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Evaluating One-to-One Scaffolding and Peer–Scaffolding in Mathematics Learning: Which is Effective?

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ABSTRACT

The dynamics of success in mathematics learning are largely determined by the interaction process of teachers, students and a conducive learning environment. The aim of the research is to determine the effectiveness of applying scaffolding to increasing mathematics learning achievement and the interaction processes that occur in learning. Data collection methods through (a) tests, (b) observation, and (c) interviews. Analysis of quantitative and qualitative data was carried out to answer different but complementary problem formulations. The research results show that the one-to-one scaffolding and peer-scaffolding methods are effective in improving learning achievement and overcoming student learning difficulties. However, the interaction in one-to-one scaffolding is unidirectional and has the potential to trigger student dependence on the teacher. Peer-scaffolding interactions are more open sharing between students as colleagues, thus allowing for cooperative interactions, assimilation and acculturation. Therefore, the peer-scaffolding method should be emphasized more in learning compared to the one-to-one scaffolding method.

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1. INTRODUCTION

Mathematics is a scientific discipline that aims to improve critical thinking so that students are able to contribute to solving problems in everyday life, including in the world of work and the development of science. The dynamics of successful mathematics learning are largely determined by the interaction process of teachers, students and a conducive learning environment. For this reason, teachers require to pay attention to the learning interaction process which accommodates the skills needed by students in the current destructive era.

In learning activities, interactions transpire between students and students, teachers and students, and between students and learning resources. However, the interaction process in mathematics learning often does not run smoothly because of the learning difficulties experienced by students. Difficulties in learning mathematics experienced by students include: difficulties in reading and understanding the meaning of questions, difficulties in understanding and constructing mathematical concepts, difficulties in using formulas and symbol notation, and difficulties in the calculation process. Learning difficulties will hinder the improvement of student learning achievement (Lodge et al., 2018; Zhang et al., 2021).

One solution to overcome difficulties in learning mathematics is, for teachers or peers, to provide assistance in learning mathematics to other students. The assistance provided is in the form of scaffolding to small groups and individuals (van de Pol & Volman, 2019). The purpose of providing this assistance is for students to solve the mathematical problems given. In the context of learning interactions, the term scaffolding is used as an illustration where teachers provide temporary assistance to students to help them complete tasks or develop new understanding, so that in the future students are expected to be able to work on new tasks independently, developing a higher level of understanding and thinking skills (Alrawili et al., 2020).

Scaffolding is a concept of learning with temporary assistance, where teachers provide assistance to students during the preliminary stages of learning. Then, teachers gradually reduce this assistance and provide students the opportunity to take over increasingly large responsibilities as soon as they are able to do it independently (Brower et al., 2018; Brownfield & Wilkinson, 2018). Vygotsky in his theory linked *scaffolding* to students' maximum stages in constructing learning material, which is known as the zone of proximal development (ZPD) (Eun, 2019). According to Vygotsky, students have two stages in actual and potential development (Kusmaryono et al., 2021). The implication of Vygostky's theory in education is a cooperative learning setting, so that students can interact around tasks and mutually generate affective problem solving strategies in the zone of proximal development.

Some literatures that adopt Jerome Bruner's suggestion about scaffolding is divided into two, namely vertical scaffolding (hereinafter called one-to-one scaffolding) and sequential scaffolding (hereinafter called peer-scaffolding) (Abune, 2019). One-to-one scaffolding is assistance from teachers who work one-on-one with one student to provide the right amount of support so that students can complete certain tasks (Kim & Belland, 2018). Meanwhile in constructivism, peer-scaffolding is when the teacher provides opportunities for more prominent students to help the teacher as a tutor for small groups. The challenge for teachers is apart from handing over some of their authority to students and teachers must be able to motivate designated students to play their role optimally (van de Pol & Volman, 2019).

Research on scaffolding in the last decade (2015–2024) has been carried out by many researchers. Research on scaffolding includes: (a) the influence of scaffolding strategies on learning motivation (Acosta-Gonzaga & Ramirez-Arellano, 2022; Yu et al., 2024); (b) the effect of scaffolding on higher order thinking abilities (Alrawili et al., 2020); (c) the impact of the scaffolding approach on mathematics learning achievement(Brower et al., 2018; Brownfield & Wilkinson, 2018); (d) application of scaffolding in classroom learning (Dominguez & Svihla, 2023; Garderen et al., 2021; van de Pol et al., 2015; van de Pol & Volman, 2019); (e) integration of computational thinking skills in scaffolding learning (Bereiter, 1999; Ihechukwu, 2020); and (f) the importance of complementary distribution between teacher scaffolding and lesson material content (Martin et al., 2019).

The authors have conducted a literature review of scaffolding articles that have been published in the last decade (2015–2024). The results of the review are summarized in the following points: (a) researchers still focused on the influence of scaffolding on motivation and learning outcomes; (b) the scaffolding instructional strategy implemented is still general and not specific; (c) researchers have not compared the advantages and disadvantages of one-to-one scaffolding and peer-scaffolding methods and their implementation in mathematics subject in the classroom. Thus, we have the opportunity to study and discuss further about student interactions and the effectiveness of one-to-one scaffolding and peer-scaffolding methods.

The problems raised in this research are (a) Is mathematics learning using the scaffolding method effective in overcoming students' learning difficulties? If providing scaffolding is effective then, (b) Which is more effective, one-to-one scaffolding or peer-scaffolding? (c) How do learning interactions occur in learning with one-to-one scaffolding and peer-scaffolding? Bearing in mind that problems with mathematics learning difficulties that are not immediately resolved will result in students' failure to reach a level of understanding of mathematical concepts. In fact, the students are in the ZPD and have the potential to increase understanding optimally.

The authors assume that students who experience difficulties in mathematics learning due to their own different ability. The students must receive treatment (assistance) with different scaffolding methods. Therefore, this article will explain the effectiveness of one-to-one scaffolding and peer-scaffolding methods in mathematics learning. The hope is that through this article educators or teachers can obtain the latest information about the effective application of scaffolding methods to help students with learning difficulties.

2. METHODS

The research applies a combination of quantitative and qualitative research with sequential explanatory research designs. The sequential explanatory design research steps begin with quantitative research, namely determining the problem/potential, formulating the problem, then developing a theoretical basis and hypothesis, collecting quantitative data analysis and hypothesis testing results. Quantitative research will end after testing the hypothesis (proven or not proven). Then proceed by using qualitative methods to strengthen, expand, and the results may even conflict with the quantitative data obtained at the preliminary stage. The next qualitative research activity is determining the data source, collecting and analyzing qualitative data, then carrying out a combination of quantitative and qualitative data analysis. For more details, research steps with a sequential explanatory design (Dawadi et al., 2021; Gogo & Musonda, 2022; Lall, 2021; Toyon, 2021) can be seen in Figure 1 below.

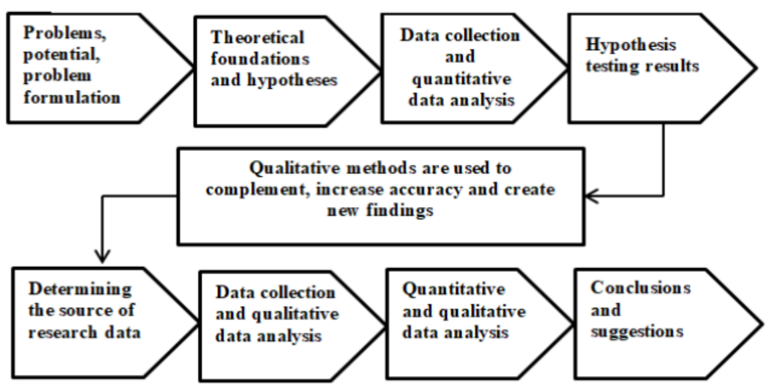

Figure 1. Research steps with sequential explanatory design

The participants in this research consisted of 80 students from classes X-A and X-B, 2 mathematics teachers, and 2 observers. The student criteria are early grade students at the high school level. They are in the process of adjusting to learning in a new class. They are between 15-16 years old. The selected mathematics teachers are teachers who have more than 5 years of teaching experience. Teachers master the material and understand problem-based mathematics learning. Teachers are able to implement learning using the scaffolding method. The observers have been trained to fill in the observation format and are able to be independent in conducting learning observations. Determining the subjects interviewed was carried out using a purposive snowball sampling technique (Kirchherr & Charles, 2018; Zickar & Keith, 2023).

The data collection instruments in this study consisted of (1) a test instrument in the form of a mathematics test question sheet, (2) an observation instrument in the form of a learning observation sheet, and (3) an interview instrument in the form of a list of interview questions. The test is the instrument to obtain quantitative data about test results, scores (mathematics learning achievement).

The observation is to obtain qualitative data about teacher interactions with students in mathematics learning classes with scaffolding. The interview contains semi-structured interview questions which can be developed by the researcher according to the research objectives (Aung et al., 2021; Elhami & Khoshnevisan, 2022). The purpose of the interview is to obtain more in-depth information (qualitative data) in the form of students' opinions or responses, and students' learning experiences when learning mathematics using the scaffolding method.

Research data analysis with sequential explanatory design was carried out to answer different but complementary problem formulations (Hardiansyah et al., 2024; Noyes et al., 2019). Quantitative data analysis includes analysis of preliminary data and final data. Preliminary data analysis used statistical tests, namely classic assumption tests consisting of normality tests and variance homogeneity tests (Flatt & Jacobs, 2019). Final data analysis uses a comparative test, namely the independent samples t-test.

Activities in qualitative data analysis include data reduction, data display, and conclusion or verification (Miles et al., 2019). The results of qualitative data analysis are useful to support and/or explain the general picture of the quantitative data (Gogo & Musonda, 2022; Istimuryani et al., 2023). To enhance the reliability of these findings, we evaluated the accuracy of the data through triangulation, credibility, and confirmability (Alita et al., 2021). The researchers conducted credibility tests through discussion forums with teachers, observers, and educational psychology experts in groups.

The researchers conducted this study by using sequential explanatory designs through 3 stages, namely: First stage, (1) the researcher takes quantitative data from the results of preliminary tests in classes X-A and X-B; (2) researchers analyzed data from preliminary test results in classes X-A and X-B through descriptive statistics: normality and homogeneity of variance tests; (3) the researcher determines the classes that receive one-to-one scaffolding and peer-scaffolding treatment based on zone of proximal development (ZPD) as seen from previous learning results (prior learning). The second stage, (1) the teacher carries out mathematics learning in classes X-A and X-B. Class X-A where students with low abilities receive one-to-one scaffolding treatment. X-B class where high ability students receive peer-scaffolding treatment; (2) two observers recorded the activities and interactions between teachers and students in mathematics learning; (3) at the end of the lesson, the teacher gives a final test to all students; (4) researchers analyze the final test result data. The third stage, the researcher conducted qualitative research, namely (1) the researcher prepared a list of questions for the interview; (2) researchers conduct interviews with selected subjects; (3) researchers collect data from interviews and conduct qualitative data analysis; (4) researchers collaborate on findings to generalize qualitative research results using quantitative research findings.

3. FINDINGS AND DISCUSSION

Explanatory research data is presented using various methods, such as tables, graphs or diagrams, and narratives. This data presentation makes the data more organized and easy to understand. It is also accompanied by a good analysis process so that conclusions can be drawn.

3.1 Students' Mathematics Learning Achievement Before and After Receiving Scaffolding

In this research, the preliminary data was obtained in the form of test results data for class X-A and X-B students after participating in mathematics learning without scaffolding treatment. The preliminary data in Table 1 is used as a basis for researchers to manage research actions by implementing mathematics learning based on the scaffolding method.

Table 1. Student preliminary test results in mathematics learning without scaffolding

Statistics	Class X-A	Class X-B
Number of Samples	40	40
Percentage of Correct Answers	65%	60%
Percentage of Incorrect Answers	35%	40%
The highest score	80	78
Low Value	65	68
Average	65.7	68.9
Standard deviation	9.82	10.24

Preliminary test result data (Table 1) shows that students' mathematics learning achievements are less than satisfactory. Table 1 indicated that the average score of class X-A and X-B students does not meet the minimum completion standard of 75.0 and the achievement level is still below 80%. Based on these results, researchers suggest teachers to implement mathematics learning using the scaffolding method (one-to-one scaffolding and peer-scaffolding).

The results of the preliminary data normality test suggested the value of Asiymp.Sig. of .432 and .991 > .05, it can be concluded that the two samples have a normal distribution. Meanwhile, the results of the homogeneity test of the Komogorov-Smirnov variant obtained the Asiymp.Sig value. (2-tailed) .721 > .05, it can be concluded that the two samples have homogeneous variances. Thus, the classical assumption test has been fulfilled in terms of normality of data and homogeneity of variance, so that both samples can be treated for further research (Alita et al., 2021; Flatt & Jacobs, 2019) . In the next stage, the researcher prepares a lesson plan, observation sheet and test questions, while the teacher conducts the mathematics learning process. At the end of the lesson, the teacher provides a final test to the students. Data on the results of the final test for learning mathematics using the scaffolding method are presented in Table 2 below.

Table 2. Final test results for learning mathematics with scaffolding

Statistics (n = 40)	Class X-A	Class X-B
Highest score	100	100
Lowest score	75	81
Average	84.5	80.7
Standard deviation	11.07	9.43

In Class X-A, the teacher performed his role as a facilitator by providing one-to-one scaffolding according to student needs. The average final test score has increased from the preliminary test. Classical learning completeness reaches more than 80%. In class X-B, the ten students appointed as mentors in peer-scaffolding carried out their roles well. The average final test score has increased from the preliminary test. Classical learning completeness reaches 80%.

Based on data on students' preliminary test scores and final test scores (Tables 1 and 2), researchers have conducted comparative tests using independent samples t-test statistics. The results of statistical tests for class X-A data show that the value of Asiymp.Sig. (2-tailed) .004 < .05, it can be concluded that there is a difference in the average score of the preliminary test and the final test. Statistical independent samples t-test was also carried out on class X-B data. The statistical test results show that the value of Asiymp.Sig. (2-tailed) .002 < .05, so it can be concluded that there is a difference in the average score of the preliminary test and the final test. A comparison of the results of the preliminary test – final test and scaffolding requirements is presented in Figure 2.

The researchers conducted an independent samples t-test on the final scores between class X-A and class X-B after both classes received learning treatment using the scaffolding method. The independent samples t-test statistical test shows that the Asiymp.Sig. (2-tailed) .000 < .05, it can be concluded that there is a difference in the average final test score between students who received mathematics learning using the one-to-one scaffolding method (class X-A) and the peer-scaffolding method (class X-B).

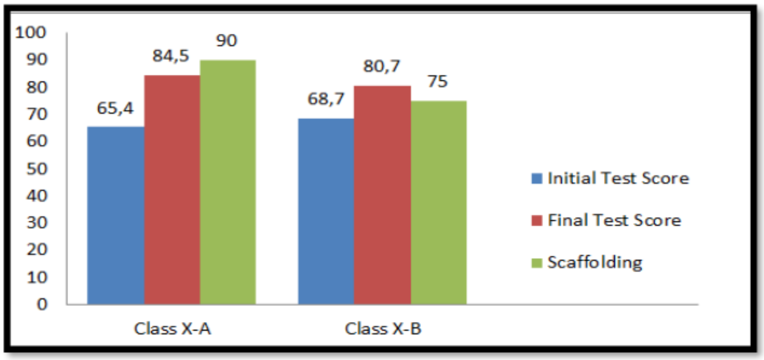

Figure 2. Comparison of preliminary test results – final test, and scaffolding requirements

3.2 The observation of mathematics learning activities and interactions

In this research, two observers manage to observe and record during the learning process. The things observed include the activities and interactions of students with students, and teachers with students when learning mathematics using the scaffolding method. Class X-A received mathematics learning treatment with one-to-one scaffolding, and class X-B with peer-scaffolding. The results of learning observations are presented in Table 3 below.

Table 3. Display data on observations of mathematics learning interactions

Stages of the *scaffolding method*	Description of observation results	
	Student groups with one-to-one scaffolding (Class X-A)	Student groups with peer-scaffolding (Class X-B)
Explaining: The teacher provides a detailed explanation of the concepts to be studied, so that students clearly understand the purpose and objectives of learning	The teacher detects the student's ZPD level; The teacher explains the learning objectives. Students understand the learning objectives to be achieved.	Students (tutors) provide preliminary explanations to small groups The tutor explains the learning objectives. Students understand the learning objectives to be achieved.
Reviewing: The teacher attempts to invite students to connect the material they will study with the basic concepts of the supporting material	Teachers determine appropriate forms of assistance for students with different abilities; Students reveal concepts that have been mastered previously.	Students (tutors) guide small groups with great effort; Associative learning interactions occur in the form of cooperation, assimilation and acculturation.
Developing conceptual thinking: Teachers develop students' thinking concepts starting from non-routine problems given to understand new concepts, students try to develop concepts to find solutions to these problems	Teachers and students interact progressively; Students communicate their ideas. Teachers give and answer all students' questions with enthusiasm; All student difficulties are resolved.	Students (tutors) and peers have open interaction; Guidance given to colleagues can improve critical thinking but is not yet optimal;

Limitation: The teacher controls activities during the student's thinking process so that they remain in line with learning objectives.	The teacher gives idea-provoking questions; The teacher asks further questions to check students' understanding; Students convey the results of their thinking processes in discussions.	The tutor provides idea-provoking questions; Students ask each other questions and answers in small groups; The tutor asks follow-up questions to check students' understanding; Students ask questions and convey the results of their thinking processes in discussions.

Data from observations of mathematics learning in Table 3 have gone through a strict reduction process. Next, the researcher conducted interviews with respondents who had been selected using a purposive snowball sampling technique. The summary of the interview results has been reduced and is presented in Table 4 below.

Table 4. Data from interviews with respondents

Interview questions	Description of interview results	
	Student groups with one-to-one scaffolding (Class X-A)	Student groups with peer-scaffolding (Class X-B)
What obstacles prevent you from understanding the material when studying mathematics?	Students have lack of confidence to openly communicate their problems to the teacher.	Students experience high level of mathematics anxiety. Students lack confidence when learning mathematics
Do you need discussion sessions while studying mathematics?	Students demand discussion sessions when experiencing difficulties learning mathematics.	Students demand discussion sessions with peers when experiencing difficulties learning mathematics.
In discussions, do you prefer (often) asking questions or answering questions?	Students ask more questions and follow the teacher's instructions. Students respond to questions only when asked by the teacher.	Students ask each other and have two-way interaction in a number of mathematical tasks.
How does scaffolding affect your critical thinking skills?	Students said their understanding of mathematics had increased. Students become more critical, careful and thorough in understanding problems.	Students said their understanding of mathematics had increased. Students have systematic critical thinking control.
Will you always expect scaffolding help in learning mathematics?	Students require concentration and focus in learning mathematics. Students who experience learning difficulties always require help (scaffolding).	The students aspire to change roles as a tutor. Students become more confident if they are in the position of a tutor who shares knowledge.

Finally, the researcher has succeeded in presenting findings in the form of quantitative and qualitative data. Next, researchers provide synthesis to increase the generality and applicability of these findings and develop new knowledge through the integration process.

3.3 Educational interaction in mathematics learning using the scaffolding method

Learning is a process of interaction between students, educators and learning resources in a learning environment. In the learning process, the teacher's most important task is to be able to condition the learning environment and provide guidance or scaffolding assistance to support changes in student behavior.

Based on interview data (Table 5), in general students' demand for scaffolding in mathematics learning is relatively high. Scaffolding requirements can be interpreted as the score required to reach the maximum value. The observation results, supported by data in Figure 2, suggested that students of class X-A x demand more one-to-one scaffolding by 90%, and the demand for peer-scaffolding for class X-B students is by 75%.

The observation results (Table 4) indicated that in learning using the one-to-one scaffolding method there tends to be unidirectional interaction. Students still have lack of confidence to communicate ideas to teachers. Teachers are more active in asking questions and encouraging students to come up with ideas. The assistance provided by teachers can be in the form of instructions, warnings, encouragement, breaking down problems into other forms that enable students to be independent. The only interaction that occurs is in the form of assimilation. Assimilation interactions occur where ideas that emerge from students are merged into a solution to solve the problem. Thus, to provide good scaffolding, especially for students with low abilities, really depends on the teacher's knowledge and abilities.

The results of learning observations using the peer-scaffolding method (Table 4) suggested that there was educational interaction between tutors and small group students. Interactions that occur in the form of: (a) cooperation between individuals or groups to obtain solutions to mathematical problems, (b) assimilation of ideas that arise from students are merged into a solution to solve the problem, and (c) combining two or more different but complementary ideas become solutions to solving mathematical problems.

Educational interactions are an important point in learning activities. This educational interaction describes an active two-way interaction with a certain amount of knowledge as the medium, so that this interaction is a creative and meaningful interaction. In educational interaction, knowledge construction occurs through critical examination (Wilkinson, 2019), in which teachers receive feedback from students and students benefit in the form of new knowledge from teachers or peer tutors. This is related to constructivist learning theory which states that students can construct their own concepts of teaching material with the assistance of tools (*scaffolding*) (Lee et al., 2023).

3.4 The effectiveness of one-to-one scaffolding and peer-scaffolding in mathematics learning

The research data in Table 2, after being analyzed using statistical tests, interpreted that the average score of the final test results in all classes (class X-A and class X-B) had increased from the preliminary test results (Table 1). Class learning completeness reached 80% or even more. This suggested that providing scaffolding is effective in improving student learning achievement (Zuo et al., 2023). The increase in learning achievement from the preliminary test score (Table 1) to the final test score (Table 2) indicated a change in students' thinking structure after receiving scaffolding. This means that scaffolding has helped students move across different zones of proximal development (ZPD) (Navaneedhan & Kamalanabhan, 2017).

The success of increasing learning achievement cannot be separated from the teacher who conduct his role as a facilitator (Mahan, 2022) by conducting one-to-one scaffolding according to the student demand in class X-A. Meanwhile in class X-B, students appointed as mentors in peer-scaffolding carry out their roles well. Through the help of scaffolding, learning difficulties experienced by students can be overcome well, so that students' understanding of mathematical concepts becomes stronger and learning achievement increases as well.

The results of statistical test analysis (data from Table 2 compared with Table 3) and data interpretation that have been carried out show that the one-to-one scaffolding and peer-scaffolding methods are both effective in increasing student learning achievement. Thus, providing scaffolding assistance can overcome students' learning difficulties. Judging from the increase from the preliminary score to the final score, the one-to-one scaffolding method has a higher and more effective learning achievement score (Alrawili et al., 2020; Awadelkarim, 2021; Huang, 2019; Kusmaryono, Gufron, et al., 2020). The researchers were not surprised when the research results indicating that learning mathematics with one-to-one scaffolding was more effective than peer-scaffolding. Bearing in mind that the preliminary test results (Table 1) of class X-A students are lower than class X-B students.

Furthermore, to improve understanding of mathematics, children (students) demand to interact with teachers who are considered as smarter than them. The high level of scaffolding required by students is a sign that students have low knowledge or critical thinking. Thus, the students require high levels of scaffolding method.

Why is the one-to-one scaffolding method more effective? Because one-to-one scaffolding has advantages, including: (a) teachers have a lot of knowledge and experience in overcoming student learning difficulties (Awadelkarim, 2021); (b) students can communicate directly with the teacher from heart to heart (one-to-one), (c) students can develop critical thinking through teacher guidance (Gunawardena & Wilson, 2021), (Yu et al., 2024), and (d) students receive appropriate support services according to the task at hand. The one-to-one scaffolding method is more suitable (effective) for increasing conceptual understanding and motivation of students who have low-enhancing understanding abilities (Acosta-Gonzaga & Ramirez-Arellano, 2022; Yu et al., 2024). However, unfortunately, the researchers recommend learning with one-to-one scaffolding which is more often used in mathematics learning. Uncontrolled implementation of the one-to-one scaffolding method can result in students becoming dependent and always expecting help from the teacher. Learning interactions tend to be unidirectional interactions so that students' learning independence develops more slowly.

On the other hand, the application of the peer-scaffolding method is also effective in improving learning achievement (van de Pol & Volman, 2019). The interaction in peer-scaffolding is more in the form of open sharing between students as colleagues, thus allowing critical thoughts to emerge during interactions that are collaborative, assimilation and acculturation . In peer-scaffolding learning, students can learn from fellow students and of course they will be more flexible to deliver their opinions. In this way, students' knowledge can be constructed in their cognitive structures quickly (Haataja et al., 2019; Kusmaryono, Ubaidah, et al., 2020). They are not afraid to ask questions if there is something they don't understand (Tammeleht et al., 2021). They learn without becoming frustrated by things that are currently too difficult for them to achieve and they learn without math anxiety (Kusmaryono et al., 2022).

4. CONCLUSION

The implementation of mathematics learning using one-to-one scaffolding and peer-scaffolding methods is both effective in increasing student learning achievement. Thus, providing scaffolding assistance can overcome students' learning difficulties. Judging from the increase from the preliminary score to the final score, the one-to-one scaffolding method has a higher and more effective learning achievement score. However, one-to-one scaffolding has the potential for greater dependence from students on teachers. The educational interactions that occur in one-to-one scaffolding are directional and assimilative interactions. Peer-scaffolding interaction is more in the nature of open sharing between students as colleagues, thus allowing for interactions that are cooperative, assimilation and acculturation. The results of this research can be considered in the context of direct learning (one-to-one scaffolding) and small group learning (peer-scaffolding) in the future**.** Therefore, it is important for teachers to recognize what types of support can overcome learning difficulties and promote students' mathematical understanding. In future mathematics learning, the peer-scaffolding method should be emphasized more in learning than the one-to-one scaffolding method. Bearing in mind that learning interactions in peer-scaffolding are two-way interactions between students and students in small groups, where students interact more actively in learning, thereby increasing students' critical thinking abilities, and students can learn independently without relying much on teacher help. The limitation of this research only involved respondents in a small sample of less than 100. In terms of methods, researchers were only limited to comparing with one-to-one scaffolding and peer-scaffolding treatments but did not add treatment with technology-based scaffolding, so there were differences in students' interest and motivation towards scaffolding.

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