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Scaffolding in Supporting Senior High School Students' Critical Thinking Skills in Sequences and Series Problems

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Abstract: Critical thinking skills are important for every individual, that they need to be developed in classroom learning, one of which is through learning sequences and series material. However, there are still many students who have difficulty solving problems on sequences and series material, so they need help using scaffolding. This study aims to describe students' thinking skills on sequences and series material, as well as scaffolding which helps students' critical thinking skills in solving sequence and series material questions. The subjects of this study were 2 students who can't solve the two critical thinking skills tests given. The two students were then interviewed and given scaffolding. The interviews were conducted in a semi-structured manner, that the researcher prepared several questions which could indicate indicators of critical thinking skills, as well as scaffolding which could assist students in solving problems, but the researcher was free to improvise by asking for other information according to the conditions during the interview. The data obtained was then analyzed by reducing the data, presenting the data, and drawing conclusions. The results showed that the students still got difficulty in solving problem that indicated the students' critical thinking skill was still low, so they need scaffolding in the form reviewing, restructuring, explaining, or developing conceptul thinking. Scaffolding in the form of reviewing played a dominant role for supporting the failure of critical thinking skills on the indicators of interpretation, analysis, evaluation and explanation. Restructuring helps the failure of critical thinking skills on the indicators of interpretation. Explaining helps the failure of critical thinking skills on evaluation indicators. Developing conceptual thinking helps indicators of critical thinking skills analysis, inference, and self-regulation.

INTRODUCTION

Critical thinking is one of the most needed thinking skills because it supports creativity through self-reflection, and guides the way of life and decision-making (Shamboul, 2022). Turan et al. (2019), also expressed the opinion that critical thinking is an important thing that individuals need to have for making a better decision. Sutour (in Shamboul, 2022) argues that critical thinking is also the most important cognitive skill in making positive changes to an individual's life, both personal and professional (work) life, which can be developed through training/practice that requires a deep thinking process. Several opinions of these experts show the importance of critical thinking so it needs to be researched and studied in more depth.

Many definitions of critical thinking stated by several experts, one of which is considered the first definition of critical thinking stated by John Dewey (1910) (in Turan et al., 2019) critical thinking is reflective thinking and is described as an active, persistent, and careful evaluation of certain beliefs or knowledge that important in the grounds that support them,

and further inferences on trends in those beliefs. Facione (2015) states that critical thinking is thinking with a specific purpose (finding the truth of a point, giving meaning to what something means, solving problems). Furthermore, Siswono (2016) states that critical thinking is a process of using thinking skills effectively to help someone make something, evaluate, and apply decisions according to what is believed or done.

The importance of critical thinking skills, causes the need to develop components of critical thinking in classroom learning, and becomes a competency goal in learning, one of which is using mathematics. In learning mathematics, indicators of critical thinking can be measured through solving problems/questions that require in-depth analysis and evaluation, or higher-order thinking skills (Shamboul, 2022). One of the materials in mathematics lessons that is often used as contextual problems and problem-solving questions that require higher-order thinking skills is material about sequences and series (Kempirmase et al., 2019).

However, several studies have shown a lack of students' ability in sequences and series material, such as research by Septiahani & Zanthy (2020) which shows that in sequences and series material, students' abilities are still in the low category, with the biggest percentage error in solving sequences and series questions in the context of everyday life. In study conducted by Kempirmase et al. (2019) in grade XI SMA students showed that students' critical thinking skills in solving HOTS questions on sequences and series material were still very low. Ismail et al. (2018) said that in the process of problem solving, each stage requires critical thinking skills, so that student errors in solving these problems can be an indicator of a failure in critical thinking skills.

In overcoming this, scaffolding can be applied to increase student learning motivation (Kusmaryono et al., 2020; Prabawanto, 2018). Pangasta (2021) says that when students have difficulty in solving math problems, the role of the teacher is needed in the form of precise and clear guidance, which will gradually be reduced until students learn independently. This assistance is called scaffolding. This is supported by the opinion of Vygotsky (in Slavin, 2018) that cognitive development is the result of social construction through interaction with other people and the environment, one of which is through the provision of scaffolding to help children build knowledge (zone of proximal development). Scaffolding comes from the word scaffold which means a ladder to step on for construction workers to assist construction (Zheng et al., 2019), so scaffolding in learning can be interpreted as an aid/technique that is carried out in a structured manner to support learning (Maksić & Jošić, 2021). Arifin et al. (2020) said that scaffolding is assistance, both verbally and in writing, given by the teacher to students who cannot complete their assignments independently. Based on the explanation above, the provision of scaffolding can be done outside of learning to help solve math problems (Agustina & Setianingsih, 2017).

Several experts have conducted research on scaffolding, including Arianto (2019) showed that in solving problems, students have a unique thought process which can be improved by giving scaffolding. Research by Kusmaryono et al. (2020) showed that by

providing scaffolding students could correct errors in the process of solving math problems. Research by Arifin et al. (2020) show that scaffolding, in the form of written questions that provide step-by-step directions, is a bridge in the process of solving math problems. Also research by Sunaryo & Fatimah (2019) with the results of research proving that there is an impact of applying a contextual approach to the scaffolding learning model of linear program material to improve students' mathematical critical thinking skills, and showing the score achievement in the experimental class is better than the control class.

Some of these studies have shown that scaffolding has an important role in the process of solving mathematical problems and is effective in supporting to improve students' critical thinking skills, so further research is needed, especially on solving problems of sequences and series. Therefore, this study aims to describe students' critical thinking skills and scaffolding which helps students' critical thinking skills in solving sequence and series problems.

METHOD

This research uses a qualitative approach with case study, that this research is from a certain case, and can be transferred or applied to a social situation (another place) if the other social situation has something in common with the social situation being studied (Siswono, 2010). The selection of a qualitative descriptive research approach was chosen with the aim that the data obtained could be described in more detail (Cohen et al., 2007). This study will describe the critical thinking skills of *Madrasah Aliyah* students in solving sequence and series problems, as well as describe the scaffolding provided to help students who were unsuccessful in their critical thinking skills.

Research subjects were selected purposively by considering the results of critical thinking tests. Subjects who will be interviewed are students who were unsuccessful to solve the critical thinking test given. From the 2 critical thinking questions given, 2 students were selected that they can't solve the critical thinking test for both questions. The selection of this subject is also based on the ability of mathematics and the same gender. Mathematical ability and gender are variables that can affect students' critical thinking skills (Siswono, 2010), so these two variables need to be controlled to make the research focus on students' critical thinking skills and scaffolding that can help these critical thinking skills. The researcher consulted with the mathematics teacher at the school where the data was collected, to find out students who were unsuccessful in solving critical thinking tests with relatively the same mathematical abilities, and had good communication skills.

The following is the relationship between the stages of problem solving (Polya, 2004) and critical thinking skills (Facione, 2015), adapted from Ismail et al. (2018) and Rusani et al. (2021) as a guide in analyzing data on critical thinking skills test results.

1. Understanding the problem, dealing with interpretation, with indicators categorizing information in the problem (what is known and what is being asked), and explaining the intent of the problem in the problem.

2. Planning a problem solving strategy, related to analysis and evaluation. Indicators of analysis, those are identifying the concepts used in solving problems, making connections between concepts, statements, and questions in compiling problem solving, and making steps in the problem solving process. And the evaluation indicators are evaluating the correctness and effectiveness of problem solving steps.
3. Implementing the strategy and solving the problems, dealing with evaluation, inference and explanation. The evaluation indicator is carrying out calculations correctly according to the problem solving steps made. The inference indicators are drawing conclusions from the calculation results, and mentioning additional information to solve the problem. The explanation indicators are writing the final results correctly, and making logical statements to answer the problems in the questions.
4. Re-checking and reflecting, related to self-regulation, with indicators is reviewing what has been done by re-reading the questions, and re-checking the calculations.

In the data collection process, researchers used critical thinking tests and interviews. The critical thinking test given is in the form of 2 questions about sequences and series which require critical thinking skills in the process of solving them. Then the implementation of interviews is intended to clarify students' critical thinking skills, as well as to provide scaffolding as an aid for students' critical thinking skills.

Critical thinking test results data were analyzed using critical thinking indicators that have relation with problem solving as mentioned above. In addition, interview data analyzed using the Miles, Huberman, and Saldana (2014) analysis technique which consists of data reduction, data presentation, and drawing conclusions. The research data credibility is maintained by conducting source triangulation and technical triangulation. Source triangulation was carried out by comparing and contrasting data from different informants (Rukminingsih et al., 2020), by selecting 2 subjects who were unsuccessful in solving the test. Technical triangulation in this study was carried out using several methods in data collection (Rukminingsih et al., 2020), by written tests of critical thinking questions and interviews.

RESULT AND DISCUSSION

Description of S1's Critical Thinking Skills in Solving Problem Number 1 and Scaffolding to Help Her Critical Thinking Skills

Subject 1 is a student with the wrong answer category for both question numbers (S – S), with the indicators of critical thinking skills in answer number 1 fulfilled only in the interpretation of the questions, while the indicators for analysis of problem solving are not fulfilled, causing indicators of evaluation, inference, and explanation in determining the final answer is also not fulfilled. The following is S1's answer to question number 1.

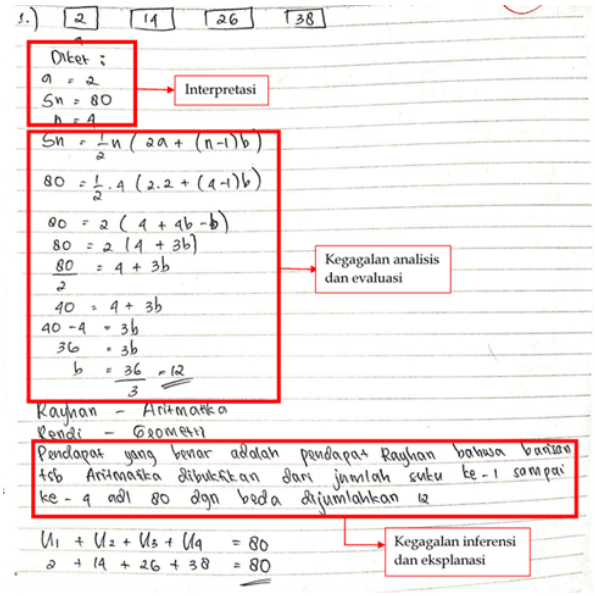

Figure 1. S1's Answer to Question Number 1

Based on Figure 1 it can be seen that S1 understands the questions well, shown from the coding of information known from the questions. It shows that S1 did the interpretation well. However, when analyzing and evaluating problem solving, S1 only tries to make an arithmetic sequence, and assumes that the answer is correct. When interviewed, the researcher provided scaffolding in the form of reviewing to ask for other possible answers, "*if it is proven that an arithmetic sequence can be made like Rayhan's opinion, will it definitely mean that Rendi's opinion is wrong?*". From the scaffolding provision, S1 said that maybe Rendi's opinion was also right, but S1 did not try to make the geometric sequence because he was confused and ran out of time.

Researchers provide scaffolding and guidance for S1 to find geometric sequences that can be made. The scaffolding provided is in the form of explaining and reviewing, this is because in finding ratios using geometric series, S1 still does not understand the concept of polynomial equations of degree more than two. Following are S1's answers in making geometric sequences after getting scaffolding.

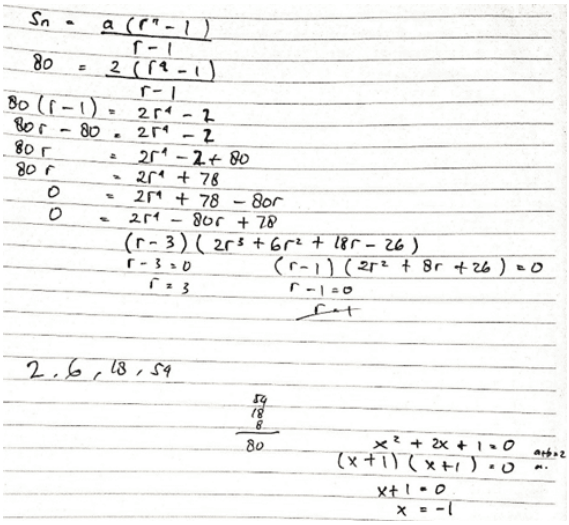

Figure 2. S1's Calculations in Finding Geometric Sequences in Problem Number 1

From Figure 2 it can also be seen that S1 can't make conclusions to solve problem number 1. After finding geometric sequences according to the provisions of the problem, S1 was given scaffolding in the form of developing conceptual thinking to make connections between the problems in the questions and the calculations that have just been she did. From the given of scaffolding S1 can explain the correct and logical conclusion, that with the provisions of the problem, arithmetic and geometric sequences can be made. From the interview results it can also be seen that S1's self-regulation in solving problem number 1 increased along the provision of scaffolding, at the beginning of the interview process S1 seemed doubtful in making geometric sequences, but at the end of the interview process S1 was able to state confidently about the conclusions and final answers.

Description of S1's Critical Thinking Skills in Solving Problem Number 2 and Scaffolding to Help Her Critical Thinking Skills

Subject 1 answered question number 2 incorrectly, this was because the interpretation of the information in the question was not quite right, which had an impact on the process of analysis, evaluation, inference, and explanation in solving the problem in question number 2. The following is S1's answer to question number 2.

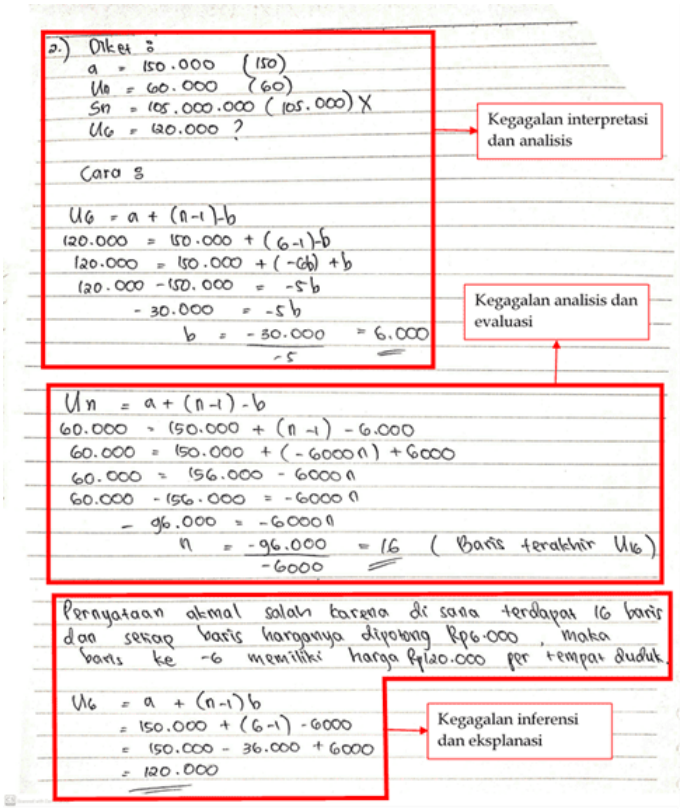

Figure 3. S1's Answer to Question Number 2

In Figure 3 it can be seen that S1 did not understand the information given in the problem, and it was resulting an error in taking the problem solving strategy. To help S1 understand the questions, the researcher provided scaffolding in the form of reviewing and restructuring by asking S1 to re-read question number 2 and then assisted by researcher by

emphasizing important words and asking questions to state information on the questions in mathematical language.

Providing scaffolding can help S1 to classify information that is known in the problem, so that S1 knows which information can be used to solve the problem. In addition, the researcher also provides scaffolding in the form of questioning about concepts that can be used as problem-solving strategies, this helps the S1 analysis process in Figure 3 which was previously inaccurate in making a plan. The researcher also provided S1 with scaffolding to assist analysis and evaluation in calculating the completion of problem number 2.

The researcher also provided scaffolding in the form of reviewing by asking whether the calculations were correct, besides that scaffolding was also provided to make connections between the results of the calculations and their meaning associated to the questions. From the scaffolding provided, S1 succeed to get that the ticket price of 120,000 should be in the fourth row. The following is S1's answer after getting scaffolding.

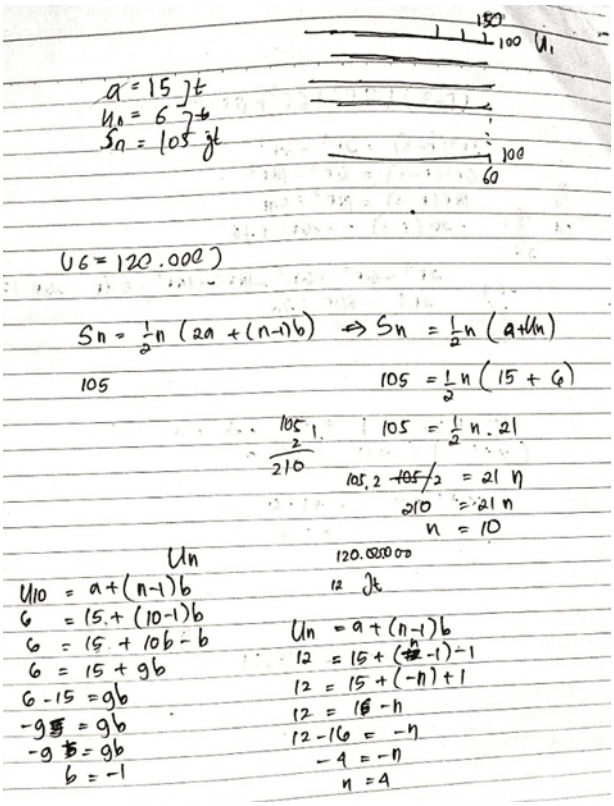

Figure 4. S1's Answer after Getting Scaffolding in Question Number 2

After S1 gets the answer that the price of 120,000 is in the fourth row, then the researcher provides scaffolding in the form of developing conceptual thinking to make connections between the results of the calculations and the problems in the questions, so that appropriate conclusions can be drawn.

From the results of the interview, S1 often confused in determining the next steps that must be taken, but after getting scaffolding S1 was able to continue her calculations in completing her answers, this shows S1 has less self-regulation, but increases along with the provision of scaffolding.

Description of S2's Critical Thinking Skills in Solving Problem Number 1 and Scaffolding to Help Her Critical Thinking Skills

Subject 2 is a student with the wrong answer category for both question numbers (S – S), with the indicators of critical thinking skills in answer number 1 fulfilled only in the interpretation of the questions, while the indicators for analysis of problem solving are not fulfilled, resulting the indicators of evaluation, inference, and explanation in determining the final answer is also not fulfilled. The following is S2's answer to question number 1.

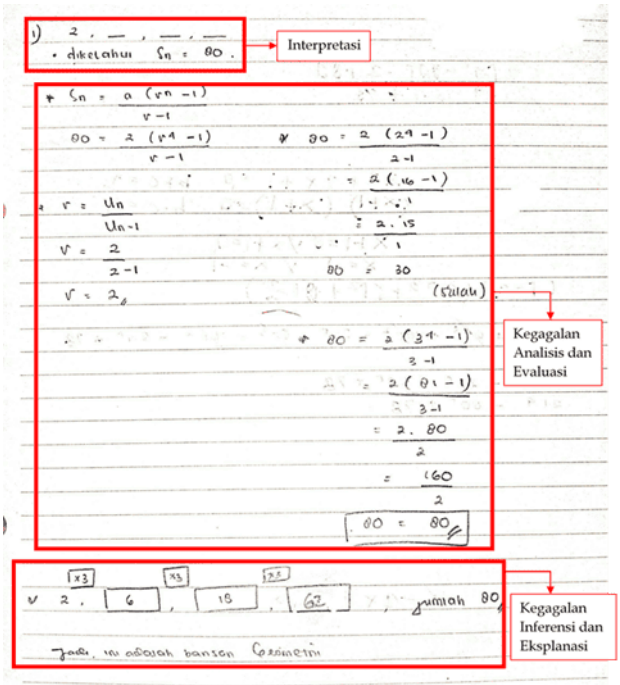

Figure 5. S2's Answer to Question Number 1

S2's answer to question number 1 can be seen in Figure 5, from the picture it can be seen that S2 understands the intent of the question, indicated by the categorization of information known in the problem. When interviewed S2 was also able to explain that the information known in the problem was $a = 2$, there were 4 numbers ($n = 4$), and the number was 80. However, S2 was still unsure whether 80 was the sum of the four numbers or the fourth number. This confusion was then assisted by the researcher using scaffolding in the form of restructuring by emphasizing the important sentence in the problem, "*Look again at the sentence in the problem, make 4 numbers that have a pattern and add up to 80, what does that mean?*". After being given scaffolding S2 was sure of what he wrote on the answer sheet, that $80 = Sn$.

Furthermore, when interviewed about the method used to solve the problem, S2 explained that at first he would use the geometric series formula to get the ratio between terms, but because he was confused about how to factor polynomials with degrees greater than 2, so S2 tried to enter any number in the ratio to get the sequence number which has total 80. However, in entering the fourth number S2 was wrong, and based on the results of interviews S2 was not focused when doing the calculations. After being given scaffolding in the form of reviewing to ask whether the geometric sequence that was made was correct, S2

realized his mistake and corrected the answer that the fourth number should be 54. After getting the geometric sequence in question, the researcher gave scaffolding in the form of reviewing by asking whether other number sequences could be made that met the requirements in the questions, S2 looks confused, so scaffolding is given in the form of explaining that an arithmetic sequence can be made according to the provisions of the problem by finding the difference between the number in the sequence. Following are the results of S2 after obtaining scaffolding in making arithmetic sequences.

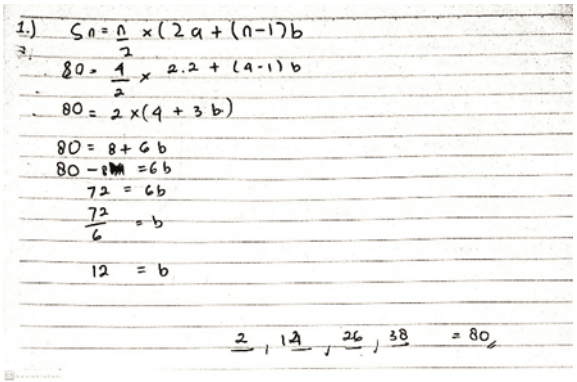

Figure 6. S2's Answers in Making Arithmetic Sequences after Obtaining Scaffolding

From Figure 5 it can also be seen that S2 can't make conclusions in solving problem number 1. After getting scaffolding and finding an arithmetic sequence according to the provisions of the problem, S2 was given scaffolding in the form of developing conceptual thinking to make connections between the problems in the questions and the calculations that she just did. The given scaffolding helps S2 to explain the correct and logical conclusion, that with the provisions of the problem, arithmetic and geometric sequences can be made. The interview results also showed that at the beginning of the interview process S2 seemed doubtful about the answer in making geometric sequences, and confused in making arithmetic sequences. However, at the end of the interview process S2 were able to state confidently about their conclusions and final answers, this shows that S2's self-regulation in solving problem number 1 increased along with the given of scaffolding.

Description of S2's Critical Thinking Skills in Solving Problem Number 2 and Scaffolding to Help Her Critical Thinking Skills

Subject 2 answered question number 2 incorrectly, and just indicated one of the five indicators of critical thinking skills on the answer sheet. S2 fulfills the interpretation indicator, it is shown from the answer sheet that she categorizes the information that is known in the question. When interviewed, S2 also explained that she understood the intent of the questions, but she was confused in preparing the steps for solving them. The following is S2's answer to question number 2.

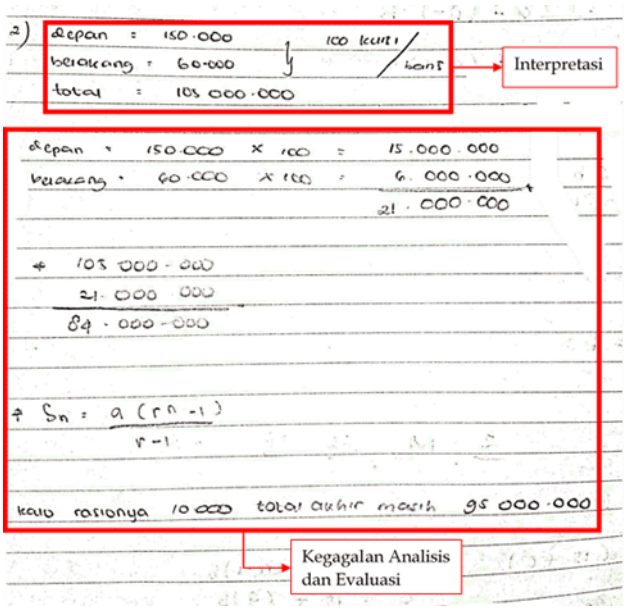

Figure 7. S2's Answer to Question Number 2

Figure 7 shows S2's answer in solving question number 2. From the picture it can be seen that S2 was confused in making steps to solve the problem in question number 2, which shows a failure in analysis and evaluation. After being interviewed, S2 said that she was confused and did not know what to do to solve problem number 2, so she concocted a solution strategy. This needs to be given scaffolding in the form of developing conceptual thinking by asking what concepts can be used in solving problems based on the information known in the questions. The researcher asked the question, "In the problem it is known that the different prices for each row are the same, which means what row pattern that the seat have?" After getting scaffolding, S2 knows that the concept she should use is an arithmetic sequence and series, and the first thing she has to do is find the number of rows of seats using the arithmetic series formula.

After getting n (the number of rows of seats) is 10, then S2 is given scaffolding in the form of encouragement questions, "*After we know that there are 10 rows of seats, then to find out at a price of 120,000 is in which row, what should be done next*", S2 knows that the next step is to find the price difference between rows, but S2 is confused about what formula to find the difference. The researcher provides scaffolding in the form of reviewing by directing S2 to recall the information known in the problem, namely ticket prices in the first row, prices in the last row (tenth row), and the amount of money collected if all tickets are sold. The provision of scaffolding helps S2 to decide that she will find the difference in ticket prices for each row using the arithmetic sequence formula, and get $b = -1$ (the price for each row decreases by 1 million). After getting the price difference between rows, S2 immediately realized that if in the first row the price for each seat was 150,000, then the prices for the next row would be 140,000, 130,000, 12,000, and so on. The following is S2's answer after getting scaffolding.

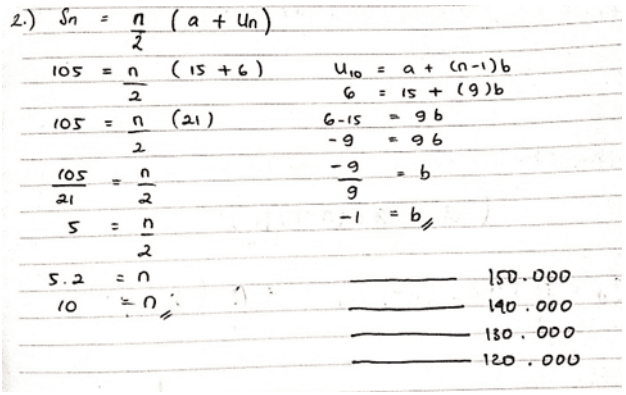

Figure 8. S2's Answer after Getting Scaffolding in Question Number 2

S2's answer in Figure 8 shows that S2 could not make conclusions because she was confused in making the steps to solve the problem. This indicates that S2 was unsuccessful in inference and explanation. To help S2, researchers provide scaffolding in the form of developing conceptual thinking by directing S2 to recall the problems in the questions, then relate them to the results of her calculations. So S2 can conclude that with a price of 120,000 per seat it is in the fourth row, so the crew gives the wrong ticket in the sixth row. From the interview results it can also be seen that S2 is often not thorough in doing calculations, but when reminded to use scaffolding in the form of reviewing by asking, "*Are your calculations correct?*", S2 immediately realized her mistake and immediately corrected it. This shows that S2 self-regulation increases with the provision of scaffolding.

Based on the result above, the scaffolding given to S1 and S2 can be seen in the Table 1 below.

Table 1. The Scaffolding Given to the Subject

Indicators of Critical Thinking Skills	Scaffolding Given to S1	Scaffolding Given to S2
Interpretation	a. Reviewing (asking the subject to read carefully the information given, and giving question to make sure the subject's understanding) b. Restructuring (emphasizing important sentences given in the question)	Restructuring (emphasizing important sentences given in the question)
Analysis	Reviewing (questioning about another sequence that can be made)	a. Reviewing (questioning about the truth of the geometric sequence that has been made) b. Developing conceptual thinking (making a connection about concept for solving the problem based on information known)
Evaluation	a. Reviewing (substituting the information given to the formula of geometric series) b. Explaining (giving explanation about polynomial with high degree)	a. Reviewing (reminding the subject about information given in the question) b. Explaining (giving explanation that an arithmetic series can be made based on the provision given)

Continuation Table 1. The Scaffolding Given to The Subject

Indicators of Critical Thinking Skills	Scaffolding Given to S1	Scaffolding Given to S2
Inference	Developing conceptual thinking (making connection the calculation with the problem given)	Developing conceptual thinking (making connection the calculation with the problem given)
Explanation	Reviewing (questioning what step chosen by the subject to get the final result)	Reviewing (questioning what step chosen by the subject to get the final result and whether the calculation is correct)
Self-regulation	Developing conceptual thinking (making connection the calculation results with the sequences and series concept, and also the information known)	Developing conceptual thinking (making connection the calculation results with the sequences and series concept, and also the information known)

The results of the analysis regarding critical thinking skills and scaffolding in S1 and S2 in solving questions number 1 and number 2, several points can be concluded as follows.

1. S1 and S2 can't solve questions number 1 and 2 with the characteristics of evaluation questions for sequences and series material
2. Difficulty to complete the Critical Thinking Skills Test questions indicates that the S1 and S2 get unsuccessful on the indicators of critical thinking skills and need help with scaffolding
3. Scaffolding is provided to help critical thinking skills for S1 and S2 in the form of reviewing, restructuring, explaining and developing conceptual thinking

CONCLUSION AND SUGGESTIONS

Students still get difficulty in solving problems related to sequences and series material. This difficulty indicates that students still get unsuccessful in critical thinking skill and need to be assisted using scaffolding. For supporting students to solve question number 1 which is formal problem related to arithmetic sequences and series, also geometric sequences and series, the students were given scaffolding in the form of reviewing, restructuring, explaining, and developing conceptual thinking. For supporting students to solve question number 2 which is contextual problem related to arithmetic sequences and series material, the students were given scaffolding in the form of reviewing, restructuring, and developing conceptual thinking.

The results of the interviews show that the provision of scaffolding in the form of reviewing plays a role which is supporting the critical thinking skills on the indicators of interpretation, analysis, evaluation, and explanation. Restructuring helps indicators of interpretation critical thinking skills. Explaining helps the critical thinking skills on evaluation indicators. Developing conceptual thinking helps critical thinking skills on the indicators of analysis, inference, and self-regulation. In this study the improvement of critical thinking skills can be seen that the subjects were able to solve the problem well after being given scaffolding.

Based on the results of the study, it shows that reviewing is scaffolding which plays a dominant role in overcoming students' unsuccessful in critical thinking indicators, so that

in classroom learning it is necessary to review regularly, especially for students who were unsuccessful in critical thinking skill indicators.

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