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Optimizing Teacher Assistance In Mathematics Learning Through Scaffolding Thresholds

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Abstract

A problem in learning mathematics in the classroom is that there are no clear guidelines on when teacher assistance needs to be given, maintained, or stopped. This lack of clarity risks causing disproportionate assistance, either in the form of over-scaffolding which creates learner dependence, or under-scaffolding which inhibits concept understanding. This study aims to identify and examine in depth the threshold for providing scaffolding by teachers in mathematics learning, based on the Zone of Proximal Development (ZPD) theory. The approach used was descriptive qualitative with the subject of six students in class XI at SMK Ahmad Yani Jabung who were selected based on the category of high, medium and low academic ability. Data were obtained through observation of learning activities, in- depth interviews, and document analysis of students' work, and analyzed through the stages of data reduction, presentation, and verification using the Miles and Huberman model. The results showed that the threshold of scaffolding is contextual and dynamic, determined by three main indicators: learners' cognitive responses, the level of dependence on assistance, and verbal and nonverbal expressions. The process of providing assistance includes three stages, namely initial assessment, implementation of scaffolding, and gradual reduction of assistance. The conclusion of this study emphasizes the importance of adjusting teacher interventions according to learners' ZPD position, as well as the need for teacher training and the development of ZPD-based adaptive learning models to improve learning effectiveness and encourage learning independence. The findings imply that teacher training programs should emphasize adaptive scaffolding techniques and the use of formative indicators to determine assistance thresholds. These insights can serve as a foundation for developing contextual frameworks for teacher professional development.

Keywords: scaffolding, threshold, Zone of Proximal Development

1. Introduction

In the practice of learning mathematics in schools, scaffolding strategies have long been recognized as an effective approach to help learners understand concepts that are abstract and complex. This strategy aims to provide temporary support in the form of directions, hints, or gradual assistance, so that learners can bridge the gap between initial competence and targeted competence. When applied appropriately, scaffolding can increase learner engagement, reduce learning anxiety, and encourage more optimal cognitive development (Chen, 2023; Kim, 2017). However, in its implementation in the classroom, many teachers apply assistance uniformly without considering each individual's learning needs and readiness.

Observations in one vocational school showed that the teacher gave instructions for solving math problems directly to all learners without conducting an initial diagnosis of their understanding. As a result, learners become passive, experience confusion when facing similar problems independently, and show high dependence on teacher assistance. This phenomenon illustrates the inaccuracy in providing assistance that should be tailored to the zone of proximal development (ZPD) of each learner (Darmawan, 2024; Kim, 2017; Sorariutta, 2017). The mismatch between the form of assistance and the level of learning readiness of learners can have a negative impact on the concept internalization process, and hinder the formation of independence in learning.

Vygotsky's ZPD emphasizes the importance of providing assistance that falls within the optimal range between what learners can do independently and what they can achieve with support. In this context, scaffolding must be carefully adjusted to fall within this zone. One of the main challenges in implementation is that there is no practical guidance on the thresholds for providing assistance. These thresholds include important decisions about when assistance needs to be provided, maintained, reduced, or stopped based on indicators of learner development (Belland, 2016, 2017; Kim, 2017)

Without concrete and systematic indicators, many teachers make intuitive decisions, risking two extremes: over-scaffolding and under-scaffolding. Over- scaffolding occurs when help is given excessively and for too long, so that learners become passive and are not trained to think independently. Conversely, under- scaffolding occurs when assistance is stopped too soon or is insufficient, causing learners to feel confused, disoriented, and ultimately less motivated to complete the learning task (Hernández-Rodríguez, 2021; Rezat, 2022).

Although a number of studies have demonstrated the effectiveness of scaffolding, most of the previous studies have used quantitative approaches and focused on academic achievement or teacher perceptions (Li, 2024; Mutia, 2023). Such approaches have not been able to capture the dynamics of classroom interactions, especially how teachers in real-time observe learners' progress and adjust assistance contextually. In addition, most of the assistance models developed are universal and pay little attention to individual variations in learning styles, cognitive readiness levels, and learners' socio-emotional characteristics. Therefore, an in-depth qualitative approach is needed to explore teachers' practices in managing thresholds of assistance based on real classroom contexts.

These gaps indicate the need for research that focuses on identifying contextual indicators in scaffolding, especially in determining the timing, duration and intensity of assistance. This research also needs to explore the dynamics of interactions between teachers and learners, including how learners' verbal and nonverbal expressions and cognitive responses can inform pedagogical decision-making. By understanding these indicators, teachers are expected to manage assistance more effectively and flexibly, and encourage learners' gradual transition from dependency to learning independence.

Despite the numerous studies on scaffolding in mathematics learning, most have focused on the effects of scaffolding on achievement rather than on *how teachers determine the appropriate level of assistance in real time*. Unlike previous studies (Kim, 2017; Sorariutta, 2017) that examined scaffolding from cognitive or developmental perspectives, this research explores *contextual thresholds of assistance* observed directly in classroom interactions. This novelty provides a practical framework for adaptive scaffolding decisions aligned with Vygotsky's ZPD principles.Based on this background, this study aims to identify and examine in depth the threshold for scaffolding by teachers in mathematics learning based on the ZPD principle. The main focus of this study is to formulate indicators that can be used by teachers to adjust learning interventions appropriately. The results of this study are expected to contribute to the development of ZPD-based adaptive learning models, as well as the basis for preparing professional guidelines for teachers in designing and implementing scaffolding strategies that are more contextual, measurable, and in favor of the needs of learners.Unlike previous studies that mainly focused on outcomes or perceptions, this research explores *real-time, contextual thresholds of scaffolding* observed directly in classroom interaction. This novelty provides a practical framework for teachers' adaptive decision-making aligned with Vygotsky's ZPD principles.

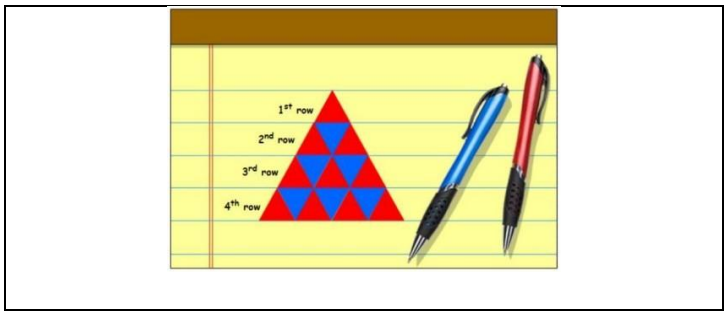
2. Methods

This research uses a descriptive qualitative approach which aims to examine the implementation of the scaffolding threshold in mathematics learning based on the Zone of Proximal Development (ZPD) theory. The research was conducted at SMK Ahmad Yani Jabung in the even semester of the 2024/2025 academic year. The research subjects consisted of six grade XI students from three expertise programs, who were selected by stratified random sampling based on mathematics formative scores, representing high, medium and low ability categories.

The main instrument in this study was the researcher himself, who was assisted by supporting instruments in the form of: (1) open description questions about triangle patterns to reveal students' mathematical thinking ability and position in the ZPD, (2) semi-structured interview guides for teachers and students, and (3) observation guidelines and document analysis of learning outcomes. The aspects observed during classroom interaction included (a) type and frequency of assistance, (b) learners' verbal and nonverbal responses, and (c) teacher decision to maintain, reduce, or stop scaffolding. Data were analyzed using Miles and Huberman's (2014) model through three stages: data reduction, data display, and conclusion drawing. Coding was conducted inductively to identify emerging themes of assistance thresholds. Researcher triangulation and inter-rater reliability were applied by cross-checking interpretations among two independent coders to ensure trustworthiness.The open description questions used can be seen in Figure 1.

Figure 1.
Problem Instrument

"Alex made a pattern of red and blue triangles. He said that, if he added more rows to this pattern, the blue triangle would always be less than half. Do you agree with Alex? Explain your reasoning!"



The data collection procedure included three main techniques. First, classroom observations were conducted to record the natural process of giving and stopping scaffolding in teaching-learning interactions. Second, in-depth interviews with teachers aimed to explore strategies in determining the threshold of assistance, while interviews with learners revealed their experiences and perceptions of scaffolding. Third, document analysis was used to link learners' work with the pattern of assistance received.

Prior to data collection, the instrument was validated by a mathematics teacher and a mathematics education lecturer. During the research process, ethical principles were maintained through informed consent, confidentiality of participants' identities, and member checking to improve data validity.

3. Result and Discussion

This study involved six Grade XI learners from high, medium, and low ability categories. The data showed that the scaffolding provided to the learners varied in type, intensity, and termination time. The following table summarizes the observation of the scaffolding process:

Table 1.

Research Results

Subject	Ability Category	Type of Assistance Provided	Dominant *Scaffolding* Stage	Threshold Status
MA	High	Light leading questions	*Fading*	Assistance is terminated after verification
RFM	High	Initial trigger	*Fading*	Full suspension of aid
IAM	Medium	Narrative explanation	*Delivery*	Assistance continued
NA	Medium	Symbolic & exploratory questions	*Delivery*→ *Fading*	Aid reduced gradually
DEA	Low	Numerical examples & explicit guidance	*Delivery*	Assistance continued
SHS	Low	Concept assertion & clarification	*Delivery*	Assistance has not been effective

In the process of learning mathematics using scaffolding strategies, variations in learners' cognitive abilities directly affect the type of assistance provided by the teacher as well as the determination of the threshold for providing assistance. The six learners in this study represented three different ability categories (high, medium, low), each showing unique responses to the scaffolding provided.

Subject MA who belongs to the high ability category showed independence of thinking from the early stages. He was given light leading questions as a form of initial assistance. At the fading stage, MA was able to recognize numerical and visual patterns well, and construct mathematical arguments logically without additional intervention. The assistance threshold was reached when the teacher verified MA's understanding, and assistance was stopped because the learner had demonstrated independent mastery of the concept.

Subject RFM, also from the high category, only needed an initial trigger to start the thinking process. He independently arranged fractions, performed symbolic comparisons, and drew conclusions without the need for further assistance. Scaffolding on RFM only lasted for a short time and ended at the fading stage. The assistance threshold was met quickly as the learner was already outside the ZPD for the task.

Meanwhile, subject IAM from the moderate category showed a need for more intensive assistance. He was given a detailed narrative explanation, but was not yet fully able to compare the number of blue triangles to the total proportionally. Despite being able to observe the pattern of increase, the conclusion drawn was still based on the increase in absolute quantity. The delivery stage is dominant in scaffolding for IAM, as help must still be provided to guide the learners' thinking process. The threshold of assistance has not been reached, and teacher intervention is still needed.

Subject NA, also from the moderate category, was given exploratory and symbolic questions. At first, assistance is needed to trigger analytical thinking, but as the learning process progresses, learners begin to show cognitive progress and independence in constructing arguments. Therefore, assistance can be gradually reduced. The scaffolding stage moves from delivery to fading, and the threshold is reached gradually with the reduction of assistance according to readiness indicators.

In the low category, DEA subjects need more concrete scaffolding, in the form of numerical examples and explicit guidance. Learners have difficulty in forming their own arguments, and tend to wait for teacher instructions. The delivery stage became dominant and assistance continued because DEA had not shown cognitive readiness to think independently. The assistance threshold has not been reached and teacher intervention is still needed consistently.

Meanwhile, subject SHS showed confusion and inconsistent responses to the assistance provided. Although the teacher had provided concept affirmation and clarification, the learners had not shown meaningful understanding. The assistance provided had not achieved the expected effectiveness. SHS still requires repeated and explicit assistance, indicating that the delivery stage lasts long, but has not resulted in significant cognitive development. The threshold has not been reached because scaffolding has not been able to facilitate the transition from dependence to independence.

This analysis shows that the determination of scaffolding thresholds is not only influenced by the ability category of learners, but also by the form and effectiveness of the assistance provided. Adaptive interventions based on the ZPD principle prove crucial in ensuring

assistance is stopped or continued in a timely manner. Teachers need to adjust assistance not only based on the material, but also based on learners' verbal expressions, thinking strategies, and initiatives during the learning process.

From the data, it can be seen that two learners (RFM and MA) have achieved learning independence and demonstrated deep mathematical thinking skills. RFM was able to analyze patterns with fraction representations such as 10/25 and mathematically deduce that the blue triangle is always less than half. MA inferred with verbal and numerical logic without additional guidance.

In contrast, participants such as IAM, DEA, and SHS still needed active scaffolding. IAM stated, "I can't explain with numbers or formulas, I still use narrative explanations." DEA revealed, "I know the new row adds the number of triangles, but I'm still confused about relating it to fractions." While SHS expressed her doubt, "I doubt if blue is always less than half."

The NA participant shows a transitional position, uses simple symbolic patterns, but has not yet fully deduced independently. Her quote, "I think this shows a consistent increase between rows." shows a good direction of development.

The results show that the success of scaffolding strategies The results of this study confirm that the effectiveness of scaffolding strategies in learning mathematics is highly dependent on the accuracy of the teacher in setting the threshold for providing assistance. This threshold is dynamic and needs to be determined contextually, depending on the cognitive development and learning response of each learner. This concept is in accordance with the Zone of Proximal Development (ZPD) theory proposed by Vygotsky, which states that optimal learning occurs when learners get help in the range of abilities that cannot yet be done independently, but can be achieved with support (Cevikbas, 2020; Sugiati dkk., 2024)

In the high ability category, RFM and MA subjects showed that light initial assistance, such as triggers or leading questions, was enough to encourage their understanding. The teacher intervention directly entered the fading stage because the learners showed independent cognitive responses and were able to build mathematical argument structures symbolically and verbally. This finding is in line with Brower (2018) and Alkan (2023), which state that a timely process of reducing assistance can strengthen conceptual understanding and accelerate the transition from dependence to learning independence. These two subjects have exceeded the ZPD limit for the given problem, so the termination of assistance is productive.

In contrast to that, subjects IAM and DEA who belonged to the medium and low ability categories showed high dependence on teacher assistance. IAM needed narrative explanations to process mathematical information, while DEA needed explicit help in the form of numerical examples. Both were in the scaffolding delivery stage, where assistance still had to be actively provided. The inability to compose symbolic representations is an indicator that both are not ready to cross the ZPD independently. This confirms Hernández-Rodríguez's opinion (2021) that over-scaffolding can hinder cognitive development if teachers are not able to read the signals of learners' learning readiness appropriately.

Participant NA showed transitional development between the delivery and fading stages. Although not yet able to state conclusions in a formal form, this participant has started to show the ability to think predictively and relate patterns of increase logically. Teachers need to be careful not to stop the support too soon, as at this stage participants are very vulnerable to misconceptions. A flexible and adaptive approach as described in the research of Sugiati dkk (2024) becomes very important to facilitate the shift of participants' position from inside to outside the ZPD zone.

Meanwhile, SHS subjects from the low category showed high conceptual confusion. Despite being given affirmation and clarification, this learner did not show deep understanding. The inability to generalize patterns and hesitation in making conclusions reflect that the assistance has not been in accordance with the learning styles and affective needs of learners. Park (2022) states that scaffolding interventions that do not consider affective aspects can reduce the effectiveness of assistance. Sugiati dkk. (2024) also emphasized that scaffolding provided to low ability participants needs to be directed at developing conceptual thinking with gradual and systematic assistance so that participants are able to understand the context of the problem thoroughly.

Table 2.
Research Question Answered by The Findings.

Research Question	Key Findings	Supporting Evidence
How do teachers determine when to give or stop scaffolding?	Based on learners' verbal and nonverbal cues, cognitive response, and dependence on assistance.	Observation and interview data
What are the contextual indicators of scaffolding thresholds?	Three indicators identified: cognitive response, level of dependence, and affective readiness.	Cross-case analysis
How can thresholds differ across ability levels?	High-ability learners reach fading stage faster, while low-ability learners remain longer in delivery stage.	Comparative results (Table 1)

These findings align with Belland (2016, 2017) who emphasized adaptive scaffolding as a dynamic decision-making process. However, the limited number of participants and single-school setting restrict the generalizability of the findings. Future studies should involve multiple schools or digital scaffolding contexts to broaden applicability.This study also corroborates the findings of Sugiati dkk. (2024) and Prayitno (2017) that the level of assistance must be adjusted to the learning situation. When learners face difficulties in understanding the problem, help in the form of exploratory questions will be effective; but if difficulties occur in the strategy or reflection stage, then conceptual and metacognitive assistance is more needed. In this context, the teacher is not just an instruction giver, but a thinking facilitator who helps learners recognize their own way of thinking.

Thus, scaffolding thresholds are not a static concept, but rather a reflective component that should be part of teachers' professional practice in designing responsive and contextualized mathematics learning. Teachers who are able to manage this threshold effectively will be better able to encourage learners' transition towards sustainable learning independence. Across cases, it was found that scaffolding thresholds are influenced not only by learners' cognitive abilities but also by their affective readiness and the teacher's sensitivity in interpreting classroom cues. This aligns with Vygotsky's principle that learning potential depends on socially mediated interactions within the ZPD.

4. Conclusion

This research reveals that the threshold for scaffolding in mathematics learning is not fixed, but must be determined contextually and adaptively based on the development of learners in the Zone of Proximal Development (ZPD). The scaffolding process takes place through three main stages: initial assessment, provision of directed assistance, and gradual reduction of

assistance. Teachers determine the time to stop assistance based on indicators of changes in learners' learning behavior, such as the ability to compile logical data, conclude independently, and no longer need constant confirmation.

The results of the analysis of the six subjects showed a variation in the threshold of assistance that reflected the different ZPD positions of each learner. Learners such as RFM and MA have reached full independence, while DEA, IAM, and SHS are still in the active ZPD and require further scaffolding. This adjustment is important so that assistance is not given too long (over-scaffolding) or stopped too quickly (under-scaffolding).

Thus, teachers play an important role in reading real-time learning signals to determine when assistance should be reduced or stopped. Appropriate application of scaffolding thresholds can support learners' transition to learning independence, improve the effectiveness of mathematics learning, and strengthen critical and reflective thinking processes. This study recommends teacher training in formative assessment and ZPD-based differentiated learning strategies, and encourages further research with a wider scope and more diverse approaches.

The findings provide valuable implications for teacher professional development. Training programs should focus on recognizing learners' readiness indicators, interpreting classroom signals, and applying adaptive scaffolding techniques. Moreover, this research can serve as a foundation for developing *ZPD-based scaffolding frameworks* that guide teachers in determining when and how to provide or withdraw assistance in real classroom settings. Therefore, this research contributes to teacher professional development by offering empirical indicators for determining scaffolding thresholds. Future training and policy frameworks can adopt these findings to design adaptive, ZPD-based scaffolding practices that promote learner autonomy.

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