration: modeling a solution to a task.

It is stated that the "responsibility-sharing" aspect of convergent development areas is the most important trait of scaffolding (Mercer & Fisher, 1993). When using the scaffolding strategy, teachers aim to turn students into individualistic people who can solve problems in a self-regulated way (Hartman, 2002). With the right word, question or other similar mechanism, a teacher may put in place the scaffolding that will allow new knowledge to be constructed, an incomplete or wrong concept to be challenged or corrected, or forgotten knowledge to be recalled. This scaffolding thus stimulates learner activity in the zone of proximal development (Holton & Clarke, 2006).

Roehler and Cantlon (1997) identified five different scaffolding strategies exploited by teachers to help students gain conceptual understanding: this classification was used in this study. Two social constructivist classrooms were observed and analyses of lesson transcripts, including English as a second language, showed that five different types of scaffolding were commonly used: o*ffering explanation; inviting student participation; verifying and clarifying student understanding; modeling of desired behaviors and inviting students to contribute clues.* These may be defined as follows.

Offering explanation: Explanations are explicit statements adjusted to fit the learners' emerging understanding about what is being learned, as well as why, when and how it is used. *Inviting student participation:* Learners are given opportunities to join the occurring process. After the teacher has provided illustrations of a particular thinking, feeling or action needed to complete the task, the learners have opportunities to fill in the pieces they know and understand. *Verifying and clarifying student understanding:* If the emerging understanding is reasonable, the teacher verifies the students' responses; if not, the teacher offers clarification. *Modeling of desired behaviors:* This is a teaching behavior that shows how one should feel, think, or act within a given situation. It includes think-aloud modeling, talk-aloud modeling and performance modeling. *Inviting students to contribute clues:* learners are encouraged to offer clues about how to complete the task (Roehler & Cantlon,1997).

This study aimed to analyze the scaffolding strategies that student teachers were using to teach math. More specifically, the following questions were addressed:

1. What type of scaffolding strategies do student teachers use?

2. What are the reflections of student teachers regarding the reasons for using those kinds of scaffolding strategies?

3. What are the students' reflections about the learning process?

Methodology

Participants

This research used two groups of participants. The first group consisted of fifth grade students, whereas the second consisted of senior-year student teachers. The first group consisted of 30 students attending the 5th grade of the elementary school where the student teachers were doing their teaching practice. These students were selected by initially implementing a pretest on the first unit of the 5th grade math curriculum, "Geometric Shapes". The most common errors made in this test were then identified and the 30 students who had made similar mistakes were admitted to the study group.

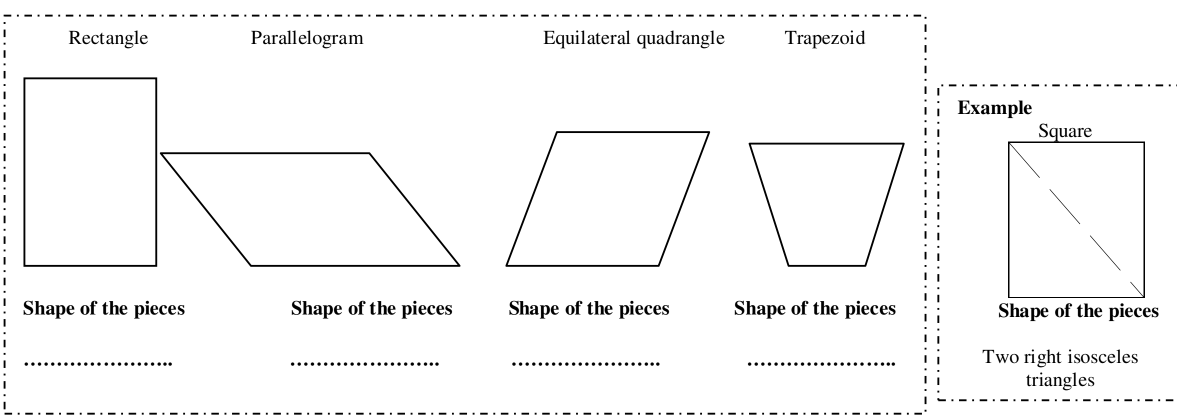
The second group consisted of 13 senior-year student teachers at Ankara University, Faculty of Educational Sciences, Department of Elementary Education, who were taking the Teaching Practice course and agreed to take part in this research. Of the student teachers, 3 were male and 10 were female.

Data Collection and Analysis

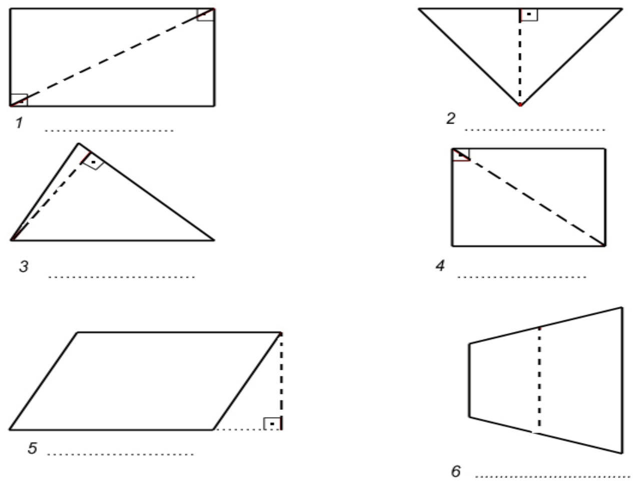
Three methods of data collection were utilized: the geometry test, an audio recording of the student teachers and student interactions, and interviews with student teachers and students.

In order to identify the students who would participate in the study, a test was prepared for the *Geometric Shapes* unit which had been previously studied. The test consisted of 17 questions. Expert opinion was obtained about the appropriateness of the questions to the students' developmental level, mathematical accuracy and the intelligibility of the language used in the questions. Accordingly, certain questions were revised and finalized in line with the views of these four experts: a math teacher, a class teacher, a math teacher educator and a Turkish language specialist. The test was piloted in a different elementary school and the answering time was set as approximately one class period (40 minutes). Several examples from the questions on the test are given below. With this test, the aim was to determine the students' current level of ability.

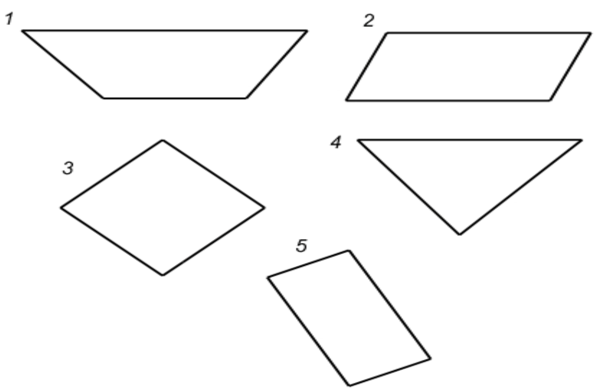
Question 6) Divide the rectangles into 2 by <u>using their diagonals,</u> as in the example. What are the geometric shapes that follow? Explain.



Question 11) Ayşe has tried to draw the height of the polygons in the figures below with dashed lines. Which of Ayşe's heights are right? Write "Right" or "Wrong" below the shapes. Correct the heights that Ayşe got wrong.



Question 18) Draw the height of the polygons given below.



Before administering the test, the students were given information about the research. It was explained that this was not a graded test and that they should leave blank those items that they did not know. The test was simultaneously administered to all 5th graders at the selected elementary school. The tests were then examined by the researchers and the questions that were most commonly answered wrongly were identified. It was found that the majority of students made mistakes in the questions about *the height of polygons*. In the test, 30 students were identified who had failed to achieve the objective "The student establishes the height of polygons" but who had answered the majority of the remaining questions about the objectives. These students were distributed among the 13 student teachers, each of whom worked one-to-one with these students. Nine student teachers worked with 2 students each, while 4 worked with 3 students each. In order to identify whether student teachers had a preferred scaffolding type, they were made to work with at least two students who had made similar errors. These one-to-one sessions with students lasted between 20 and 45 minutes.

The student teachers were also informed about the purpose of the research and were asked to examine the geometry tests of the students they were to work with before the sessions. Following this examination, the student teachers were asked to decide how they would enable the students to solve these kind of problems independently. They were not compelled to make prior preparations. They then worked one-to-one with the selected students. After the one-to-one interactions, each student teacher was asked how this process made them feel and were asked to explain why they had implemented that specific process. The interactions between student teachers and students were tape recorded, as video recording was not allowed, and notes were also taken by the researchers. These sessions were held in the school library, which was allocated for the study by the school administration.

Data were collected by the researchers between November and December, 2009. All data were transcribed by the researchers, followed by the coding and analysis of all interaction according to scaffolding types. The coding was undertaken as in the following examples:

Offering explanation:

Student: I draw a triangle like that.

Teacher: Let me help you. ABC are the diagonals of this triangle, we start from diagonals when we name these. We call it the ABC triangle, and we draw a small triangle icon on top of it. This is how we name the ABC triangle. Do you understand?

Inviting student participation;

Teacher: Brilliant. Remember, you told me you had to draw something on the outside, can you show me that inside? Inside this shape, can you show me the height? More than one height.

Student: More than one?

Teacher: Show me one.

Student: But there is no right angle here.

Verifying and clarifying student understanding:

Student: … For instance, as the top of this is at the bottom, this is the height of the trapezoid, this is the height of the rectangle, and this is the height of the triangle.

Teacher: OK, this is true. From the corner, we can only draw a perpendicular line but it must be perpendicular, as the name suggests. When showing height in the ABC triangle, we need to draw a perpendicular line from the corner to the base. What you said is correct for that trapezoid but we don't draw a perpendicular line. This is also true, this is also a height, and so is this.

Student: We can also draw it on the outside.

Modeling of desired behaviors:

Teacher: So we can draw a line from any corner of the triangle to the base, can't we? What is height, then? What you draw from the corner to the base should be perpendicular, right? For example, if I draw it like this, is this height? There can be no horizontal height. Height needs to be perpendicular, like this, is it not true?

Inviting students to contribute clues:

Teacher: How do we draw it in a trapezoid? Show me that..

Student: In a trapezoid…

Teacher: What do I need to show height?

Student: From corner to corner.

Teacher: If it is from corner to corner?

Student: It would be a diagonal.

Teacher: Yes. From a corner to the base.

Student: To the base, like this. (He draws)

Check-coding was undertaken, so each researcher coded individually. Then, each transcribed and coded interview was coded once more, with all researchers, for interrater reliability. The overall agreement of coding was 80%. According to the Miles & Huberman (1994) this rate was acceptable. Disagreements between researchers were resolved through discussion.

Findings

The results of the analysis are reported according to the research questions. The first research question was, "What type of scaffolding strategies do student teachers use?" The results of this question are given in Table 1.

Table 1 Types and frequencies of scaffolding strategies used by student teachers

Student Teacher Number	**Student number**	**1. Offering explanation (f)**	**2. Inviting student participation (f)**	**3. Verifying and clarifying student understandings (f)**	**4. Modeling of desired behaviors (f)**	**5. Inviting students to contribute clues (f)**	**Scaffolding types**
1	1	13	41	12	1	5	2,3,1,5,4
	2	7	32	13	4	7	
2	3	12	33	5	5	1	2,1,3,4,5
	4	7	41	10	5	4	
3	5	10	23	11	0	3	2,3,1,5,4
	6	7	34	8	2	2	
4	7	13	41	12	1	5	2,3,1,5,4
	8	7	32	13	4	7	
5	9	12	33	5	5	1	2,1,3,4,5
	10	7	41	10	5	4	
6	11	10	23	11	0	3	2,3,1,5,4
	12	7	34	8	2	2	
7	13	7	31	22	5	8	2,3,5,1,4
	14	5	27	20	3	9	
8	15	2	24	24	3	10	3,2,5,4,1
	16	6	16	21	7	15	
9	17	4	29	19	8	11	2,3,4,5,1
	18	4	20	10	9	5	

10	19	5	9	9	7	4	1,4,3,2,5
	20	21	22	16	24	9	
	21	31	11	17	21	4	
11	22	16	14	9	13	7	1,3,2,4,5
	23	10	12	10	4	5	
	24	18	5	12	5	7	
12	25	11	49	19	3	6	2,3,1,5,4
	26	18	60	22	7	11	
	27	14	47	10	9	10	
13	28	45	80	17	6	12	2,1,3,5,4
	29	16	65	18	2	12	
	30	19	66	28	1	12	
Total		**364 (16,9%)**	**995 (46,2%)**	**421 (19,6%)**	**171 (8%)**	**201 (9,3%)**	

An examination of Table 1 shows that the student teachers used all of the scaffolding strategies mentioned in the study when working with the students. There are similarities between the frequencies of the scaffolding strategies used. The most common scaffolding strategy used by the student teachers was *inviting student participation* (46,2%), followed by *verifying and clarifying student understanding* (19,6%), *offering explanation* (16,9%), *inviting students to contribute clues* (9,3%) and *modeling of desired behaviors* (8%).

The most common strategy of scaffolding, *inviting student participation,* is one of the most appropriate strategies for use in one-to-one work. It is natural for a student teacher who knows his/her students only by their test performance to use a scaffolding strategy that reveals students' thoughts and why they think in that way. However, the rare use of *inviting students to contribute clues* and *modeling of desired behaviors* may be attributed to the lack of math education experience on the student teachers' part. Both of these methods require a well-founded subject-area knowledge and strategic decision-making about what needs to be done in certain circumstances.

When the means of the analyses performed on the scaffolding strategies used by student teachers were taken and the commonly preferred types were compared, it was clear that five student teachers were using the same strategies (teachers 1, 3, 4, 6 and 12). Teachers 2, 5 and 13 also had similar characteristics to the group mentioned; however, they used *offering explanation* and *verifying and clarifying student understanding* more. The difference was not meaningful, though.

On the other hand, the scaffolding strategies used by student teachers 8, 9, 10 and 11 were different to the group mentioned above. While teachers 8 and 9 used the strategy of *offering explanations* the least, teachers 10 and 11 used this type of scaffolding most often. The interviews showed that these four student teachers did not do any prior preparation relating to the students' test results or decide on what to do beforehand, rather they just "went by the flow" during the process.

These four student teachers were also found to be academically behind their peers. Particularly teachers 10 and 11 had lower levels of academic achievement than the others in terms of the teaching practice course. On the other hand, the student teachers in their 7th semester of elementary teacher education undergraduate program had little or no one-to-one teaching experience with students. Therefore, it may be that the majority of the student teachers, who were for the first time working systematically with students during this study, used similar scaffolding strategies due to the emphasis placed on these in their courses. The fact that undergraduate math education is based on constructivism and adopts a learner-centered and active learning approach may have caused the student teachers to emphasize these strategies in turn.

The second research question was, "What are the student teachers' reflections on the reasons for using a particular kind of scaffolding strategy/ies?" The responses of student teachers to this question revealed that all of them used these strategies to put their students into the center of the learning environment. The quotations below show that different student teachers used these scaffolding strategies for similar reasons.

Teacher 7 explains her rationale:

"I wanted the students to see for themselves. I drew things myself but asked them to find and write down their characteristics. They got the shapes wrong in the test but right here. I also tried to relax them ... I wanted them to learn by seeing, doing and living."

Student teacher 1 stated that the instructional process should start with what the students already know, and noted:

"*I started off with what the students knew. The first thing one of them told me about height was that it's a perpendicular line going from a corner to the base. In the shapes too, it was like that. He had tried to draw height only by using this method. Of course, this is incomplete knowledge for some shapes. Sometimes height can be drawn from one side to another; so I wanted him to see that when there is an angle with the base, and no right angle, the height changes. I used real life objects to do this."*

Student teacher 10 said:

"I used the question-answer method. I started with the errors, so whatever question the student got wrong – for instance no right angle, no use of it, no mention of it – she easily saw that. She had a good understanding. She saw her own mistakes. So, it wasn't difficult for me."

The responses obtained from the same student teacher after working with a second student resulted in reasons very similar those above:

"This student was different from the previous one. He was more difficult (the student). It took him longer to understand. I even think I wasn't able to explain well, and he didn't understand well. I tried to explain in several ways. I explained by drawing the shape together (with the student), by showing it again but he forgot the previous information as we passed on to a new shape…"

This student teacher's reasons clarify why she uses the *offering explanation* strategy most frequently. The fact that the teacher said she could not explain well and that she used multiple explanations justifies the use of this type of scaffolding as a dominant strategy.

The third research question was, "What are the students' reflections on the learning process?" According to the findings, all of the students participating in this research indicated that they were very happy to be part of this process, amending their mistakes and learning new information. The research showed that, regardless of the strategy of scaffolding used, one-to-one interactions made students happy. The quotations given below show this more clearly.

Student 19, who worked with teacher 10 : *I learned the icon of height, and how to draw diagonals. I learned the pentagon, rectangle and triangle shapes. I like the way my tutor explained things. I'm happy.*

Student 2, who worked with teacher 1: *I learned new information. I found out that height is actually easy to learn if we think about it… it's really easy. If this had come up in a test, I would have answered it wrongly. It's good that I saw my mistakes.*

Student 9, who worked with teacher 5: *I learned that I had to be quick. Learning made me happy.*

Student 22, who worked with teacher 11: *I normally don't like math class. I liked it. I learned.*

The dialog between student teacher 1 and student 1 shows the feelings that the process instills in students:

- *Our session is over. What do you feel?*
- *I know more about height.*
- *How did this make you feel?*
- *It's a nice feeling. Knowing more about height and learning well made me happy.*
- *Do you feel that you understand better now?*
- *Yes…*

Conclusion

The present research aimed to analyze student teachers' scaffolding strategies that they were applying to the teaching of mathematics. In research literature on scaffolding, one-to-one interactions have been studied the least, while whole-class and small-group interactions have been investigated to a greater but similar extent (Van de Pol, Volman & Beishuizen, 2010). For this reason, the research focused on one-to-one interactions. In the one-to-one interactions between student teachers and fifth graders on the subject of identifying the height of polygons mentioned in the *geometric shapes* unit of the math class, *inviting student participation* (46,2%) was found to be the most commonly used scaffolding strategy. Lange (2002) indicated that this strategy will heighten student engagement in and ownership of the learning process.

When student teachers were asked about their reasons for using these strategies, they indicated that they used this strategy to enable students be aware of their performance, or to place them in the center of the learning process. These beliefs may be the one reason for using inviting student participation strategies more than other strategies. In fact, it may be important that this strategy be used more by teachers, although this is a point not considered here. Nevertheless, it can be clearly seen that student teachers use the one-to-one interaction process strategy intensively.

Verifying and clarifying student understanding (19,5%) and *offering explanation* (16,9%) were the less used strategies by student teachers, whereas *Inviting students to contribute clues* (9,3%), and *modeling of desired behaviors* (8%) were the least used scaffolding strategies. By inviting student participation in a one-to-one learning environment, they were able to understand explanations, which were clarified accordingly with the preferred choice of scaffolding strategy. All of these strategies require greater mathematical knowledge as well as pedagocial mathematics knowledge.

While the majority of student teachers had a similar tendency, others had different inclinations. Neverthless, the reasons for preferring and using these scaffolding strategies were not clear. All of the student teachers stated that they used a certain scaffolding strategy to center the work around their students. Regardless of the type of scaffolding used, all students who participated in this research said that they were satisfied with this process. According to Dennen (2004), scaffolding affects learners both cognitively and emotionally, impacting not just learner skill and knowledge, but also learner motivation and confidence when approaching a task (p. 815). Bean & Patel Stevens

(2002) stated that scaffolding helps students keep from getting mired in feelings of failure through the various supports that are focused on learner success (in Denen, 2004).

Lange (2002)also stated, scaffolding is helpful to failing children, both in terms of their cognitive development and in terms of self-efficacy and self-esteem: this result seems to support this notion. In this study, these features were not measured directly, but it can be understood from the students' opinions. Indeed, the students declared that their motivations were increased and they felt better about the process. As McKenzie (1999) notes, scaffolding delivers efficiency and, if done well, a scaffolded lesson should be efficient. Scaffolding provides the opportunity for students to develop their independence, sense-making and self-confidence, whilst working mathematically (Williams, 2008).

These results indicate that student teachers should think more carefully about the instructional process and that they were not able to offer a comprehensive rationale regarding their preferences. Therefore, throughout their undergraduate education, student teachers should ought to be equipped with direct teaching experience, particularly via teaching practice classes, and these experiences should be analyzed and interpreted together. Such actions would help to develop a more solid construction of awareness.

The present study has been conducted with a small group of participants. It is therefore important that it is replicated within similar sample groups so that results can be verified. As with this study, future studies might work towards identifying the types of scaffolding strategies used in the teaching of the math course both by practicing teachers and student teachers in whole class, small group and one-to-one environments. One recommendation may be that similar studies are conducted for different courses, and that comparative studies are conducted regarding the types of scaffolding used by practicing and student teachers. In this research, follow up study for students and the study of determination of efficiancy of scaffolding could not be conducted. Future studies may focus on determining the effectiveness of the scaffolding process. On the other hand, no criteria were used about the selection of student teachers, although in further studies, the selection of student teachers might be made according to their beliefs about teaching and learning, their academic achievement, or their department, for example, and the research may focus on the determinitation of the relationship between these varibales and the types of scaffolding which they have used.

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