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PROCEDURAL *E-SCAFFOLDING* IN IMPROVING STUDENTS' PHYSICS PROBLEM SOLVING SKILLS

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Abstract

The purpose of this study was to design scaffolding that is connected to an ICT system (e-scaffolding) which was implemented with blended learning to improve students' physics problem solving skills (PSS). The research method used is Borg & Gall research method and the effectiveness test used is T-test in analyzing whether there are differences physics PSS in the experimental and control classes. This article describes scaffolding systems that focus in procedural types which using prompt questions and facts found during the implementation of this product. The results showed that the developed e-scaffolding was appropriate to be used for several examinations after being evaluated by experts and practitioners. In a limited implementation, e-scaffolding has proven not to be out of the social constructivist scope and adapted to the actual abilities of students. At effectiveness test, e-scaffolding is able to connect between students in solving problems both in synchronous and asynchronous collaboration. In addition, e-scaffolding is able to split problem categories that students are experts and beginners, giving shape to performance and increasing students' physics PSS. So, it can be concluded that e-scaffolding has been successfully developed. Suggestions for further research have been presented in this article.

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INTRODUCTION

Problem Solving Skills (PSS) is an important domain in supporting "life capabilities" to lead to a knowledge era "21st century" (Antonenko et al., 2014; National Research Concuil, 2010; Trilling & Fadel, 2009). In the context of education in Indonesia, PSS is adjusted to the curriculum at each level of education as stipulated in the Indonesian National Qualification Framework. PSS not only makes individuals able to solve mathematical problems but also makes them able to solve problems in the surrounding environment (Agustina et al., 2018; Praptiwi et al., 2018; Hertiavi et al., 2016). PSS is not enough if it is only owned by each individual, but it needs a routine to be honed and improved because the problems that will be encountered in the environment tend to have different levels of difficulty.

Especially in physics learning, there is always a session where PSS is honed after students receive learning material, especially quantitative physics problems (McDaniel et al., 2016; Lin, 2015). Students often have difficulty in solving physics problems so that it becomes an obstacle to improving their PSS. In line with this interpretation, a number of studies show several reasons that make physics PSS difficult to improve because it requires complex mathematics (Prahani et al., 2016), requires high metacognition (Saputri & Wilujeng, 2017), often occur misconceptions (Halim, et al., 2014; Alwan, 2011) and lost the concepts (Von Aufschnaiter & Rogge, 2010).

Following up on the explanation of the reasons above, that in the process students will usually be able to solve problems when presented by familiar problems. But if faced with an unfamiliar problem they will have difficulty, this is because the problem is outside their actual ability so that scaffolding is needed to help it solve the problems.

Scaffolding is social supports (Cheng et al., 2018; Belland, 2017; Amelia et al., 2016; Vygotsky, 1978) provided by individuals who have excess experience to individuals who have less experience. Scaffolding activity is usually held by peer interaction in small groups. Social supports makes individuals out of their actual zones leading to the zone of proximal development (ZPD). The term of ZPD was introduced by vygotsky (1978) where this zone is the distance between zones where individuals are able to do a task independently and zones where they need the help by competent peers in carrying out their tasks.

Scaffolding is proven to bring students to ZPD (Harland, 2003) and becomes an important attribute of PSS (Tawfik et al., 2018), but there are shortcomings that are still in the spotlight, scaffolding which is often used still in conventional contexts so that students do not routinely interact. For this reason, scaffolding is needed which can be used anywhere and anytime, one of the solutions to this deficiency is to integrate it with technology (ICT). Actually there have been several studies (Chen, 2014; Malayao & Tagupa, 2014; Deejring, 2014) related to scaffolding that is integrated with ICT.

Chen (2014) built the system using adaptive scaffolding that supports the cognitive needs and motivation of students. The results of the research show that the advantages of an adaptive scaffolding system appeal to students and have proven to be able to improve performance improvements and motivation.

Malayao & Tagupa (2014) built the system by mixing ICT and non-ICT scaffolding, their research focus on conceptual scaffolding. The results of their study showed that the groups that used scaffolding were significantly superior to those who did not use scaffolding in their learning activities.

Deejring (2014) built his system with a complete types of scaffolding, including conceptual, procedural, strategy and metacognitive. The results of his research, the e-scaffolding system proved to be able to encourage students to build knowledge and improve their competence and support collaborative learning.

From the above findings, researchers are interested in developing e-scaffolding that focuses on procedural types that can be used anytime and anywhere (assisted by online website) to help students solve physics problems. The main characteristic of this procedural e-scaffolding is that remains in a social constructivist scope, can be adapted to students' actual abilities and can facilitate collaboration both synchronous and asynchronous. In terms of the system, The difference of e-scaffolding from the existing e-scaffolding is that e-scaffolding developed is able to split the solving categories of students who are expert and novice through recording the problem solving process activities and able to provide formative assessment through feedback on the students physics problem solving process.

METHODS

This study is Borg & Gall's R&D research design (1996) in product design stage, expert and practitioner validation, limited implementation and effectiveness test to improve physics PSS. The design of the developed e-scaffolding I was evaluated by experts and practitioners who were competent in the application of technology in physics learning. Expert and practitioner evaluation data obtained were quantitative data and testimonials through questionnaires related to their views on the design of e-scaffolding. After the first draft has been evaluated, it would be revised so as to produce draft II e-scaffolding that would be tested on students for their readability. The data retrieval technique was by collecting empirical findings that appear in the limited implementation of draft II and will be reviewed descriptively, which then becomes a reference for revising draft II to become a draft III of e-scaffolding.

The next stage is testing the effectiveness by using quantitative research methods where two classes are taken from the population in a cluster random selection, one class is used as an experimental class (N = 31) and the other class as the control class (N = 32). The experimental class using design III e-scaffolding that used blended learning while in the control class using conventional learning. The physics learning materials used at this stage was particle dynamics. The research design uses pre-post control group design. The technique of retrieving the data through problem solving tests with essay questions before and after treatment is then analyzed to obtain the increase value. Then, the improvement value is analyzed by T-test to see whether there is a difference between learning in the experimental class and the control class.

RESULTS AND DISCUSSION

The problem used in this study was a non-routine problems (Figure 1). Physics information in the problems was summarized in the form of visual representation and was not verbally told with the aim of making students challenged to think analytically to describe precisely the context of the problems.

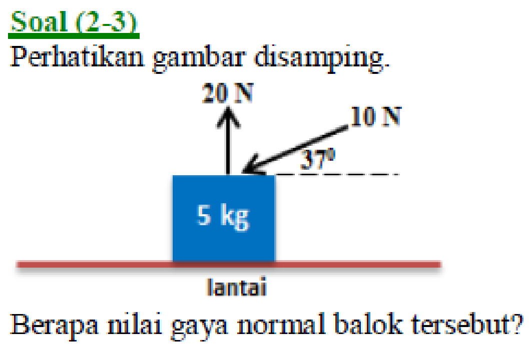

Figure 1. Example of Non-Routine Problems

E-scaffolding developed was a procedural type in the form of prompt questions that contained questions about Polya's problem solving procedures (1957). There are two types of e-scaffolding that are developed, although both are in the prompt questions but the difference between them is that in e-scaffolding 2 there is specific information on each question. The reason for making these two types of e-scaffolding is that researchers can split students who have PSS in the expert category (accessing e-scaffolding 1) and novice (accessing e-scaffolding 2 after e-scaffolding 1 has no effect). The characteristics of e-scaffolding developed can be seen in Table 1.

The procedure for using e-scaffolding, when students access e-scaffolding 1, a pop-up would appear which contains 4 prompt questions (what is known ?, what is the problem ?, how is the problem solving strategy ?, how is the result?). After receiving the four questions, students reflect on the their scheme of knowledge on the problems of particle dynamics given. Then, peer scaffolding is perform by asking for direction from his group friends or from other groups who are more competent to complete his knowledge scheme. If the peer scaffolding activity is claimed to have met a meaningful solution in solving particle dynamics problems, students can directly answer the problems, but if there is solution on the problem solving solution or the solution they input is wrong, students can accesses e-scaffolding 2.

Table 1. E-scaffolding characteristics

Aspects	Scaffolding 1 (Expert Problem Solvers)	Scaffolding 2 (Novice Problem Solvers)
Type of scaffolding	Procedural E-Scaffolding 1	Procedural E-Scaffolding 2
Scaffolding attributes	***Prompt questions*** containing 4 problem solving procedure questions: What is known? (***defining*** the problem) What is asked? (***reviewing*** what is at issue) What is the solution strategy? (***solving*** the problem) How is the result? (***Confirming*** the solution obtained by checking the correctness of the solution in the solution input in the problem and ***evaluating / reflecting*** the solution based on feedback from the solution)	Individual scaffolding in the form of prompt questions containing specific information (incorrect information) on each question.
How does scaffolding support problem solving?	prompt questions are answered based on peer scaffolding between students where students are more competent to assist their friends in answering the prompt questions	Choose one specific information that is considered correct that is displayed at each prompt question. Then revise the choice based on feedback from prompt questions if something goes wrong.
When to use scaffolding?	When the problem is outside the student's actual development zone	When a solution is inputted on a wrong question or when e-scaffolding 1 does not provide a meaningful solution in constructing students' ability to solve problems.
Scaffolding description of the problem solving shown in Figure 1.	**What is known?** **What is the problem?** **What is the problem solving strategy?** **How is the result?**	**What is known?** **• The objects that are pulled up are on the floor then there is a force that presses to form an angle with a horizontal line** **• The objects that are pulled up are on the floor then there is a force that presses perpendicular to the vertical line** **What is the problem?** **• Normal cuboids force** **• Weight of cuboids** **What is the problem solving strategy?** **• Determine the normal force of the cuboids by studying the forces acting on the cuboids through the law of Newton 1** **• Determine the weight of the cuboids by studying the forces acting on the cuboids through the law of Newton 1** **How is the result?** **(N = 36 N)** **(Note: green is the right option)**

E-scaffolding 2 contains prompt questions that are the same as in e-scaffolding 1, but in e-scaffolding 2 there are aspects that contain correct and wrong instructions at each of the prompt questions and students must choose one of the instructions that they consider correct. When they finish choosing, there will be feedback (formative assessment by the system) of their performance which will help them to diagnose their mistakes at prompt questions. But if the feedback results describe each of the instructions selected are correct at the prompt questions, students are ready to answer the problems.

Blended Learning Method

In a limited implementation, the blended learning method is set to support cooperative learning. We use a method in which online and face-to-face sessions are carried out simultaneously so as to make these two sessions a non-separate entity. The main reason why the use of blended learning methods simultaneously between online and face-to-face is because we want the developed e-scaffolding still in the social constructivist scope.

Online sessions, students open particle dynamics learning materials in website with computer to access particle dynamics problems. Students are also allowed to use other electronic equipment such as mobile phones or smart phones to support additional information search in solving the problems. Face-to-face sessions, where students give or receive cooperative peer scaffolding with their group friends to follow up on the steps they take in an online session.

Evaluation Results of E-Scaffolding by Experts and Practitioner

E-scaffolding feasibility evaluation data was collected after validated by 2 experts (physics lecturers) and 4 practitioners (high school physics teachers) who experienced applying technology in physics learning.

Table 2. Evaluation result of e-scaffolding

Aspects	Average	Criteria
Pedagogy	4.29	Very good
Contextual principles	4.42	Very good
Website based learning	4.51	Very good
Collaboration	4.44	Very good
Average	4.45	Very good

Based on the results of the feasibility evaluation by experts and practitioners shown in Table 2, e-scaffolding was developed in the "very good" category so that it was feasible to be used in classroom learning with some improvements. Testimony from the two experts together in responding to the example of the problem used is physics information from the problem must be delivered with verbal to clarify the contextual of the problem. Then the testimonials from practitioners that became an important note for researchers in revising the e-scaffolding II design are the problems raised above the cognitive level of high school students, so that it is necessary to adjust the problems given.

Limited Implementation of E-Scaffolding

There were several findings related to the limited implementation of e-scaffolding products in the class. These findings were testimony of students and findings that were seen when directly observed when students used e-scaffolding products. These findings are first, peer scaffolding did not occur when accessing e-scaffolding 1 but since students read the problem. It was very apparent that students had started to discuss with their group friends when they read the problem together, even though the researchers hoped that this peer scaffolding session would be when following up on e-scaffolding I that had been accessed. This finding provided a reference that the problem that was accessed whether outside the student's actual zone was not only proven when students answer incorrectly or directly access e-scaffolding I, but also could be known when the peer scaffolding occured when reading a problem.

The second finding, the peer scaffolding activity that occurs was collaborative and not cooperative. Researcher's expectation, peer scaffolding was cooperative activity where students who had excess ability to provide assistance to friends who have less ability because they have more learning experience than their friends who have less ability (Cahill et al., 2018). However, the fact was that students collaborated and covered up each other's deficiencies where they shared their tasks and shared their thoughts and together construct their knowledge to solve problems, this was similar to what was stated by Chang et al. (2017); Shin et al., (2017); and Belland (2010) in his research that students could construct their knowledge through collaborative activities. In addition, collaborative activities can provide cognitive benefits (Weaver et al., 2018). This finding indicated that the schemes of students' knowledge when solving problems were still very minimal. As an important note also that e-scaffolding developed was still not flexible or in other words it was not really adjusted to the actual level of students. However, through peer scaffolding could cover these shortcomings and e-scaffolding 1 also appeared to play an important role in minds-on activities among students.

The third finding, in the problem solving process there were several students who went to other groups to collaborate because their group friends could not be invited to work together and the e-scaffolding accessed was not very helpful. So that for product development online discussion forums are created to facilitate collaboration between students of different groups without having to move places. Based on this discovery, the next stage of the research (effectiveness test) was used blended learning that supports the collaboration between students both synchronous and asynchronously which were carried out simultaneously.

The fourth finding, 100% of students prefer to look for additional information to solve problems through electronic devices (such as devices) and no one opens the book. This was because getting information would be faster if through electronic media because only by entering the keyword information on the search engine the desired information would be immediately available. Searching through printed books can take a lot of time because they have to look for by reading. It can even cause boredom if they have read a lot but the information they want was not obtained. Although information retrieval via the internet was more efficient, but there were things that become susceptible to the process of information absorption by students, that they are free to access information available on the internet so that a high probability of misconceptions would be found. So, to follow up on these findings, the researchers would include material content of particle dynamics on the validated page of the concept's truth.

Of the four findings on the limited implementation described above, there are actually other problems that are found but only limited to technical problems. Students were confused in carrying out the instructions in the guidelines and procedures for using e-scaffolding developed. Therefore, at the next stage of the research, a problem sample was needed to be simulated as an habituation before accessing the problem with real learning. All of these findings would be followed up to become a reference for the revision of the e-scaffolding draft II to produce the e-scaffolding design III, which would be tested to increase student physics PSS.

Effectiveness Test

The effectiveness test was carried out for 4 meetings to see the effectiveness of e-scaffolding to improve student physics PSS. The results of student PSS improvement can be seen in Table 3, the improvement in student PSS in the experimental class is in the high category, while in the control class is in the medium category.

Table 3. Results of student PSS improvement

Class	Pre-test			Post-test			Gain Score				
	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Std. Dev.	Category
Experiment	10	23	15,74	28	42	35,52	0,46	0,94	0,70	0,13	High
Control	10	24	18,29	25	41	31,52	0,24	0,88	0,51	0,17	Medium

Note: Ideal maximum score at 44.

Then inferential analysis is done to see whether there is a significant difference in the increase in physics PSS between the experimental class and the control class (Table 4). Normality test shows that the number of significance in Shapiro-Wilk is above 0.05, so that the data on increasing physics PSS of students in both classes is normally distributed. The homogeneity test shows that the significance number is also above 0.05 so that the data on increasing the physics PSS of students in both classes has homogeneous variance.

After the test conditions for normality and homogeneity were met, a T-test was carried out. The results of the t-test obtained the value of $p <$ 0,05 so it can be concluded that there was a difference in the increase in physics PSS of students in the experimental class with the control class. Based on the description in Table 3, students in the experimental class who learned using e-scaffolding III design had an increase in physics PSS better than students in conventional learning control classes.

Table 4. Result of inferential statistics test

Shapiro-Wilk Test as Normality Test				Lavene Test as Homogeneity Test		T-Test		
Class	**Statistics**	**df**	***p***	**F**	***p***	**t**	***p***	**Std. Error**
Experiment	0.98	31	0.79	1.80	0.19	5.138	0.00	0.04
Control	0.96	32	0.36					

The findings on the effectiveness test of e-scaffolding in the experimental class are not so much different from the findings on the limited implementation. However, the experience at the readability test can suppress the technical and operational constraints that occur during this effectiveness test. Learning activities carried out using blended learning also do not encounter significant obstacles, students were collected in small groups of 2 to 3 people to directly solve problems presented through the particle dynamics website. The task of the teacher as the "control holder" of the learning process (Nurita et al., 2017) and not to deliver learning material, but students were directed to construct their own knowledge by accessing abundant learning resources both in books and on the internet or through collaboration with friends the group. In the control class, learning activities began with introductory materials. Then, they are presented with practice questions, but the practice questions given were not through the website.

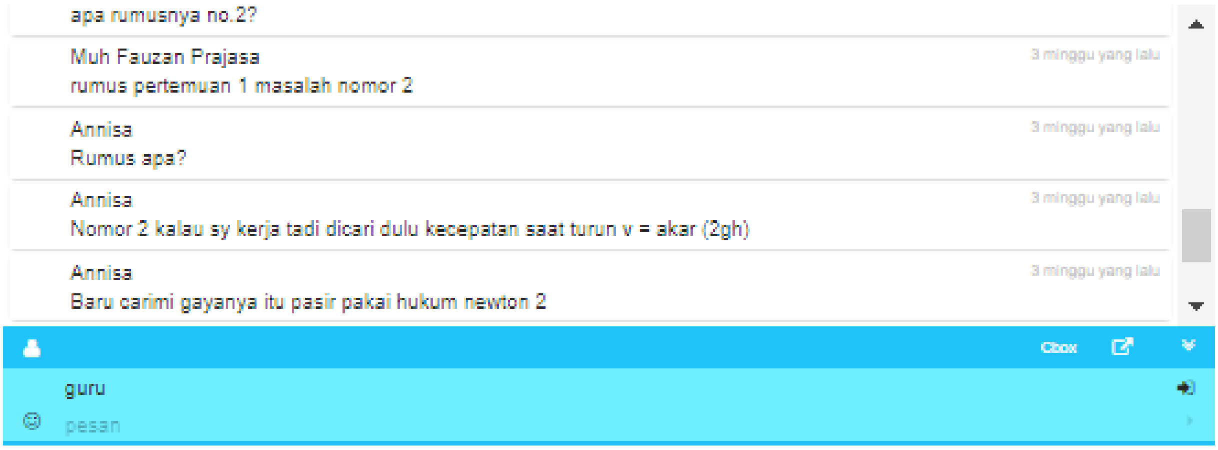

Figure 2. Asynchronous Collaboration through Live Chat

The problem solving process by students in the experimental class took place in synchronous and asynchronous collaboration through the live chat column (Figure 2). To find additional information in solving problems, students used teaching materials provided on the particle dynamics website and there were also through e-books they get from surfing the internet. Students were also seen preparing several alternative solutions if their solutions are declared wrong by the feedback system.

The problem solving process in the control class did not occur peer scaffolding activities, but it appears that students who have excessive experience intervence in other students by providing a solution without explaining how the process of solving it. Then the feedback provided by the teacher regarding the results of problem solving is not followed up by the students.

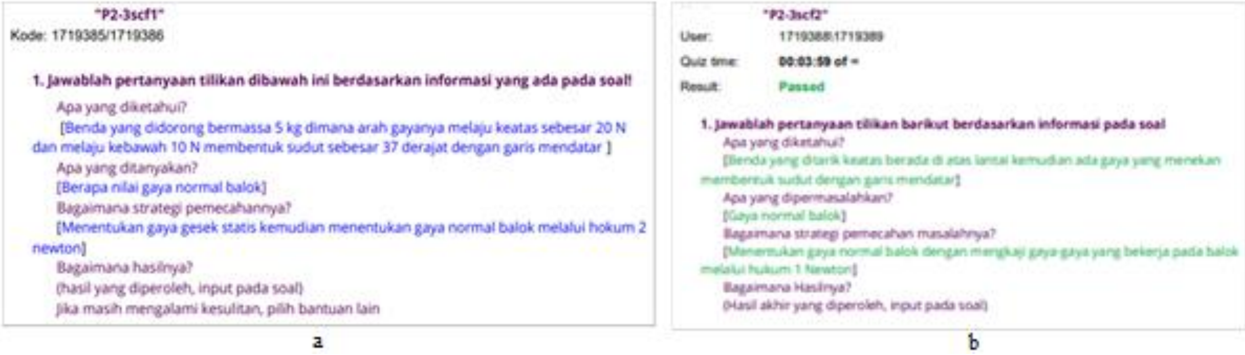

Figure 3. Performance Records of students who Accesses E-Scaffolding 1 (a) and E-Scaffolding 2 (b)

The e-scaffolding developed was able to split the categories of students who had PSS expert (Figure 3a) and novice (Figure 3b) through the recording of student performance when solving problems at Figure 1. Based on the recording of problem solving performance in Figure 3a, students with expert problem solving categories were able express the concept of the problem and can qualitatively argue the problem solving process (Riantoni et al, 2017; Sujarwanto et al., 2014; Mason & Singh, 2011), whereas for the novice category, student knowledge organizations tend to be "fragile" (Docktor et al, 2016; Docktor & Mestre, 2014) so that giving specific information at each prompt question is able to strengthen knowledge that is proven by the correctness of all the specific information selected in e-scaffolding 2 (see Figure 3b). E-scaffolding that was developed was able to make students physics PSS gradually improve because the effectiveness test was obtained by recording the performance of students who rarely access e-scaffolding 2 at the last meeting.

Based on the explanations related to the implications of using e-scaffolding above, there are some that are lacking. First, the problem presented is still not contextual with the students' initial knowledge. Secondly, learning activities are limited to minds-on among students in solving problems and there is no hands-on activity so that solution of the problem are less precise.

CONCLUSION

Based on the explanation of the results and discussion, it can be concluded that procedural e-scaffolding has been successfully developed. E-scaffolding is declared feasible to be used and effective for improving student physics PSS.

As a follow-up to further research related to the development of e-scaffolding. First, we hope that the technical page is identified with the computer-based national examination system because it can be a vehicle for habituation of students from an early age to face it. Second, the physics problems presented is more contextual with everyday life.

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