Development of soft scaffolding strategy to improve student's creative thinking ability in physics

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Abstract. Student's creative thinking ability in physics learning can be developed through a learning experience. However, many students fail to gain a learning experience because of the lack of teacher roles in providing assistance to students when they face learning difficulties. In this study, a soft scaffolding strategy developed to improve student's creative thinking ability in physics, especially in optical instruments. The methods used were qualitative and quantitative. The soft scaffolding strategy developed was called the 6E Soft Scaffolding Strategy where 6E stands for *Explore* real-life problems, *Engage* students with web technology, *Enable* experiment using analogies, *Elaborate* data through multiple representations, *Encourage* questioning, and *Ensure* the feedback. The strategy was applied to 60 students in secondary school through cooperative learning. As a comparison, conventional strategies were also applied to 60 students in the same school and grade. The result of the study showed that the soft scaffolding strategy was effective in improving student's creative thinking ability.

1. Introduction

Each can think creatively, but the ability is still potential. Creative thinking ability in Physics means the ability to think in creating an original idea to solve a problem related to Physics, where the resulting idea is new is the surface capability of a student [1]. Student's creative thinking ability is important to be improved in Physics learning because it can assist students to solve problems in everyday life [2].

The low ability of student's creative thinking was described by some international research results such as TIMMS and PISA scores in recent years. The empirical results of preliminary research also showed that students were not guided to find material-related issues independently. Even students were rarely asked to write down or mention some alternative solutions to one problem that students face. Teachers only played a role in directing students to determine the most effective solution to solving a problem or testing a hypothesis. It was also not supported by the evaluation process of the solution taken as one form of follow-up of decision-making by students.

Many studies had led to the improvement of creative thinking ability, one of them by developing learning process through cooperative learning [3], because life experiences in learning process may have stronger impacts on creative thinking [4]. The implementation of cooperative learning in Physics will not obtain optimal and meaningful results in improving student's creative thinking ability if there

are still many students who experience learning difficulties especially in optical instruments material that requires a good conceptual understanding [5]. One strategy that can be combined in cooperative learning is soft scaffolding. Soft scaffolds are dynamic, situation-specific aid provided by a peer teacher to help the learning process. Soft scaffolding requires teachers to continuously diagnose the understanding of learners and provide timely support based on student responses [6]. Scaffolding tool can be designed to help students reflect on their thoughts on different levels of cognitive processes when working on or with their ideas [7]. It means soft scaffolding can be designed as a tool to help students in Physics through cooperative learning.

This study has two objectives, firstly, we developed a soft scaffolding strategy in physics learning especially in optical instruments material through cooperative learning. Secondly, we applied the soft scaffolding strategy to describe the enhancement of student's creative thinking in optical instruments.

2. Method

The methods of this research were qualitative and quantitative. This research was conducted in two phases of development and measurement. In the first phase, we developed the soft scaffolding strategy and the second phase we applied the soft scaffolding to measure student's creative thinking in optical instruments. According to Borg & Gall, research and development is a process used to develop and validate the products that are used in education and learning. The procedures in this study were using the Research and Development (R & D) by Borg and Gall.

Finally, the strategy developed was called the 6E Soft Scaffolding Strategy. Content and construct validity were done by three experts using questionnaires with Likert scale and analyzed by descriptive analysis. The cognitive test instrument to measure student's creative thinking ability after the implementation of the strategy was analyzed using Product Moment Pearson equation to describe the validity and using Alpha Cronbach equation to describe the reliability of the instrument.

The second phase was a phase of measurement. This stage involves 120 students in secondary school, of which 60 students were taught using soft scaffolding strategy and as a comparison, conventional strategies were also applied to 60 students in the same school and grade. The creative thinking ability aspects assessed were flexibility, fluency, originality, and elaboration. Analysis of the improvement and comparison of student's creative thinking ability were done through the pretest and posttest scores by using inferential statistical analysis of t test. The analysis was also supported by the result of the average gain analysis to describe the level of effectiveness of soft scaffolding strategy. The effectiveness of soft scaffolding strategy was also supported by the descriptive analysis results of the implementation of learning, teachers' performances, student learning activities, and student responses.

3. Result and discussion

In the first step, we develop soft scaffolding strategy. In the second step, the effects of the soft scaffolding were discussed. Results of the expert's validity analysis showed the soft scaffolding strategy was feasible to be used. The content validity analysis showed the percentage of 83% which means very high and the construct validity analysis showed the percentage of 87% which also means very high. Finally, the strategy developed was called the 6E Soft Scaffolding Strategy where E6 stands for E1 (*Explore* real-life problems), E2 (*Engage* students with web technology), E3 (*Enable* experiment using analogies), E4 (*Elaborate* data through multiple representations), E5 (*Encourage* questioning), and E6 (*Ensure* the feedback). Specific soft scaffolding strategy can be seen in figure 1.

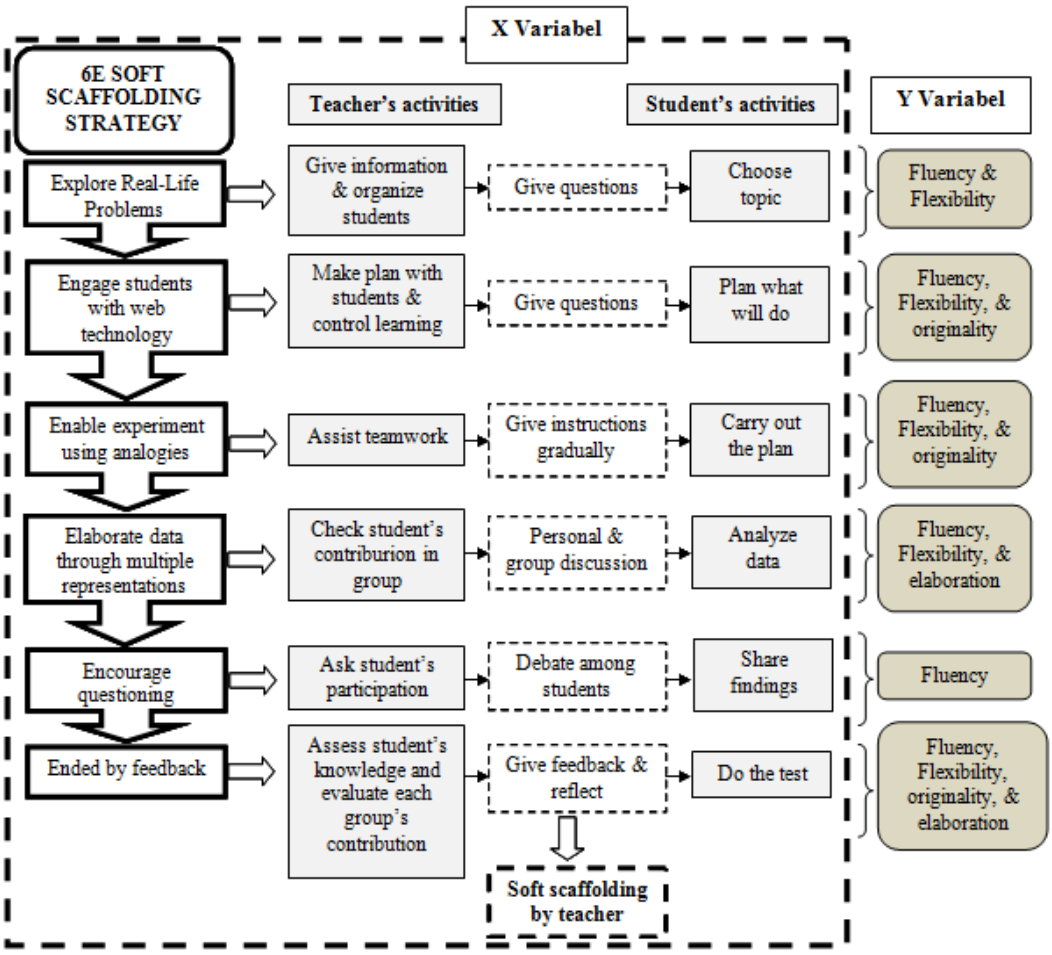


Figure 1. The soft scaffolding strategy developed through cooperative learning of group investigation.

We also examined the instrument used to measure student's creative thinking. The result of validity and reliability of creative thinking ability instrument which consisted of 10 items showed that the instrument was valid and reliable to be used.

The result of this study showed that the soft scaffolding strategy was efficient to improve student's creative thinking in physics, especially in optical instruments material. The effectiveness of the soft scaffolding strategy in improving student's creative thinking ability in Physics learning was known from some indicators, they were (a) the achievement of learning objectives, (b) the achievement of student's learning activity, (c) the achievement of teacher's performances, and (d) students' positive responses [8].

The achievement of learning objectives in experimental class was described by figure 2 which showed the improvement of students' creative thinking ability significantly with the sig value < 0,05 at the real level of 5%, n-gain analysis also show that strategies such as Figure 1 were effective to be used with mean value of gain were 0,7. The control class that implemented the conventional strategy shows a gain value of 0.2 which means less effective. The result of effect size test using Cohen's showed the result that soft scaffolding strategy gives effect in the medium category.

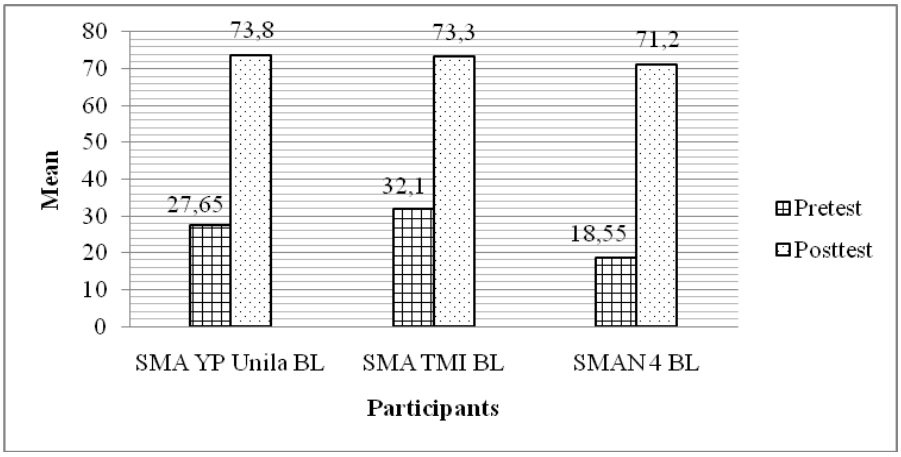


Figure 2. The enhancement of students' creative thinking ability in experimental class

Figure 3 showed the highest percentage of all aspects of creative thinking ability is fluency. Fluency was the ability to think smoothly indicated by several indicators such as the student replied with some answers if there were a question, smoothly expressed his ideas, and could quickly see the errors and weaknesses of an object or situation.

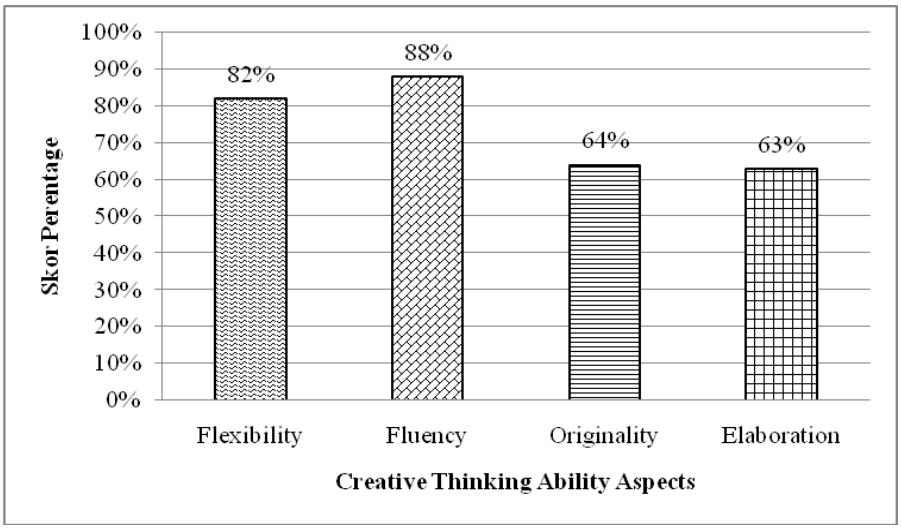
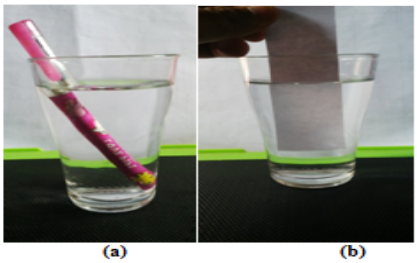


Figure 3. The attainment of creative thinking ability aspects in experimental class

But overall the achievement of students' creative thinking ability based on posttest results was in high category. The achievement of student's learning activity was described by observation score percentage of 72% which means in high category, and teacher's performances got the percentage of 89% which means in a very high category.

Perhatikan gambar dan bacalah ilustrasi berikut.



(a) (b)

Seorang siswa melakukan sebuah eksperimen yaitu memasukkan pensil ke dalam gelas berisi air. Setelah diamati, pensil terlihat patah seperti Gambar (a). Kemudian, anak tersebut mengeluarkan pensil dari gelas berisi air tersebut, lalu memasukkan sepotong kertas HVS ke dalam gelas tersebut. Setelah diamati, ternyata hasil yang ditunjukkan kertas pada Gambar (b) tersebut tidak terlihat patah seperti pensil dalam Gambar (a). Apa yang menyebabkan kondisi pada Gambar (a) dan (b) berbeda? Buatlah dugaan atau hipotesis untuk menjelaskan peristiwa tersebut.

Figure 4. The example question of fluency aspect.

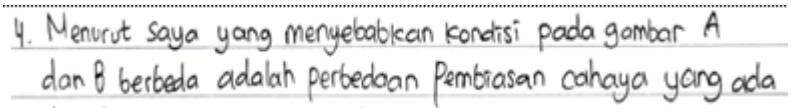


Figure 5. Student's answers in the pretest

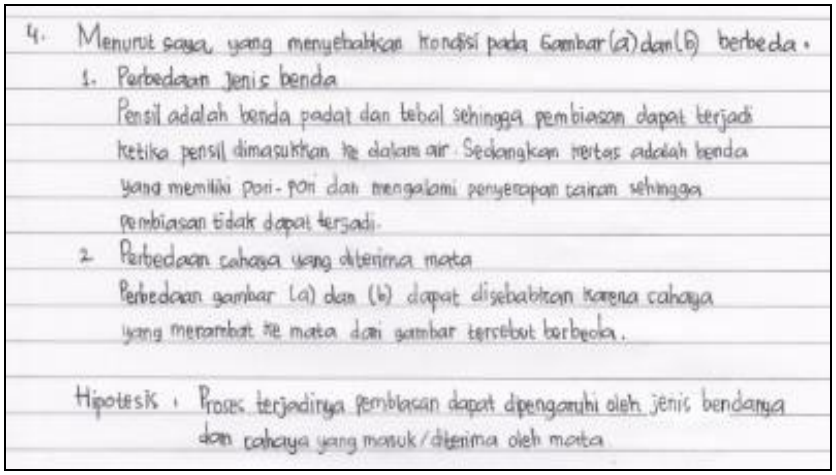


Figure 6. Student's answers in the posttest

The general finding of the improvement of student's creative thinking in fluency described through student's answers like a figure 4, 5 and 6. Optical instruments are closely related to the concept of light refraction. When students were asked about the different appearance of two phenomena related to light refraction in [the pretest], the students only answered that the two phenomena were different because of different refraction processes like a figure 5. The student answered without describing his idea through the reason why he answered so and the student has not been able to reveal more than one answer. He just mentioned that phenomena could happen because of the different light refraction without giving a reason why the factor was the cause of the differences between two phenomena. But after learning through the developed strategy, students' answers become more accurate and diverse. Students were also able to give two ideas like a figure 6. He could explain that light refraction can only occur in solids rather than porous objects, then he was able to mention that the difference of light travels to the eye could also affect the refraction of light. The answers given by the student were

correct and logical. The student could express his ideas through the reasons of the answer given, even the student found the concept that the refraction was determined by the object.

The other general finding was found when researcher interviewed students after the posttest related to the question number 4 like a figure 4. Students stated that they were able to answer that question like a figure 4 because during the learning process the teacher allowed the students to access information using the web or the internet. Students stated that they could explore new information to develop their ideas through the web. The teacher gave instructions on what information was relevant related to the students' activities, including the design of the project, the phenomena of light reflection and refraction, optical tools in everyday life, and so on. Applying web-based learning evidently could improve students' ability to think fluently through instruction given by teachers [9].

The overall improvement of student's creative thinking ability was caused because students were involved in exploring real-world context physics problems [10], by students discovering problems related to tools to see the solar eclipse and the spearfishing systems through observation method. Web technology also played a role in learning [11], this was shown when students made a plan to create the pinhole camera and the spearfishing system using laptops and the internet in groups through discussion. Students are also stimulated to develop analogy skill [12], they attempt to apply forced analogy in processing tools and materials and linking the concepts of lasers and the spearfishing system. Students make a presentation of data and analysis in the form of multiple representations through diagrams and figures [13]. Students' creative thinking ability also increase when teachers implement the strategy of encouraging questioning [14], through debate activity. The description of soft scaffolding that teachers have successfully implemented can be seen in table 1.

Table 1. Soft scaffolding summary given in learning process

Learning phase	Stage of student's difficulties	Soft scaffolding form	Creative thinking ability successfully improved
Topic selection by using E1 strategy	Describe observation results	Give 5W questions	Fluency & flexibility
	State physics fundamental principles	Give key questions	Fluency
	Ask or answer quantitative questions	Give key questions	Fluency
	Propose an assumption	Give signal questions	Flexibility
	Choose an assumption	Give signal questions	Fluency
Cooperative planning by using E2 strategy	Find keywords to get information on the web or internet	Give signal questions	Flexibility
	Collect some important information sources	Give signal questions	Originality
	Bring together ideas from some sources into meaningful information	Give key questions	Elaboration
	Find new ideas	Give key questions	Originality

	Design procedures	Give key questions	Fluency
Implementation by using E3 strategy	Do the experiment	Give instructions gradually	Fluency
	Collect data	Give instructions gradually	Fluency
	Make an analogy	Give instructions gradually	Flexibility
Analysis & synthesis by using E4 strategy	Make a report	Have personal and group discussion	Elaboration
Presentation the final product by using E5 strategy	Evaluate and ask questions or responses to the topics presented.	Have debate activity	Fluency
Evaluation by using E6 strategy	In this phase, the teacher evaluated by holding a written test to measure the achievement of students' creative thinking ability. Soft scaffolding that teachers gave as feedback is by sharing in the form of weaknesses and strengths of each group.		

Based on table 1, the strategy was implemented through cooperative learning of group investigation and teachers provided soft scaffolding intensively and continuously based on student's difficulty. When students had difficulty in the topic selection stage and cooperative planning that implement the E1 and E2 strategies, the teacher gave soft scaffolding through giving questions for students [15], for example in finding the same idea of two articles and in making procedures of a pinhole camera and a spearfishing system. The questions consisted of 5W questions, key questions, and signal questions. In the implementation stage that implement the E3 strategy, teacher gave soft scaffolding through giving instruction gradually [16], especially how to collect the data related to the hypothesis and find the analogies. In the analysis and synthesis stage that implements the E4 strategy, the teacher gave soft scaffolding through giving discussion [17], especially how to interpret the data in diagrams and figures. In the presentation of final product stage that implements the E5 strategy, the teacher guided students in debate activity [18]. In the presentation of final product stage that implement the E5 strategy, teacher only gave feedback to students as the evaluation of their contributions in learning.

Researcher also found that conversation and interaction between students and teachers were very important to this strategy. Creative thinking ability indicator could directly indicated when student and teacher had discussion like a table 2.

Table 2. The example of interaction between students and teachers using soft scaffolding

Learning phase	Stage of student's difficulties	Interaction between students and teachers using giving signal questions
Cooperative planning by using E2 strategy	Bring together ideas from some sources into meaningful information	The questions the teacher asks are as follows. Look at source A, what did the author mean when writing that ....? Now consider the other source, what was the meaning of the idea written by the author in the paragraph ....? What conclusions were derived from these sources? Is there a common opinion with that written by some sources? Try to describe the similarity of opinion.

	These are the students state: "Pinhole cameras from source A were able to take pictures in cloud even at night, but pinhole cameras from source B were only capable of capturing images when the weather was sunny or there was a light source. It turns out that two forms of pinhole cameras produced were different and made of different tools and materials. It means that the working principle of pinhole cameras depend on the shape and the tools and materials used. So it could be wrong that the pinhole camera can not be used when there was no light. "

Based on table 2, through soft scaffolding in the form of signal questioning, students were able to develop elaboration skills. This was shown based on the findings of the researcher that students are able to develop an idea from source A by adding information from source B to become a unity.

4. Conclusion

From the analysis and discussion, it can be concluded that the soft scaffolding strategy can be used to improve student's creative thinking in physics especially in optical instruments. The soft scaffolding strategy can help the teacher to help students who have difficulties in learning physics. Students also learn better because the strategy not only develops their creative thinking but also their mathematic skill and conceptual understanding in physics so that the soft scaffolding strategy can promote higher order thinking skills.

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