Scaffolding for elementary students in solving mathematical problems: a case study

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Abstract. Mathematics subject matter does not only emphasize the result of the work but also emphasizes the understanding of the learning process. Previous studies revealed that the failure of students to solve mathematical problems may be caused by the infectivity of the students’ mathematics communication, thus they may need certain scaffoldings, especially in the online distance learning policy during the Covid-19 pandemic outbreaks. This study aims to describe how elementary students require scaffolding in solving mathematics problems. It uses a descriptive qualitative approach. The data were analyzed by using an interactive analysis model. The data were collected by participant-observation and semi-experimental methods. The subjects were four 2\textsuperscript{nd} to 9\textsuperscript{th}-grade students who were undergoing online learning from home policy. Their abilities to solve mathematics problems were observed, then scaffoldings were regarded as becoming the appropriate solution. The result indicated that students’ failure in solving mathematics problems began with their failure to understand the questions. Therefore, when communicating mathematics problems, teachers should ensure that students can understand them well. Besides, even if the questions have been delivered afterward, they frequently hampered at the next stages. Therefore, they do need personalized scaffolding in mathematics. It must correspond to each of their prior knowledge and skills, and be prepared in a clear step-by-step manner.

1. Introduction
Mathematics is one of the sciences needed in life. Unfortunately, it is not the favorite subject for most students, and even many students find that it is boring. Its abstract and systematic characteristics become one of the reasons why the students get difficulty to learn it \cite{1,2}. The integration of character values in mathematics has a positive impact on students’ achievement and behavior, although it also harms the workload of teachers \cite{3}. It proves that teaching this subject will have more burdens than other subjects.

Now, during the outbreak of the Covid-19 pandemic, schools are still running with the switched learning method from classroom learning to online distance learning \cite{4}. The students’ needs to solve mathematics assignment problems correctly become challenges for parents who expect good grades achievements of their children. The most correct choice to achieve this goal is to make them willing...
and able to do them. Parents should support them by providing appropriate scaffolding that improves their skills, not makes them lazier and more spoiled. Besides, even though the internet may be used, it is still often difficult to search for solving mathematical problems due to there are some symbols or expressions that are not easily typed [5].

Choosing the type of scaffolding becomes urgent so that students can still achieve the learning targets set without being substituted by their parents in doing the assignment or cheating. Lin & Singh’s findings emphasize the fact that appropriate scaffolding support commensurate with students’ prior knowledge and skills must be determined through research to be effective [6]. Therefore, this study was conducted to narrate experiences of providing scaffolding for elementary students in solving their mathematical assignments.

A previous study claimed the failure of students to solve mathematical problems may be caused by the infectivity of communication when students misread and/or misunderstand the questions [7,8]. It also can occur if the student misdirects in following instructions. A mathematic work may be correct at the previous steps, but then the final result is wrong because the steps to solve the problem are not done in line with the instructions [9]. However, communication failures should not be blamed on one party. Communication activities are a series of processes that involve communicators, messages, channels, communicants, feedback, and the environment. Each element has an equal chance of causing communication noise or misunderstanding [10]. Thus, the failure should also be evaluated from all of the components. As communicators, the teachers or instructors should consider their audience’s (students) characters, as well as other communication elements to achieve high-quality communications when they send the messages (lessons or instructions). Lest the students could not solve math problems because the subject matters have not been conveyed well to them. This study would discuss students’ failures from the point of view of how teachers are also responsible.

Other studies claimed that the scaffolding provision for students improved their ability. It made some of them be able to correct their mistakes, while others still made similar mistakes but with lower error rates [8,11]. However, it was also found that for problems involving strong alternative conceptions, simply guiding students to work through analogical problem-solving in advance is not sufficient to help most of them distinguish the similarities among problems. On the contrary, they were more likely to see the underlying similarities between problems and avoid being slipped by alternative conceptions when solving the targeted problem when an additional scaffold that directly helps them examine and refine the elements of their knowledge involving alternative conceptions was provided [6]. Therefore, this study would also discuss whether the provision of scaffolding is still needed by elementary students or not.

2. Methods
The current research used a qualitative descriptive approach. The purpose of this type of study is to comprehensively summarize certain events experienced by individuals or groups of individuals [12]. Accordingly, the data were obtained using the participant-observation technique, it produces practical and theoretical truths about human life that is based on the realities of everyday life. It requires researchers to get involved directly as participants in the daily life of the observed subjects so that the world of everyday life opens from an insider’s point of view [13].

Besides being obtained from direct observations and experiences, the data were also obtained from unstructured interviews, semi experiments, and document analysis. Unstructured interviews are appropriately used to explore certain phenomena which are based on the assumption that reality is socially constructed by participants in backgrounds of interest [14]. Semi-experimentation is an investigation of ‘what if’ scenarios that aim to determine the causal properties of the data that can be applied from one data set [15]. Document analysis is a cost-effective way to obtain empirical data which, when combined with data from interviews and observations, will minimize bias and build data credibility [16].

The data collection occurred from July to September 2020. It was recorded in the form of notes, photos, and videos. The data collected included: observed student profiles, the types of math problems
they had to solve, their ability to solve them, and the form of scaffolding that was suitable to help them solve the problems correctly. The data on their ability to solve math problems were obtained from observations when they did the mathematics assignments based on the combination of the IDEAL problem-solving model [17], and Newman Error Analysis (NEA) [7]. The observations were combined with the 'what if' semi experiments to determine the suitable scaffolding according to the implementation of the Anghileri instructions [18] or other means worth trying.

IDEAL problem solving is an abbreviation of ‘Identify, Define, Explore, Act, and Look’. It gives six steps instructions for math problem solving: identifying problems, defining the goal, exploring possible strategies, doing the strategies, and looking back at the results. It is a strategy to increase creativity, increase memory, criticize ideas and generate alternatives, and communicate more effectively with more people [17]. NEA proposes five steps for solving any word math problems: reading the question, identifying what the question asks, finding a strategy on how to answer the question, doing the calculation, and writing the answer to the question [7]. The current research combined the IDEAL and NEA problem solving to become: reading the question, identifying what the question asks, defining the goal, exploring possible strategies, choosing and doing the strategy, writing the answer, and evaluating the results.

Scaffolding is defined as a technique of providing structured learning support, which is carried out at an early stage to encourage students to learn independently. The provision of learning support is not carried out continuously, but along with the increase in student abilities, gradually the teacher must reduce and release students to learn independently. Anghileri [18] suggested 3 levels of scaffolding as a series of mathematics teaching strategies. The first level is environmental provisions in the form of teacher assistance for learning environments that can support learning and classroom arrangement. The second level is the activities of explaining, reviewing, and restructuring. This activity involves direct interaction between teachers and students which is specifically related to the mathematics material being worked on. Explaining means of showing and telling. The strategy limits the pupil contribution, because of the teacher's high control over maintaining the structure of the conversation in ensuring the 'next steps' they have planned. Reviewing is refocusing students' attention to modify experiences and bring mathematics closer to their existing understanding. Restructuring is rebuilding understanding such as simplifying something abstract so that it is easier for students to understand. At the third level of developing conceptual thinking, teacher interaction is directed at developing conceptual thinking. This highest level of scaffolding consists of teaching interactions in the form of developing conceptual thinking by creating opportunities to express understanding. Students are supported to make connections and develop representations of skills and understandings that can be transferred or communicated. In the current research, level 1 of the scaffolding such as a studying room equipped with learning equipment, books, computer, air conditioner, and security (blocking people or things that are considered disturbing) is immediately provided.

The number of observed and interviewed students were 4 students in Makassar, Indonesia: O-1, a 9th-grade junior high school student, O-2, the 8th-grade junior high school student, O-3, the 6th grade of an elementary student, and O-4, the 2nd grade of an elementary student. They were decided to be observed because they had never met and received any direct (offline) lessons from their mathematics teachers since the grade promotion of the new school year in June 2020. The questions that were tested to assess their ability were the original questions given by the mathematics teachers from their respective schools. Besides the limitations due to the outbreak of the COVID-19 pandemic, the total amount of the research subjects was small but considered to be enough, because, in qualitative research, the number of subjects is not the most important, but the essence [19].

The current research uses Miles & Huberman’s interactive model analysis. It is a data analysis circle cycle process from data collection to conclusion which has two ways interactions on data reduction and data display, data reduction, and conclusions, as well as data display and conclusions. by this method, data that has been concluded is possible to be clarified and refined by adding information from repeated or advanced data collection [20,21].
3. Results
O-1 often expressed her pessimism whether she could do the math assignments from school correctly at the very beginning of the 'learning from home policy' were implemented. She reasoned that she did not understand the explanation from her teacher that had given her online learning. She stated that she had chatted with the teacher to get more detailed guidance in completing the assignment, but she still thought that it was delivered in pieces, incomplete, and unclear steps guidance. She admitted that she did several searches on the internet to help him complete the task properly, but could not find it. She might mistype on symbols or expressions as Hodges & Hunger [5] explained. Even so, she still collected her haphazardly done assignments, regardless of right or wrong. "The important thing is that the assignments have been collected," she said. As time went on, it seemed that stereotypes were forming on her. She was getting demotivated. Based on the observation, at the beginning of the new school year, in July 2020, she often hastily claimed that solving math problems is difficult. She said that even before watching, listening, and carefully reading the subject matter, and the problems assigned.

![Figure 1. Mathematics assignments for the observed 1.](image)

Figure 1. Mathematics assignments for the observed 1.

![Figure 2. Observed 1’s answer.](image)

Figure 2. Observed 1’s answer.

Investigations on her ability to solve mathematics problems were done when she got the tasks about the quadratic equations as shown in figure 1. Before continuing to provide scaffolding, firstly, the observer learned the mathematics problems and prepared cues to solve them. The cues steps were found on the internet [22] in English (not the native language of all observed students who are Indonesian), so the observer translated it. When reading the assignment, she remembered that the factoring method was one of the lessons she ever heard taught by the teacher. However, she admitted that she did not understand the meaning of $3x^2$, $11x$, $2x^2$, and $12x$, thus she could not differ among these numerals. She was explained that $x$ is a number that has a certain value, it's just not mentioned, while $x^2$ is the $x$ that is given a square code, and that’s all. This finding means that her reading question ability was still low. Because of that, she was told to open and re-watch/re-read the explanatory material given by her teacher. Also, if there was anything she wanted to ask, she was welcome to ask. Her questions were not answered immediately but began with cues so that she could answer them herself. When she still could not, then the answer was given.

After re-watching the explanations, she acknowledged being a little bit understanding what the questions asked, and what the goals were. She did not have to explore more strategies, since the tasks have determined the strategy. However, when started to run the strategy, she was paused. She seemed
confused and didn't know what to do, so she was directed to note down the samples from the video his teacher had sent, then follow the paths. In several sections, she was shown where attributes come from since she asked. In writing the answer, she still needed supervision since she often did miswrite and/or miscalculation. Finally, when he stated that the assignment had been completed, he was asked if he was sure the answer was the answer to the questions expected. She said: “I don’t know.” Thus, she was asked to re-read the questions, understand what was expected, make sure the pathway that was imitated was appropriate, and ensure that the writing and calculations have been passed were correct. She did what was asked, but seemed rushed and unfocused. The observer (who acted as an instructor) convinced her to be patient and focused on evaluating because this step will determine her success in answering the questions. The hard work she had put in would be in vain if there was an undetected mistake just because of her haste. By these steps of scaffolding, she succussed to do the tasks as shown in Figure 2.

1. Find the equation for the line that passes through the coordinate point (2,7) and is parallel to the line x-2y+12=0!
2. Find the equation for the line that passes through the coordinate point (1,-2) and is perpendicular to the line 2x-y+3=0!

Figure 3. Mathematics assignments for the observed 2.

1. Finding the line that passes the point (2,7) and is parallel to the line x-2y+12 = 0
1.1. Determining the slope (m) of parallel lines formula: m1 = m2;
1.2. Determining x and y by the formula: y = mx + c;
1.3. Rewriting the equation of the problem (line 1) and formatting it according to the formula in step 1.2:
   - x - 2y + 12 = 0
   - 2y = -x – 12
   - 2y = x + 12
   - y = ½ x + 6;
1.4. The slope is found: ½;
1.5. Determining the formula to find the line that passes a point: y - y1 = m (x - x1);
1.6. Determining x and y by point (2,7): x1 = 2, and y1 = 7;
1.7. Determining the line that passes the point (2,7) and is parallel to the line x-2y+12 = 0:
   - y - y1 = m (x - x1)
   - y - 7 = ½ (x - 2)
   - 2y - x - 14 = 0
   - 2y - x - 12 = 0
   - x + 2y + 12 = 0
2. Find the line that passes point (1,-2) and is perpendicular to the line 2x-y+3 = 0
2.1. Finding the slope by transforming the line equation 2x-y+3 = 0 according to the formula:
   - y = mx + c
   - 2x-y+3 = 0
   - 2x+3 = y
   - y = 2x+3
2.2. The slope is found: m1 = 2;
2.3. Determining m2 by using the formula of the perpendicular line slope:
   - m1 * m2 = -1
   - 2 * m2 = -1
   - m2 = -½
2.4. Determining the formula to find the line that passes a point: y – y1 = m * (x – x1)
2.5. Determining x and y by point (1,-2): x1 = 1, and y1 = -2;
2.6. Determining the line that passes the point (1,-2) and is perpendicular to the line 2x-y+3 = 0
   - y – (-2) = (-½) * (x-1)
   - y + 2 = -½x + ½
   - y = -½x + ½ - 2
   - y = -½x - 1½
2.7. Multiplying the equation by 2 to get integers of coefficient and constant, then converting:
   - 2y
   - x + 2y + 3 = 0

Figure 4. Cues for mathematics assignments of the observed 2. 

Mathematics was also not O-2's favorite subject, but she seemed to have better motivation than O-1. When she had a hard time doing a math assignment, the first thing she did was asking the math
teacher, then her parents. If she thought the answer she got was inadequate, she might linger in front of the computer looking for ways to solve her math problems on the internet. If she did not find the answer or the way she was looking for, she used to continue to do the try and error to finish it correctly until she was closed the deadline. If she could not finish it until the deadline, then she gave up and submitted the results of her work as was.

At the time, O-2 got the task of solving problems about the equations of parallel lines and perpendicular lines as shown in figure 3, then the observer prepared the cues as in figure 4. When observed, she had accessed the task since it was first uploaded. It had 10 days limit for being done, but until the 4th day, she has not finished to solve it. Under supervision, he began to do her job by reading questions. Under supervision, she began to do her job by reading questions. She misread question number 2, which was originally the coordinate point (1, -2), instead, he read it (1,2) thus she was given a correction.

At that moment, she admitted that she had not understood the subject matter. She also claimed she was weak in algebra. She did not know what was asked, and the goal. Therefore, she was guided to re-watch and make a note of the tutorial and examples her teacher sent. The observer (who acted as supervisor) added a little definition or explanation about parallel lines, perpendicular lines, slopes, the x,y diagram coordinate point, and algebra. After that, she was asked to follow the pathway. She did it slowly while several times asking where certain numbers or expressions came from. Besides, she had several miscalculations or miscalculated or incorrectly substituted numbers. As it turned out, she was also weak in arithmetic (substitution), so she was told the key-hints of it. The observer supervised her carefully and guided her little by little, while sometimes asking if she was sure of her decision to write a certain number in a certain position. After she finally completed the assignments, she was invited to evaluate her answers. She was willing as long as with guidance in detail because she admitted that she was not able to do it herself.

1. Calculate the results of the following operations:
   1.1. (-12 + 17) * 8 + 12 = ...
   1.2. 24 * (-12): 4 - (-10) = ...
   1.3. 120: (-10) * 8 + (-20) = ...

2. The peak of Mount Merbabu is located at an altitude of 250 m. The Pahalun Shelf is located 525 m below the peak of Mount Merbabu. How high is the Pahalun Shelf?

**Figure 5.** Mathematics assignments for the observed 3.

| 1. Cues for positive and negative numbers calculation: |
|---------------------------------|
| a. precedently complete the parenthetical arithmetic operation |
| b. perform count operations in the order: divide, multiply, add, subtract |
| c. whenever two of the same marks meet (+ meets +, or - meets -), it means / the result is positive (+) |
| d. whenever two different marks meet (- meets +, or + meets -), then it means / the result is negative (-) |
| 1.1. (-12 + 17) * 8 + 12 | = 5 * 8 + 12 |
| | = 40 + 12 |
| | = 52 |
| 1.2. 24 * (-12): 4 - (-10) | = 24 * (-3) – (-10) |
| | = -72 – (-10) |
| | = -72 + 10 |
| | = -62 |
| 1.3. 120: (-10) * 8 + (-20) | = -12 * 8 + (-20) |
| | = -96 + (-20) |
| | = -96 – 20 |
| | = -116 |

| 2. A cue: if it is explained up means positive, and down means negative: |
|---------------------------------|
| Noted: the mountain height | = 250 m |
| the shelf height | = 525 m from the top of the mountain, |
| thus, the shelf height = +250 m - 525 m | = -275 m |

**Figure 6.** Cues for mathematics assignments of the observed 3.
The O-3 acknowledged that he liked math. Although it rarely happened, when he found difficulty in doing math problems, he would ask his parents how to do it or search for answers on the internet. However, just like O-1, if he did not find the answer he was looking for, he would submit his job as it was. The mathematics problems about calculations of positive and negative integers as shown in figure 5 were the tasks he should do when observed. For these, observer prepared cues as the scaffolding preparation as shown in figure 6. Based on observations, he had no difficulty working on these mathematics problems, from the reading of the questions to complete. It's just that, he was not used to evaluating his work. He used to ask his parents to check his work out. Therefore, the observer invited him to practice evaluating himself, and he was willing.

The O-4 preferred playing to studying, especially if the assignment was considered difficult to complete. When working on assignments, he preferred to be read about the questions to reading by himself. He had been able to use his fingers and toes as a tool for calculating addition and subtraction operations up to 100. He was willing to be invited to do the task (to be observed) because he was promised a reward if he wanted to. At the time, he got a multiple-choices maths task as shown in figure 7. To help him answer these questions, the clue prepared was in the form of examples of similar problems and guiding questions as shown in figure 8.

| 1. 8 * 4 = … |
| --- |
| a. 8+8+8+8 |
| b. 4+8 |
| c. 4+4+4+4+4+4+4 |

| 2. Ana prepares 7 plates of cakes. There are 2 cakes placed on each plate. Many of the wholes of Ana’s cakes are… |
| --- |
| a. 9 |
| b. 14 |
| c. 72 |

**Figure 7. Mathematics assignments for the observed 4.**

| 1. Solving 8 * 4 = … |
| --- |
| 1.1. 5 * 7 means there are 5 numbers 7 which are added up |
| 1.2. 3 * 5 means there are 5 numbers 7 which are added up |
| 1.3. So, 8 * 4 means what? |
| 1.4. which of the multiple-choice matches your findings? |
| 2. Many of the wholes of Ana’s cakes are: |
| 2.1. 7 plates * 2 cakes |
| 2.2. 2 cakes + 2 cakes + 2 cakes + 2 cakes + 2 cakes + 2 cakes + 2 cakes =14 cakes |
| 2.3. So, the answer is: b. 14 |

**Figure 8. Cues for mathematics assignments of the observed 3.**

He solved problem number one with the help of clues. At first, he just imagined that there were 7 plates and 2 cakes. He concluded that there were only 2 cakes, but the answer was not there. He was then asked to read the problem carefully but still could not find the key clue of the matter. The observer then pointed to the word "each", but he didn't understand what it meant. Finally, it was explained to him that it means that every single plate has 2 cakes. After that, he solved problem number 2 by imagining that there were 7 plates, each containing 2 cakes. After that, he used his finger to add “2 + 2 + 2 + 2 + 2 + 2”, and he managed to get the correct answer.

**4. Discussion**

Reflecting on the findings, some students may not able to solve mathematical problems because they have not mastered the subject matter yet. Maybe to pursue the results of the specified syllabus, assignments are still given even though students have not mastered them, thus the student's assignments are prone to pile up, as found previously [23–25]. Besides, Tambunan & Naibaho found that all mathematics teacher performance indicators in building high order thinking skills (HOTS) have a very significant influence on student abilities. The indicators were understanding concepts, communication, creativity, problem-solving, and reasoning [26]. Therefore, the failure of students to solve math problems should not only be blamed on them.
Qualitatively, it appears that they failed in the first third of all mathematical problem-solving steps, as seen in table 1. They might fail to solve the problem due to they did not understand the word chosen in the questions by the teacher. Therefore, teachers as communicators have the responsibility of providing appropriate scaffolding in supporting their students in doing assignments. This problem has been anticipated by several teachers who provide video recordings of subject explanations. Unfortunately, some students got bored watching these explanations, especially those that were long or too complex. This finding is in line with previous findings that students expected for instant answers/ways to get the results rather than lingering over to look at detailed explanations [4,27]. According to Hasibuan [28], it is better to postpone new teaching materials than to pile up student misunderstandings. However, it seemed to be impossible, since the specified syllabus should be fulfilled indeed.

**Table 1. Observed students’ motivation, failure, and given types of scaffoldings in Mathematics**

| Observed | Motivation | Read | Identify | Define | Explore | Choose | Write | Evaluate | Scaffoldings |
|----------|------------|------|----------|--------|---------|--------|-------|----------|--------------|
| O-1      | low        | fail | succeed  | fail   | fail    | fail   | fail  | fail     | all          |
| O-2      | medium     | fail | fail     | fail   | fail    | fail   | fail  | fail     | all          |
| O-3      | high       | succeed | succeed | succeed | succeed | succeed | fail   | evaluation |
| O-4      | low        | fail | fail     | fail   | succeed | succeed | succeed | succeed   | reading, identification, definition |

Based on the semi-experimental 'what if' analysis, a detailed but short video explanation presented step by step accompanied by written explanations are more suitable in helping students understand mathematics and complete their assignments. It is in line with the previous study which concluded that detailed support for every investigation made students obtain significant learning outcomes in all components of scientific explanation (i.e., claim, evidence, and reasoning) [29]. McNeil et. al have reminded that this method cannot be used continuously. It must be broken down little by little so that later they can construct scientific explanations their selves when they are no longer equipped with support [29]. However, it can be provided because the students referred to in this study are elementary students. The scaffolding that is given to them may be a good scientific foundation for them to remember. Young children prefer and remember more the explanation of something they seek and want [30].

The students who failed to solve mathematical problems misread or misunderstood the questions. It is in line with the NEA [7]. The semi-experiment resulted that they need detailed and focused supervision to overcome this problem. Student errors would not be detected if the tutor is negligent.

Although the findings of the current study are in line with previous findings that there are students have been able to access the internet and try to find solutions to the problems they are working on [4,31,32], however, it proves that for math problems, the students do not necessarily find the right solution, because this subject field emphasizes not only the result but also on the process of solving the problem. This implies the need for scaffolding which is more intense and personalized for students in doing math assignments compared to other subjects. Thus, different characters of students will require different treatments. This study agrees with the suggestion emphasized by Lin & Singh’s [6] that the scaffolding support should be matched with the students' prior knowledge and skills through research.

Detailed supervision is also needed by children when solving math tasks, because many times they misread, miscalculate, or write wrong, as predicted in NEA [7]. Besides, this study also proves that even though they master some of the early stages of the IDEAL problem-solving model [17], they will not necessarily be able to master the next stages and vice versa.

**5. Conclusion**

Communication that runs effectively is one of the keys to the success of students in completing math tasks. The initial factor that determines whether or not students can solve math problems is their understanding of the grid that is informed by the problem, and identification of what is being asked. Besides, detailed, clear, and easy to remember question-solving instructions (for example: showing the
origin of a number from previous calculations/equations, etc.) delivered during the course material or scaffolding can lead students to solve the mathematics problems. Therefore, it is suggested that the teacher or instructor should provide the subject matter with detailed steps to help elementary school students solve math problems correctly. Besides that, scaffolding is given personally based on the characters of each student. Future research may discuss how to involve and prepare parents who have different levels and majors of education to support the success of children's studies, especially mathematics.

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