The ZPD Perspective on Teachers' Question-Answer Strategies In Mathematics Classroom

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Abstract. As teaching methods continue to change, the ability of students to think and solve problems autonomously has become one of the main focuses of teaching, and therefore teachers' question answering strategies have become essential. Many researchers have raised the importance of the zone of proximal development theory in question answer strategies, but few have summarized the specific type of question-answer strategies need to be used in different scenarios. For this reason, this paper will research on teacher question-answer strategies in mathematics classrooms from the perspective of ZPD. A case study was conducted based on two videos of mathematics class, and qualitative analysis was conducted through conversation analysis transcript. Research shows that the selection of question-answer strategies is related to identifying the zone of proximal development of students. If students' questions are in their ZPD, then teacher will allow learners to explore the solution on their own and will follow up by asking more questions to students. On the other hand, answers should be provided directly for removing meaningless barriers that restricts discovery. Having different question-answer strategies is to balance learners' cost of learning in the discovery process. This will enhance students to be autonomous learners by reaching achievable learning goals at potential developmental levels.

Keywords: Zone of Proximal Development; Question-Answer Strategies; Scaffolding.

1. Introduction

In the current era, the methods and thinking of teaching have changed greatly, which also promotes teachers to change their teaching methods according to the needs of students. Then through the learning process, students should be able to raise questions, analyse problems, solve problems, communicate with others, and reflect. Many teachers are beginning to realize that in their teaching, students are the main body of the classroom. They pay attention to cultivating students' question consciousness, giving full play to students' ability to ask questions, and developing students' thinking and creativity. Put the main body of the classroom on the students, cultivate the students' awareness and ability of problem-solving skills, and stimulate the students' learning fun.

To develop students 'ability in a better way, effective teaching strategies are thought essential for teachers' instruction. Researchers put forward various teaching methods to promote students' understanding of learning content. For example, adopting a communicative teaching method is beneficial for motivating students in the learning process [1]. Meanwhile, teachers work with inclusive teaching strategies to develop an inclusive learning environment [2]. The subject is a key element that should be considered in designing teaching methods. There is a surging interest in Mathematical teaching strategies, which aim to cultivate critical thinking and metacognition [3]. However, limited research has occurred on the question-answer method used by Mathematics teachers. When students ask questions in math class, it's important that what question-answer strategy teachers apply to guide learners. Scholars adopt the major principles of the Cooperative Principle and

Politeness Principle to develop effective teaching methods in the question-answer process. In this way, students are willing to express themselves and build a positive teacher-student relationship [4]. Students can perform better in test scores, correct answers, and on-task behavior when teachers respond appropriately [5]. Effective theories to analyse and decide on teaching strategies are significant in discovering effective teaching strategies.

The Zone of Proximal Development (ZPD), a theory developed by Vygotsky, is effective in analyzing teaching strategy. According to Vygotsky, when we try to understand the degree of children's development, we must focus not only on the functions that children have already matured, but also on the functions that they are developing. The interval between the problems that children can already solve and the problems that children can solve after adult guidance or even autonomous activities is defined as the Zone of Proximal Development [6]. Although scholars after Vygotsky, including Bruner, Wells and Mercer have different understandings of this theory, one thing is certain: the ZPD theory will inevitably lead to a revolution in classroom transformation. In the old classroom, the teachers were the centre of education: the teachers set the goals to be learned, and then observed whether the students achieved them. The way students achieved such goals was to memorize the knowledge. With the introduction of the ZPD theory, however, the teachers' tasks were changed. They should design the "scaffolding" of group activities for the students to construct their own knowledge. In this way, the teachers become participants rather than leaders in educational activities, helping students to construct their own knowledge through dialogue and communication [7].

To guide students to enter the ZPD, Vygotsky put forward the idea of scaffolding, which refers

to the assistance instructors provide to help students [6]. Researchers found out the effectiveness of contingency, an aspect of scaffolding in student teacher interaction, but didn't address how could teacher diagnose students' understanding [8]; On the other hand, some researchers scrutinized the three general concepts of scaffolding, whereas the problem of measurement still exists [9]. Classroom dialogue and interaction in teaching is a key component of the teaching process carried out by teachers, not only to provide student participation but also to build a good teacher-student relationship. Those two papers show the deficiency of ZPD research, hard to measure the effectiveness of scaffolding, and to classify the question-answer strategy under different scenarios. This paper is aiming to analyze teachers' question-answer strategy from a ZPD perspective and classify the most efficient question-answer strategy to use under different conditions. Teachers need to choose the appropriate strategies to effectively help students reach the potential level, encourage them to become autonomous learners, and stimulate their desire to explore and motivate them to learn.

Based on the above discussion, scaffolding is vital to lead students to enter the ZPD. However, studies about scaffolding related to the question-answer strategy in the mathematics classroom are limited. Therefore, this paper focuses on teacher question-answer strategies in mathematics classrooms from the perspective of the Zone of Proximal development.

According to the literatures above, it can be acknowledged that the issue about teachers' question-answer strategies from the view of ZPD prospective in mathematics classroom is of great importance and there has been much attention from the academia. However, systematic awareness has not been formed. Thus, this paper mainly focuses on how teachers should ask or answer students in the class with the theory of ZPD and tries to offer some suggestions, using the methodology of case analysis.

2. Background and Methodology

In this study, two videos of mathematics class have been chosen for case study. The two videos selected were from YouTube and published by Massachusetts department of Elementary and Secondary Education in the same date. Choosing videos from the same publisher ensured videos were recorded by similar technique. The students in both videos are high school students, so the knowledge they have, and their thinking patterns will be similar, allowing the two videos to be compared on the same basis.

2.1 Background of Video 1

Some eleventh graders were solving problems given by the teacher through group discussion in their mathematics class while they seemed to encounter some difficulties. In this video, the teacher tried to figure out what the students already knew by asking questions, then provided some help to guide students to discover in a certain direction and sometimes just give them the answer directly, enabling students to enter their zone of proximal development.

It is worth noting, however, that the teacher's choice between guiding students and answering them directly is based on the students' situation and the questions they ask, so we are interested in analyzing the teacher's various answers in this video to summarize some patterns.

2.2 Background of Video 2

The teacher has just finished using algebra tiles to find the area of a square and now it is the turn of the students being asked to find the area of a rectangle using algebra tiles. In this video, there are eight students in the classroom, sitting in pairs. The student answering the question is a boy, sitting in the first row, closest to the teacher and the whiteboard. This boy did not answer the teacher's question correctly and in time, therefore the teacher wanted to ask the question to find out what the students already knew or did not know, and to provide some help to guide the students to discover the answer. this knowledge.

2.3 Methodology

Qualitative analysis will be conducted based on conversation analysis transcript. Based on dialogues and body language in the student teacher interaction, inferences will be delivered through the student's knowledge and understanding of the teacher's questions and determine whether the student has really understood the teacher's questions. Given the inferences and combined with ZPD's theory, evaluation of whether the question answer strategy used by the teacher in this scenario was effective and whether it was the most efficient strategy will be delivered. If in the evaluation, the strategy used by the teacher is not the optimal one, a new strategy that is more effective given the situation will be proposed and compared with. In conclusion, different scenarios will be categorized and the most appropriate and effective question answer strategy to use in the different contexts will be provided.

3. Results

3.1 Conversation Analysis of Video 1

01	INS:	Did you all decide on a s^cale?
02		[((walk towards ST1 and ST2))]
03	ST1:	Yeah, we’re gonna go by 12s on this one.
04		We can’t figure out like what-(2.2).
05	INS:	[O^kay.((nod, look at ST2))
06	ST2:	[We’d have to go about like (.) 16 （units） to do
07		that(.)so::.
08		((take a glance at calculator))

We can see that the teacher was asking the students about their progress, and she noticed that the students were having hesitation in their answers, which meant they were not sure if their answers were correct.

11	INS:	so: where do you wanna start, (.)maybe.(0.5)
15	INS:	You are starting at the exact?

We can see that the teacher asked two questions 'where do you wanna start' and 'you are starting at an exact'. And this presents what we need to do before we respond to the students' questions: using interactions to fully grasp what the students have already mastered and to understand where the students' zone of proximal development is

18 ST2: [or maybe a little [bit further (more negating)

The students responded by a questioning tone, but this response wasn't correct considering the later text.

27 INS: Do you need to though?(0.5)

However, since the students were not ignorant, and they had some opinions about the issue, the teacher did not reject their ideas directly, but responded to the students' questions with another question 'do you need to though', trying to lead the students to think independently in this way, and to motivate them to become autonomous learners.

35 INS: =([Do you need a squiggle on the ^x: or
36 do you need a squiggle on the y::.

Unfortunately, the students didn't seem to understand the hint given by the teacher, so the teacher reminded them more directly by saying 'or do you need a squiggle on the y'. Then both students answered y at the same time. It looked like the students had reached their potential level for they answered the question they were having trouble with before, but the teacher wasn't sure, because they probably guessed the answer by analyzing the teacher's words and actions.

40 INS: Why,(0.4) what are you going to start with on the x.

Therefore, to confirm that the students really had a good command of the knowledge, the teacher asked them why in line 40 and directed their thinking by asking 'what are you going to start with on the X'.

43 INS: =((turn around))no on the [X-axis=
44 ST2: =Oh[the X-axis oh=
47 INS: so there's really no brea:k there(0.5)
48 okay but you do have a break on the y-axis (0.5)

When one student seemed to give a wrong answer because of carelessness, the teacher directly corrected him and then give the real reason for having the squiggle on the y-axis: 'you do have a break on the y-axis'.

3.2 Discussion

The Zone of Proximal Development (ZPD) theory, presented by Lev Vygotsky, started a revolution in teachers' response strategies. In the past, teachers were the center of the class, whose purpose was to pass the knowledge on to the students through interactions. While after the formulation of ZPD, teachers are no longer dominating the classes; instead, they are just a part of the class. It is the students, however, that should be focused on. What's more, the goal of education has also changed. Now what teachers need to achieve is leading students into their zone of proximal development by asking and answering questions, as well as enabling them to manage to accomplish something that they can't do before. And it explains the teacher's behavior in the video. Before answering any question, teachers should first have a clear perception of the students' zone of proximal development. This is especially important in mathematics education because different students may fail to understand different points in the same problem, so teachers should know their students well before starting interaction to make their process of asking and answering effective.

Secondly, the way teachers answer their students' questions is related to the status of the students. As we all know, mathematics is a subject that needs plenty of thinking, which means students are more likely to become autonomous learners in this subject. Autonomous learning is very helpful in students' academic performance so in order to stimulate this process, when students have not yet thought deeply about the problem, teachers should guide them to think independently by giving more implicit answers instead of giving the correct answer directly, so that there is still room for students to think about the problem. And as soon as they succeed in solving the problems themselves with the

hints of the teachers, they are becoming autonomous learners. On the other hand, if students have spent too much time on a single problem without getting the right answer, the teachers should give the answer immediately, because in mathematics, there are some problems that are too difficult for them to solve. If students continue to waste time on these problems, there will be a blow to their self-confidence, and they will lose their interest and enthusiasm in learning mathematics.

3.3 Conversation Analysis of Video 2

01	STU:	((playing the algebra tiles))
02	INS:	Flip them around, Let's see the colors.
03		Green is Y:(.) I mean, XY. Now, why is it X^Y?
04		Why is it X^Y? (Hhh) ((laughing))

The teacher provided algebra tiles (scaffolding) to help students visualize what they were about to learn and asked the question: Why was the area of the rectangle is X times Y?

05	STU:	Mm::,(2.0) I'm just,(0.5) ^I don't know.(0.3) I forget.=

The student said he didn't know the answer and made a confused gesture. Here the ZPD level of the student had been determined: The concept of area of the rectangle had not been developed.

06		=[^It looked like=
07	TEA:	[Think about]
08	STU:	=Mm::(1.0) Like,(0.2) mm:::
09		((shake head and shrug))(4.0)

When the student was trying to figure out the answer on his own, the teacher interrupted him, causing the student's thoughts to be cut off.

10	INS:	Why is=(why is) this X^Y?(.)
11		W- w-=(why)=How did we get(.) Y squared here?

The teacher didn't give enough time for the student to think independently, but provided the scaffolding directly, and wanted him to be guided through the same kind of question-finding the area of a square-to find the answer.

12		Mm: you multiplied the two Ys, which is the(.)two ^what.
13	STU:	Em:eh::, Ys.=

The student again did not provide an accurate answer.

14	INS:	=The two sides.
15	STU:	Yeah, the two sides.=

The teacher gave the answer directly, and the student accepted the teacher's opinion directly without the time to think. This was just a repetition of the correct answer, and the student didn't come up the answer by himself.

16	INS:	=Okay, all right, so then what do we do,
17		what is this ^here then,
18		what's this telling you?
19		[((point to the rectangle))]

20 STU: [Same thing eh:: as the eh::when we ^em:::],
21 multiplied the sides.

The teacher threw out the main question: How do you find the area of a rectangle? The student hesitated at this point because he did not think sufficiently earlier.

22 INS: ^Good.
23 STU: X and Y.
24 INS: X and Y, good.
25 So that would (.) that would mean that ^what,
26 What would be the side length of this.
27 ((point to the rectangle of XY))
28 STU: X and Y.
29 INS: X and Y, X and Y, good.

Only now is this new knowledge fully understood.

3.4 Discussion

Scaffolding is based on the concept of the zone of proximal development, first theorized by Soviet psychologist Lev Vygotsky in the 1930s.The zone of proximal development (ZPD) is the distance between what students can do on their own and what they need help with.

Stone describes an analysis of scaffolding inspired by Vygotsky. In Stone's view, students are not passive participants in teacher-student interactions; both teachers and students should be active participants. Teachers and students actively build their common understanding through communication, in which students learn from the perspective of the more knowledgeable side. Since scaffolding can be adjusted to the student's situation, the support given by the teacher during the scaffolding process depends greatly on the type of assignment and the student's response [10]. Therefore, scaffolding works differently in different situations.

Proper scaffolding motivates students to learn, reduces student frustration, and builds effective independent learning skills.

But scaffolding can be detrimental to the teacher because it requires constant monitoring of the class and giving up control, allowing students to think at their own pace is time-consuming in limited class time; there is likely not enough time to complete the entire scaffolding or to correctly determine student's ZPD that needs to be scaffolded. In some cases, this may force a reduction in the amount of time given to each student. For example, the teacher in this case, when the student says "I forgot" shakes his head and shrugs his shoulders, assumes that he really "forgot" rather than not knowing the point at all. In the fast pace of the class, the student was not given enough time to think and was given the answer directly, which made the student spend more time mastering the point and increased the learning cost instead of reducing it.

Therefore, the result has shown that before asking or answering any question, teachers should first have a clear idea of students' zone of proximal development; secondly, when students have not yet thought deeply about the question, teachers should guide them to think independently and give more implicit answers rather than directly giving correct answers, so that they are more likely to become independent learners. But on the other hand, if the direction and quality of their thinking are affected by something other than thinking itself (e.g., carelessness in acquiring information), then teachers should give accurate answers in a timely manner because such barriers to thinking are meaningless.

4. Conclusions

From the perspective of ZPD theory, the result shows that there are conditions in that instructors encourage exploration and ones that provide answers directly. Different question-answer strategies

are various scaffolding teachers provide to assist students' learning. Based on the analysis of two case studies, it was found that the selection of question-answer strategies is related to identifying the zone of proximal development of students. When teachers find that problems students meet are in their ZPD by analyzing students' responses, they tend to allow learners to explore the solution on their own or with group members. In this process, students have guiding questions to discover and adequate time for thinking. Meanwhile, instructors monitored students' understanding constantly by asking different questions, which ensured learners worked in the right direction. Under the circumstance of providing answers directly, teachers may notice that questions that students meet are out of their ZPD.

Therefore, when students have discovered independently, instructors should verify the result after their exploration by giving the correct answer. At the same time, providing answers is beneficial for removing meaningless barriers that hinder discovery, such as misreading the number. The goal of taking various question-answer strategies is to balance learners' cost of learning in the discovery process. In this way, students may neither find the task too challenging nor too easy. The balance of the cost is consistent with the theory of ZPD, which encourages students to be autonomous learners by reaching achievable learning goals at potential developmental levels. This study analyzed teachers' question-answer strategies with the ZPD theory. The selection of strategies is closely related to students' potential developmental level and appropriate scaffolding. However, the limitation is the number of case studies. In the future, researchers may discover the research topic further by taking more cases in different subject fields into consideration. Researchers may design pre-test and post-test to compare the effect of various question-answer strategies and the extent to which students want to be autonomous learners.

References

[1] Amir O, et al. Interactive teaching strategies for agent training. In Proceedings of IJCAI 2016, 2016.

[2] Molbaek M. Inclusive teaching strategies–dimensions and agendas. International Journal of Inclusive Education, 2018, 22(10): 1048-1061.

[3] Su H.F.H., Frederick, A.R., Mamikon, M. Mathematical teaching strategies: Pathways to critical thinking and metacognition. International Journal of Research in Education and Science, 2016, 2(1): 190-200.

[4] Liu L. Application of cooperative principle and politeness principle in class question-answer process. Theory and Practice in Language Studies, 2017, 7(7): 563.

[5] Haydon T., William H. The effects of two types of teacher questioning on teacher behavior and student performance: A case study. Education and Treatment of Children, 2011, 34(2): 229-245.

[6] Margolis A.A. Zone of proximal Development, scaffolding, and teaching practice. Cultural-Historical Psychology, 2022, 16(3): 15-26.

[7] Zhong Qi Quan. The Zone of Proximal Development: A theoretical basis of class transformation. Global Education, 2018, 34(1): 11-20.

[8] Van de Pol J., Elbers, E. Scaffolding student learning: A micro-analysis of teacher–student interaction. Learning, Culture and Social Interaction, 2013, 2(1): 32-41.

[9] Van de Pol J., Volman, M., Beishuizen, J. Scaffolding in Teacher—Student Interaction: A Decade of Research. Springer, 2010, 22(3): 271–296.

[10] Stone C. A. What is missing in the metaphor of scaffolding. Contexts for learning: Sociocultural dynamics in children's development, 1993, 169-183.