The Application of Scaffolding in Junior School Teaching
-- Taking a Math Class as an Example

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Abstract. The scaffolding strategy is very important and widely applied in practical teaching. The correct application of scaffolding can assist students to enter their zone of proximal development and achieve personal development. This research analyzes the scaffoldings used by the teacher in a specific math class, which is the multiplying and factoring of polynomial expressions. The teaching framework is reasonable, and the difficulty is progressive. Students can develop from the existing knowledge, comprehend the multiplying and factoring polynomial expression and apply the knowledge finally. However, there are no examples close to students' life and experience, which is concise and clear but decreases their learning agency perhaps at the same time. During the teaching process, teachers encourage students to think creatively and guide students to understand error-prone points by asking questions continually.

Keywords: ZPD; Scaffolding; Case analysis; Polynomial expression.

1. Introduction

As the development of society, more and more people pay attention to education. No matter in the east or the west, mathematics is a core component in children’s school teaching, as it plays an important role in improvement and development of students’ ability in mathematical abstraction, logical reasoning, mathematical modeling, visual imagination, mathematical operation, and data analysis. However, as mathematics is sometimes abstract and obscure, it is crucial for mathematical teachers to have a deep though in class structure and preparation, pondering problems from the perspective of students, contingently response and adapt explanation, starting from the existing knowledge and experience, and connecting to the reality of life. Hence, how to structure a mathematical class and utilize tools in the classroom to decrease the difficulty of comprehension is an issue requiring careful consideration.

To help students to grasp knowledge as firmly as possible and develop students as autonomous self-propelled learners, teachers should create a mild learning environment, improve students’ interest, and provide guidance. Teaching should not be indoctrination, as it is immoral and insignificant [2, 4], but target for discovery. Discovery learning increases the intellectual potency, studying agency, the heuristics of discovering and memory. Students are learning for understanding and constructor structured and integrated knowledge framework, but not fragmentary and one-sided, since the ability of constructing the meaning of knowledge decides the amount of knowledge obtained from teachers.

In 1978, Vygotsky put forward the concept, the zone of proximal development (ZPD). It is the distance between the actual developmental level and the level of potential development, while the former is determined by independent problem-solving ability and the latter is depended on the level with adults or peers’ guidance or collaboration. ZPD is a dynamic area, requiring guidance of instructors or collaboration with peers. Based on specific situation and different ZPD diagrams, teachers provide appropriate support and guide students to master, construct and internalize knowledge that is consistent with their own age and cognitive level, and control those parts that are beyond the existing ability of learners. ZPD emphasizes that teaching should be ahead of development.

Based on ZPD, Jerome Bruner proposed scaffolding, and lots of constructivists develop the concept and make it concrete [1,7,8]. The word "scaffold" comes from the construction industry, which is a working platform set up to ensure the smooth progress of each construction process. In education, “scaffolding” and “scaffold” are used as the same, which is a systematic and orderly
teaching mode based on students’ current development level and guide them to actively construct knowledge and enter ZPD by using a variety of methods. There are 6 basic functions of scaffolding: simplifying tasks, maintaining goals, attracting attention, determining the gap between tasks and students’ ability, controlling learning difficulties and implementing rational behavior. It is a collective term of tools, strategies and materials which are used to move students progressively toward stronger understanding and greater independence in the learning process.

Scaffolding strategy intends to decompose learning objectives to decrease the learning difficulty as well as the cost of learning. It plays an important role in promoting children's cognitive development, improving learning ability and mastering problem-solving strategies, as scaffolding is not indoctrination teaching, but a strategy respecting the dominant role of learners, which can arouse students’ learning agency. Scaffolding supported by adults are dynamic, receding, purposing to reduce the learning frustration and increase interest [7, 10]. The students stand at the center, while instructors should stimulate their initiative, enthusiasm and creativity with proper environment and assistance, so that interaction appears between students and environment with adults’ encouragement.

There is no unified classification of scaffoldings. For examples, scaffolding can be divided into interactive scaffolding and instructional scaffolding. Scollon claims that scaffolding can be classified as vertical construction and sequential structure. Similarly, there is no unified process of scaffolding. However, scaffolding must include three stages: beginning, development and end [1,7,10]. Diagnosis is the initial stage, which is aiming to define learners’ ZPD. All guidance and teaching should be constantly adjusted based on students’ ability and within ZPD. Finally, instructors should handover to independence and evacuate scaffolding.

Although scaffolding is wildly used in teaching practice, it is noticed that there is a gap of the research of the scaffolding application in mathematical class. Based on the Piaget’s theory of cognitive development, the 12 to 15 years-old students are at the formal operational stage. Students struggle with abstract concepts and hypothetical reasoning without concrete event. It is improper to adopt too many orders and compulsory education, but encouragement and guidance, as well as suggestions and improvements, which is in accordance with the principle of scaffolding strategy. Hence, this article intends to focus on a specific mathematical class in junior high school and analyze the scaffolding the teacher utilized, the efficiency of the strategy and provide suggestions for a class with a higher quality.

2. The background information of the class

A polynomial is formed from constants, which is called a coefficient, and terms. Generally, it is a basic concept, and it is a foundation of subsequent learning of algebra knowledge. For example, functions, calculus, and equation. In different countries, the studying of multiplying and factoring polynomial expressions is arranged in different grades. In the US, it is an eighth-grade course, but it is learned in seventh grade in China. However, it is a junior high school class in general.

2.1 Prerequisite for students

Before studying multiplying and factoring polynomial expressions, students already have mastered numbers in letters. Students must be familiar with expressions in the alphabet, as this lesson is formed and constructed by letters and numbers. Besides, as the area of a rectangle is utilized as an aid, the calculation of rectangular area is also a vital part. Students learned the calculation formula for rectangle, i.e., rectangle area is equal to length by width, in primary school and most of them skillfully grasp the calculation formula as it is practiced repeatedly. Moreover, the law of distribution is an integral part at the same time. As the meaning of the polynomial expression is comprehended with the aid of a split of the rectangular area, to understand equality from the perspective of algebra, distributive law is necessary. Finally, merging similar terms and simplifying polynomials are required. Students must know what is polynomial and the addition and subtraction of polynomial expressions.
2.2 Teaching objectives

There are four main teaching objectives in this lesson. In knowledge learning, the most important goal is understanding the meanings of polynomial expressions and mastering the methods of multiplying and factoring polynomial expressions with the assistance of rectangle area. Secondly, utilizing the knowledge of multiplying and factoring polynomial expressions and solving practical problems, and realizing the relationship between polynomials and real life. Finally, in terms of students' skills, encouraging students to find a variety of solutions to the same question, is expected to increase the ability of creative thinking and problem-solving ability, becoming creative learners but not passive learners.

2.3 Student analysis

Students at each stage have their own unique physical and mental development characteristics. Students' cognitive development has a tremendous influence on knowledge understanding. Similarly, each subject has its uniqueness, which puts forward requirements for students' cognitive abilities in different aspects. Piaget's cognitive development stage theory points out that students in the formal operational stage have abstract thinking and can make hypothetical deductive reasoning. In mathematical class, it signifies that students rely less on intuitive teaching compared with primary school students. Factual and symbolic are two characteristics of middle school students while generalizing patterns. Hence, it is suggested to use concrete materials, like learning with graphs, to enhance and deepen students’ understanding and reduce forced memory of formulas and rules in mathematical class.

2.4 Difficulties

Polynomial expressions are abstract for middle school students, as there are letters in expression. Middle school students, although they enter the formal operational stage, they are at the beginning of this stage. Students cannot master abstract operations adroitly. The expression of polynomials plays a connecting role in the process of mathematics learning. It is built on the knowledge learned in primary school and lays a foundation for subsequent learning. For instance, it involves the law of distribution, the law of commutation, the law of association, and the addition, subtraction, and multiplication of letters. If the students cannot master the knowledge and ability well, it leads to frustration and weak confidence. The learning of multiplying and factoring polynomial expression requires higher calculational ability, which is an error-prone part and conceptual confusion. Students' knowledge reserve is insufficient, understanding of mathematical knowledge is unclear, students' metacognition is not strong, students' choice of factor decomposition method is improper, students lack mathematical learning motivation, are parts of the reasons for the errors.

3. Scaffolding analysis

Multiple scaffoldings are utilized in this class. The teacher constructors the class with strong logic and use strategies to assist students comprehend the meaning of polynomial expression. From simple to complex, promote students' understanding gradually and smoothly. To make analysis more logical, the scaffoldings are analyzed from two categories, interactive scaffolding, which works through interpersonal communication, and instructional scaffolding, which can be defined as tools used in class, that assisting students’ comprehension.

3.1 Teaching framework

![Figure 1. Teaching Framework](image-url)
The teaching process of this lesson is clear. In general, the class can be divided into four parts. The first part is review and introduction. The teacher asks 2 questions and builds a bridge between the known and the unknow. Based on the students' existing knowledge, i.e., communicative law and distributive law, the teacher puts forward a calculation problem, and encourages students to find out different calculation methods. $12 \times 15 = ?$ After a short time thinking and calculation, students answer this question quickly and correctly.

INS: instructor  STU: students  ST1: student1
INS: What do you _all_ think the answer is.  
(3.0)
ST1: One eighty?
INS: Do you need- look it _again:_? Call it out to me that’s what I'm saying.  
(1.0)
STU: One eighty?
INS: One eighty?  
(3.0)
INS: ^All right, one eighty. Does _anyone_ think it’s something ^other than one eighty::? (0.8) No? (0.5) All right.
INS: So:, how about, a _way_ = to so_1ve this::?

INS: instructor  ST1: student1  ST2: student2  ST3: student3
INS: ST1, what'd you come up with. 
ST1: Um::, I _know_ that twelve times twelve::, is a hundred and forty-^four.  
(0.8)
ST1: So then::: I::: Three plus= twelve is fif^teen, so I a^dded three times ^twelve which is thirty^-^six: to one hundred and forty^-^four.

INS: St2, what'd you come up with. 
ST2: Um::: Twelve times ^ten::, is one: hun- and twen^ty.  
(2.8)
ST2: An’ you hav’ to have the extra ^five:: from the fif^teen::.
ST2: So twelve times fiv-=, twelve times fi::ve is sixty, and I add tho:se, um: the one twenty (to it).

INS: ST3 what do you _get_ for me. 
ST3: Um::, I did _fifteen_ times ^three, which was forty^-^five.  
(0.8)
INS: You did fifteen times _three_? Whoopsie that color will _not_ show ^up.  
(1.8)
INS: Fifteen times ^three which is forty^-^five.
ST3: And then, I multiplie like, (the forty-five by ^four).(.)
INS: And you multiplie your forty-five::, by _four_.
ST3: Which was::, one hundred and eighty.
From the dialogue, even though the teacher asks three times, students are confident in their answers. Then, the teacher asks for the calculation method. Three students showed their solution methods differently. Even though students use different strategies, they adopt the same calculation law, distributive law. This is basic and known knowledge, which is essential in this class. Hence, it can be inferred that students are familiar with the calculation and master multiplication of two digits and two digits well. Hence, the teacher asks a more difficult question. 

\[0.5 \times 16 \times \left(\frac{3}{4}\right) = ?\]

After a short discussion and calculation, students answer the question in a different way, which is the same as the first question. From the conversations, it is clear that students are familiar with the calculation, even though they cannot figure out the answer skillfully and quickly. Since the calculation is not the main goal of this class, the calculational strategy is the core of the formula. Moreover, both two questions are set up for revision and show less connection with the next part, which is the key point of this class, knowledge explanation. It is advised to modify the question and enhance the connection between numbers and letters.

(1) Question 1

Write an expression of the area of these figures.

![Figure 2. Question 1](image)

(2) Question 2

\[3a^2 + 3a \text{ square units}\]

Figure 3. Question 2

For the polynomial expression, the teacher adopts two questions and instructs multiplying and factoring respectively. The first question is: write an expression of the area of these figures. Through the formula of the rectangle area, students understand how to multiply polynomial expressions. Similarly, the teacher shows a polynomial expression and asks students to factor it and enhance their understanding. Both questions are expressed by letters, which causes barriers to understanding. To provide scaffoldings and assist students to enter their ZPD, it is considered to use a question and connect the numbers and letters. After students finish the calculation of \(12 \times 15 = ?\), the teacher can add a short question: what do you think the formula, \(12 \times (10 + 5) =\), means? The question is simple, and just cost several minutes, but it builds a bridge between the known knowledge and the teaching target of this class, as it is the same question and turns numbers into letters only. Similar questions are more likely to trigger students' associations and use the same method or strategy to solve the problem. In general, it is a scaffolding decreasing the difficulty by starting with students' known knowledge and using the same methods and strategies to solve new problems.
3.2 Case background

For question 1 and question 2, the teacher asks the question in a direct way. The questions are clear and straightforward, but without any background information. They are pure mathematical questions, which seem irrelevant to real life. For students in grade 8, it is still important to select questions from experience, as it is beneficial for understanding and arousing interest. Pure mathematical questions are abstract and indigestible for junior high school students. Free students from extrinsic motive, such as the immediate control of environmental rewards and punishments, is important to lead them to effective cognitive activity. It is a core part in discovery learning. When students actively and spontaneously want to learn, showing learning expectation, the efficiency of learning can be improved, and meaningful learning can be promoted. Hence, it is considerable to improve the way to ask question. The teacher can set a context for the question from the student's real life. By making students experience the application of polynomials, as well as the connection between mathematics and practice, students' learning interest and agency can be stimulated.

3.3 Verbal guidance

In knowledge imparting and practical teaching, it is inevitable to transfer knowledge through verbal information and communication, no matter in large-scale classes or small-scale classes teaching. Teachers' words occupy most of time in class. By understanding teachers' language and receiving teachers' guidance, students modify or enlarge existing schema through the assimilation and accommodation, and finally achieve equilibrium. This is the cognitive development of students in class. Hence, teachers' ability to guide students to comprehend knowledge is one of the criteria to judge teachers' teaching ability. A quality class should contain clear structure and well-designed language, which is the target of teaching preparation. However, effective and efficient guidance establishes on the teacher's knowledge of the students, including the characteristics, cognitive development, and savvy etc. It requires long-term communication, and deepen understanding and forming tacit understanding in the process.

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INS: instructor    STU: all student    ST4: student 4
INS: And=, can you convince me, (1.2) that the area of the blue rectangle really is:::, two z squared?
INS: Or what would you, try to tell me= if you were to convince me.
STU: Well, z times z= is, z squared. (4.8)
INS: Mm-hmm. (1.0)
STU: And then there's a two (z).
INS: And then there's a two?
STU: Yeah. So::, (like:), two sets of them.
INS: Oh, two sets: of them.
INS: Is that something you could= draw::, to help me see that?
STU: Sqaures. (3.0)
INS: How many z squares would I end up with over here. Two::.
INS: What shape: would my z squares be?
STU: Squares.
INS: Why::?:
STU: Cause it's (.)
INS: Cause it's why::?:
STU: Well=
INS: Who think=. What do you think?
STU: Because, um:::, you're multiplying z by z so it's the same length.
INS: Okay, we'll find the same::: length, by the same::: width, so it's the same value, same value, so you're gonna get a what shape?
STU: Square.
Students are always confused about $z + z = 2z$ and $z(z) = z^2$ since they are similar. The teacher enhances the understanding of these formulas by repeatedly asking “why”. By combining the figures, students understand that $2z(z) = 2z^2$ calculates the area of the blue rectangle. A student divides the rectangle into two small rectangles. Since the length and width of the small rectangles are the same, they are two squares. The area of the two squares is $z^2$ respectively and the sum of them should be $2z^2$.

![Figure 4. Teaching Process](image)

4. Conclusions

The scaffolding strategy is a teaching strategy widely used in teaching. Teachers help students understand knowledge through their language and teaching tools. The main purpose is to help students enter their ZPD, which is the area cannot get into without the assistance of instructors or the cooperation of peers. However, there is a gap in the research on the application of scaffolding strategies in specific mathematics classes. Therefore, the main purpose of this study is to try to analyze the application of scaffolding strategy in a specific math class and provide suggestions for math teachers’ lesson preparation. The study selected a middle school mathematics class for analysis, focusing on the application of scaffolding strategy. Because the teaching content of this lesson is the expression of polynomials, which belongs to the algebra plate, instructional scaffoldings are not core parts. Therefore, this research focuses on the application of interactive scaffoldings.

This lesson is mainly divided into four parts, which are review, polynomial multiplication, polynomial factorization, and its application, which is clear and progressive. Build a bridge between the known and the unknown by starting from what students already know, that is, by multiplying two-digit numbers. The level of difficulty is progressive, allowing students to understand multiplying and factoring polynomial expressions in depth. In this lesson, however, the teacher selects to teach in a purely mathematical way. Junior high school students aged 12-15 years old, who have just entered the stage of formal operation, still need to deepen their understanding of knowledge and improve their interest in mathematical learning with the assistance of concrete examples. The purely theoretical class will make students feel tired and bored, and easy to be distracted, which is not conducive to the
improvement of classroom efficiency. Therefore, it is considered to put the problems into the background which is close to students' real life to help students understand the meaning and purpose of learning the multiplying and factoring polynomials.

Although lots of scaffoldings are used in this class, due to the limitation of data, it is impossible to further analyze the learning effect and feedback of students. Whether students have mastered knowledge in class, whether they can enter the ZPD with the help of the scaffoldings provided by the teacher and obtain personal development is the key point to test the effectiveness of scaffoldings. It is not clear whether the teacher removes the scaffoldings successfully and whether students acquire the ability to apply knowledge. Therefore, the effectiveness and optimization of the scaffoldings used in this lesson deserve further research and analysis.

References


