Patterns of Scaffolds in One-to-One Mathematics Teaching: An Analysis

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ABSTRACT

Educators have been talking much about constructivism as the learning theory for mathematics education since the last quarter of the last century but the practice in teaching of mathematics in Pakistan is still the traditional content teaching approach. Scaffolding was formulated from Vygotsky's concept of the zone of proximal development. It emphasizes active participation or a greater degree of control from students over their learning. Application of scaffolding in one-to-one or small group teaching of mathematics is easier than the large group teaching. The purpose of this paper is to explore and improve the prototypes of scaffolds in one-to-one mathematics teaching that may help to enhance classroom teaching especially for slow learners, in the mathematics classes.

The results indicate that generally teachers provide ready-made solutions of the problems to students by traditional lecture method that ultimately produces a trend of memorizing the rigid methods to solve a problem and do not encourage them any independent venture. Teachers need to change their role in the classroom from the sole source of mathematical knowledge to facilitators in the development of students' mathematical constructions, while employing scaffolding.

Keywords: Scaffolds, Zone of proximal Development (ZPD), Zone of actual Development (ZAD), Conceptual understanding, Cognitive memory, Self-efficacy

INTRODUCTION

Mathematics is taught mostly by lecture method in our schools within a very strict framework of procedural knowledge followed by rigorous practice of the mathematical problems. The memorization of formulae, learning of the methods/procedures to apply these formulae in solving the sums and doing the repetition of these sums is a taken as a teaching of mathematics. Mostly students try to memorize whole working of the sum like other subjects where rote memorization is quite common. System of examination, completion of syllabus in a restricted time and other issues might be the hurdles but many teachers use different methods to foster the learning in their classes within their capacity. The effectiveness of these innovations in pedagogies should be checked and improved through research. Self-reflections of the teachers in this regard are an important tool for check and balance and further improvement.

A considerable amount of research on teaching and learning mathematical problem solving has been conducted during the past 40 years. In 1990s a theory of learning called constructivism emerged (Kilpatrick, 1987; Glasersfeld, 1990; Ernest, 1991; Bettencourt, 1993; Cobb, 1994; Steffe & Kieren, 1994). Wood, Bruner and Ross (1976) introduced the word scaffolding for the first time but Vygotsky's school of thought probably has the most profound influence on the formation of the concept of scaffolding in the cognitive development of a child (Greenfield, 1984, Rogoff & Gardner, 1984, Stone, 1993). Vygotsky conceptualizes the idea of the zone of proximal development. He says that a child can study

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any subject if instructed within his zone of proximal development. In Vygotsky's words, "what the child is able to do in collaboration today he will be able to do independently tomorrow" (Vygotsky, 1987, p. 211). This difference between the two levels is the child's 'Zone of Proximal Development' (Ellis & Worthington, 1994). The scaffolds are temporary frameworks, provided by experts for novices as an assistance to complete a task but without affecting the difficulty level of the task (Cadzen, 1983; Lehr, 1985; Remond, 2000).

A scaffold is a tool to provide support in order to extends the range of a worker or to accomplish the task not otherwise possible or to aid the worker in selectivity where needed (Greenfield, 1984, p. 118).The scaffolds provided during the course of instruction in the form of verbal conversation, clues, signals, remarks etc. are termed as soft or contingent scaffolds while he scaffolds that are pre-planned to be used at different stages during the solution of problem are called hard or embedded scaffolds (Van Lier, 1996 ; Saye & Brush, 2002; Simon & Klein, 2007).

Teaching of mathematic is generally taken as the explanation of a number of sums by lecture method and giving some more sums from the text books for further practice. Students being taught in this way mostly try to memorize the complete procedure/working of the sums along with formulae. The existing practice doesn't discourage the students from cramming in mathematics which is complete denial of the objectives and goals of teaching mathematics to the students.

The study deals with an in depth investigation and explanation of the factors involved in mathematics class, where the teacher researcher has attempted to apply the phenomenon of scaffolding as an instructional strategy, in the teaching of mathematics. He conducted and participated in an action research study in order to explore the general style of scaffolding in his mathematics class. The research will help to identify major shortcomings and guide to improve teaching methodology especially in small group teaching of mathematics.

RESEARCH METHODOLOGY

The study adopted mixed method approach in an action research setting with the focus specifically on the following factors:

1. The number of scaffold used by the teacher in the class and the time (during explanation/during student's working on the given problems/end of the lesson) of their application.
2. Types of the scaffolds used
3. Area of cognitive domain targeted by the application of these scaffolds.

The researcher was himself a participant of the research being a mathematics teacher. Three groups of students participated in the study. These groups were named as class-A, class-B and class-C. Each class consisted of an average of five students having a fair representation of both genders. The students belonged to different private schools of GCE system and the classes were small group (one-to-one) in nature. The duration of each class was 60 minutes. The study was conducted in five phases.

Phase I: In the first phase the teacher-researcher has identified his areas of specifications;

1. Frequency and timings of the scaffolds.
2. Nature of scaffolds
3. Area of cognitive domain targeted.

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Phase II: The teacher-researcher has formulated the following self-questions that would guide his action research project.

Do I provide only necessary scaffolds?

Do I provide different levels and types of scaffolds?

Do I provide scaffolds on proper time?

Do I provide proper time to solve the given problems?

Do I respond to their queries patiently?

Do I help them to think independently?

Do I instruct them within their zone of actual development (ZAD)?

Do I provide them problems that help to construct knowledge?

Phase III: In phase III the teacher-researcher undertook an audio-video recording of the activities of his three routine classes. In class A, the topic was (matrices), in class B, topic was (vectors) and in class C the topic of (probability) was taught.

Phase IV: In phase IV the same lessons were taught through revised plan.

Phase V: In phase V the lessons taught through the draft plan and the revised plan were presented on tabulation sheet and results were compared by graphical method.

The process is illustrated below:

Cycle 1

Plan: My students believe that mathematics means to learn the formulae and the methods/procedures of solving mathematical problems and applying this knowledge whenever and wherever required. How can I change this pattern of thinking? I can change the instructional strategy of my teaching. Change in instructional method instead of providing direct solution of the problems by lecture method, learning will be enhanced by providing improved and well organized scaffolds to the students andlet them solve problems by themselves.

Action: Providing scaffolds to the students at three stages (prior to getting started, during the working on problems and at the end of solution of the problems). Let the students work, lessons will be recorded.

Observe: Recording of three lessons shows inconsistent and unnecessary and out of time provision of scaffolds.

Reflect: My enquiry suggests having a more structured, only necessary and on time provision of scaffolds.

Cycle 2

***Revised Plan*:** Continuation of general plan with improvement in structure and timings of the provision scaffolds.

***Action*:** I would provide well organized and well-timed scaffolding.

***Observe*:** Recordings show a better organization and implementation of scaffolding technique as an instructional strategy.

***Reflect*:** In the next class I will keep this habit on with more innovations.

THE DRAFT PLAN (ANALYSIS)

The draft plan analysis has been divided into three main categories: frequency and timings of the scaffolds, nature of scaffolds, and area of cognitive level elicited. The outcomes have been presented in tabular and graphical forms as well as in descriptive form in the upcoming discussion.

Table 1. Frequency and Timings of the Scaffolds

	Class A	*Class B*	*Class C*
N.S(E)	3	4	5
N.S(G)	2	2	2
N.C(E)	3	3	3
N.SCFD(B.S.P)	7	6	9
N.SCFD(W.O.P)	5	4	4
N.SCFD(E.O.P)	2	3	1
T.N.SCFD	14	13	14

Key:

N.S (E): Number of sums explained.

N.S (G): Number of sums given

N.C (E): Number of Concepts explained.

T.N.SCFD: Number of scaffolds.

N.SCFD (B.S.P): Number of scaffolds before starting the problems.

N.SCFD (W.O.P): Number of scaffolds working on the problems.

N.SCFD (E.O.P): Number of scaffolds at the end of the problems.

Table 1 shows that in case of class C most of the information has been directly passed during the explanation and this class was explained 5 questions in advance. This class posed least queries during working independently on the given problems. While for class A where least number of sums were explained during the lecture presented more queries during working in the given sums. Class B with an average number of sums explained and even least T.N.SCFD worked better independently on the given problems.

Table 2. Nature of Scaffolds

	Number of Scaffolds Used Class Wise			
	Class A	*Class B*	*Class C*	*Total*
F.KNLWDG	4	3	5	12
P.KNLWDG	3	2	4	9
TIPS(A.COMP.ERR)	3	3	2	8
TIPS(A.COMMN.ERR)	3	1	2	6

Key:

F.KNWLDG: Factual knowledge,

P.KNWLDG: Procedural knowledge.

TIPS (A.COMP.ERR): Tips to avoid computation errors.

TIPS (A.COMMN.ERR): Tips to avoid common errors.

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Table 3. Educational Domain Targeted

	Number of Scaffolds Used Class Wise			
	Class A	*Class B*	*Class C*	*Total*
Cognitive Memory	3	2	4	9
Conceptual Understanding	2	2	2	6
Mathematical Communication	2	1	2	5
Application of Mathematical Concepts	4	3	4	11
Mathematical Accuracy	2	1	1	4

THE REVISED PLAN

The recordings of the draft plan of each class were carefully examined by the teacher-researcher and revised plan was constructed very carefully keeping in view the previous shortcomings. The important reflections of the draft plan were: (i) Excessive support provided during explanation. (ii) Incorrect timings for the provision of support (scaffolds). (iii) Non-systematic Scaffolding. (iv) Answering the questions before they arose in the minds of students.

Table 4. Frequency and Timings of the Scaffolds

	Class A	*Class B*	*Class C*
N.S(E)	4	2	3
N.S(G)	3	3	3
N.C(E)	2	2	2
N.SCFD(B.S.P)	3	3	4
N.SCFD(W.O.P)	7	8	7
N.SCFD(E.O.P)	2	3	2
T.N.SCFD	12	14	13

Table 4 illustrates that during the revised plan the scaffolds were relatively less in frequency and well organized and were well-timed. The teacher-researcher embedded three types of hard scaffolds this time: conceptual scaffolds, specific strategic scaffolds, and procedural scaffolds. The conceptual scaffolds assisted the students in organizing their ideas and connecting them to related information. The specific strategic scaffolds were included to help the students ask more specific questions and the procedural scaffolds were useful to clarify specific tasks such as presentations.

Table 5. Nature of Scaffolds

	Number of Scaffolds Used Class Wise			
	Class A	*Class B*	*Class C*	*Total*
Procedural	3	3	3	9
Process	3	2	4	9
Strategic	3	3	2	8
Interpersonal	3	1	3	7
Conceptual	5	3	6	14

Table 5 shows that in the revised plan the teacher-researcher used different scaffolds and consciously selected those scaffolds that target the higher level thinking skills of the cognition. During the explanation of concepts this time researcher selected fewer problems as compared to the draft plan. Relatively less number of concepts was explained and then students were given problems on the same concepts to solve independently. Students raised higher order queries this time and constructed knowledge through active participation in the learning activities.

Table 6. Educational Domain Targeted

	Number of Scaffolds Used Class Wise			
	Class A	*Class B*	*Class C*	*Total*
Cognitive Memory	3	3	4	9
Conceptual understanding	2	2	2	6
Mathematical communication	2	1	2	5
Application of mathematical concepts	4	3	4	11
Mathematical accuracy	2	1	1	4
Self-efficacy	2	3	2	7

Table 7. Summary of Findings

Scaffolds	*Initial Plan*	*Revised Plan*
Nature	Procedures, Tips to avoid mistakes, shortcuts	Procedures, Strategies, signals, Clues and questions
Frequency	Surplus	Essential
Timing	Any time	On demand or necessity
Educational Domain	Factual knowledge, Procedural Knowledge and its application in computation accurately	Conceptual Understanding, application of problem solving skills and mathematical accuracy

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CONCLUSION AND RECOMMENDATIONS

The results of study indicates that the frequency of scaffolds decreased after the revised plan which means that during these classes students worked more confidently. Moreover the timing and nature of scaffolds after the revised plan also show a deviation from the initial plan. The results illustrate that scaffolding is a successful teaching strategy that can enhance learning in mathematics and help implementing constructivist's approach of teaching mathematics in the classrooms. It helps in building concrete mathematical concepts and higher order thinking skills. It is very helpful in boosting the confidence level of low achievers in mathematics. However, five critical features need to be addressed for successful scaffolding. These are:

(1) Scaffolds should cover a variety of educational domain, (2) The number and frequency of the scaffolds should be taken into consideration, (3) teachers' should continuously assess students' understanding, (4) Scaffolds should not be provided before the arousal of questions in the minds of students, (5) teachers take into consideration students' perspectives. Finally, teachers need to re-conceptualize their role as facilitators in the development of the students' mathematical constructions rather than the sole source of mathematical knowledge while employing scaffolding in the classrooms.

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