E-learning assisted problem based learning for self-regulated learning and mathematical problem solving

R P Yaniawati¹, B G Kartasasmita¹ and J Saputra²
¹Departement of Magister Mathematics Education, Faculty of Postgraduate, Universitas Pasundan, Bandung, Indonesia
²Mathematics Education, Faculty of Education, Universitas Pasundan, Bandung, Indonesia

*Corresponding author’s email: pyaniawati@unpas.ac.id

Abstract. This study aims to analyze the effectiveness of e-learning assisted problem-based learning (PBL) to enhance self-regulated learning and its impact on college students’ mathematical problem-solving. This study used mixed methods research with embedded design by comparing groups of e-learning assisted PBL and conventional learning. The subjects were undergraduate students of mathematics education in Bandung Indonesia. The instruments were a test, questionnaire, interview guidelines, and observation guidelines. The results show that: The mathematical problem-solving ability of students who used e-learning assisted PBL is better rather than those who used conventional learning; The self-regulated learning of students who used e-learning PBL is better rather than those who used conventional learning; There is an influence of self-regulated learning on mathematical problem-solving skill.

1. Introduction
The attainment of the learning process in higher education can be identified by the level of comprehension, material mastery, as well as students’ problem-solving skill. According to NCTM [1], mathematics learning aims to develop students’ mathematical problem solving, mathematical reasoning and proof, mathematical communication, mathematical connection, mathematical representation, knowledge of technology, and dispositions. Thus, mathematical problem-solving skill is an essential cognitive competence in mathematics.

Students’ mathematical problem-solving skill needs enhancement, Yaniawati [2] stated that the pre-service teachers’ mathematical skills have not been optimum yet. Most of the students are not familiar with the completion of mathematical skill questions. Mathematical skill can be defined as the ability to solve mathematical problems, mathematical communication, mathematical reasoning, and proof, as well as mathematical connection.

There are several factors which influence the limited mathematical problem-solving skill of the students, such as students’ limited prerequisite knowledge to solve problem-solving questions. Additionally, the monotonous mathematics learning process which tends to be mechanical does not habituate the students to think rigorously. The mathematics learning process carried out by most teachers is still in the conventional way (teacher centred).

The Problem Based Learning (PBL) model is one of the learning models to enhance mathematical problem-solving skills. PBL is an approach to learning and instruction with the following characteristics: (1) the use of problems as starting points for learning, (2) small-group collaboration, and (3) flexible
tutor guidance. Since problems steer the learning process with the number of lectures are limited. The learning is to be student-initiated with sufficient time for self-study should be available [3].

Wardon et al. [4] showed that the implementation of PBL could create more conducive learning, improve students’ participation in classroom activities, and create learner-centred learning. The results are better improvement in mathematical problem-solving skill of students who are learning with PBL rather than those who use conventional learning. Therefore, the PBL model is one of the useful models to improve mathematical problem-solving skill.

In addition to the mathematical problem-solving skill, self-regulated learning is also an essential component that matters in learning mathematics. Self-regulated learning also determines students’ achievement in learning. Liu [5] stated that self-regulated learning has a strong correlation with students’ learning success. The same thing is said by Suárez et al. [6] in all, learners' agency assumes learners to be responsible for their learning, the content, the rhythm and the strategies they used as well as for monitoring the progress and assessing its outcomes. Controlling the process of one's learning is strongly linked to the concept of self-regulated learning. Students’ self-regulated learning can be achieved if the students are given ample opportunity to study independently in the mathematics learning process. The students do not only acquire knowledge by doing what is instructed by the lecturers but also they can construct knowledge specifically mathematical concepts from the information received, although they still need guidance from the lecturers.

Utilization of e-learning in mathematics has positive influences. Other than as an effort in solving technical problem as learning media, this can also become an effort to address substantial learning problem as learning material. During the implementation process, students can empower themselves to study independently without the time and distance constraints so that their independence can be encouraged after involvement in the e-learning process, for cognitive and affective competencies, and the development of creativity, for the stakeholders in education. However, research of Yaniawati et al [2] reported that blended learning is more effective than full e-learning and conventional learning. Based on the above explanation, the purpose of this research is to analyse the implementation of e-learning assisted PBL in improving problem solving skills and self-learning of students, regarding students’ initial ability based on Student Academic Competence (high and low achievers)

2. Methods
This study used mixed methods research with embedded design by comparing groups of e-learning assisted PBL and conventional learning. Some 100 undergraduate students (second semester) of Mathematics Education at Universitas Pasundan participated in this research; 50 of those were categorized as the experimental group while the other 50 were classified as the control group, in which the participants were selected randomly. Both groups were asked to take the Students’ Academic Competence (SAC) test wherein each group there were to be found high and as low achiever students. In the experimental group, there were 24 students classified as high achievers and 26 students low achievers. In the control group, there were 27 students of high achievers and 23 students of low achievers.

This research was conducted for seven meetings before the mid-term test. The research material was School Mathematics III, a second-semester course. The students discussed the available topics on e-learning every week based on a list of problems. The material discussed was three dimensions. The issues were: (1) locus of a point, line, and plane in three-dimension in space; (2) distances involving points, line, and planes in three-dimension; (3) angles between lines, line and plane, plane and plane.

Before conducting the lesson, a pre-test was taken to discover the students’ prior knowledge. Additionally, validation for the test was screened by four experts to ensure that the e-learning system is valid for the learning material. During the lesson, observations were conducted by observers. At the end of the lesson, the students were given a post-test which was composed of 6 problem-solving questions, 30 questions of self-regulated learning questionnaire in the form of Likert scale, as well as an interview on e-learning, assisted PBL, problem-solving skill, and self-regulated learning. The appearance of e-learning using Moodle application can be seen in Figure 1 and Figure 2.
3. Results and Discussion

3.1. Students’ mathematical problem-solving skill

Figure 3 is a descriptive statistical measure of the class that gets PBL using e-learning and a class that receives an expository model.

In Figure 3, it can be seen that the gain average of mathematical problem-solving skill for students who received PBL using e-learning is higher than for the students who received conventional learning in each group of SAC. The highest gain average of mathematical problem-solving skill is achieved by the experiment class of the high-achiever group, while the lowest gain average of mathematical problem-solving skill is achieved by the control class of the low-achiever group. The gain of mathematical problem-solving skill based on SAC was tested by utilizing two-way ANOVA. The calculation result is
significance score 0.000 based on the class. Since $\text{sig} < 0.05$, then $H_0$ is rejected, meaning that there is a significant improvement of students’ mathematical problem-solving skill between experimental and control class. Based on SAC, significance score of 0.000 is obtained; since $\text{sig} < 0.05$, then $H_0$ is rejected, meaning that there is a significant improvement of students’ mathematical problem-solving skill between the high and low achiever groups.

Analysis of the research results shows that the student’s mathematical problem-solving skill is better for those who received PBL with the help of e-learning than that of the students in expository learning. The students who have learned PBL with the help of e-learning can increase their skill in the average category. The students with conventional learning can increase their skill in a low category. Against the SAC, high achiever students with e-learning assisted PBL, and high achiever students with conventional learning increased their skill in the average category. Although the type is similar, the increased measure of high achiever students who received PBL with the help of e-learning is higher than the increased measure of high achiever students with conventional learning. Low achiever students who received e-learning assisted PBL and low achiever students who received conventional learning increase their skill in low category; however, the increased measure of low achiever students who received e-learning assisted PBL is higher than that of low achiever students received conventional learning.

These findings indicate that PBL with the help of e-learning is quite useful in the mathematics learning process. However, this increase is not examined further by the writers, whether it is the effect of PBL or e-learning. The implementation of e-learning can also be affected by factors of teachers. Scott [7] states that teachers’ beliefs and practices of e-learning can change according to circumstances and this will have an impact on learning outcomes. Moreover, teaching material, the important part in the problem-based learning model, is also a supporting aspect in improving students’ mathematical problem-solving ability. Teaching materials that can be accessed through e-learning which contain realistic problems are influential in increasing students’ mathematical problem-solving. Phumeechanya [8] stated that “Problem-solving will be very successful when the problem presented in the teaching material is in the form of the realistic, reasonable, and complex problem.”

Another study was conducted by Shen, Lee, and Tsai [9] with a Quasi-Experimental Study of a Short-Term Module for Taiwan vocational school students. The sample was 106 students. In their research, it is reported that the PBL and self-regulated learning methods that can contribute more to the students through online learning/e-learning. This problem-based learning is also with e-learning assistance. According to Chaeruman, Wibawa, & Syahrial [10], there are three aims in integrating technology and learning, one of those is to develop “knowledge-based society habits,” such as problem-solving skill. Yaniawati et al., [2] Also states that e-learning functions as a supplement, complement, or substitution, so that the students can study and practice problem-solving ability through e-learning anywhere and at any time. To analyse the mean differences in student self-learning between the two classes we used non-parametric statistics with the Mann-Whitney test, because the data were not normally distributed. It is found that $\text{sig}$ score (2-tailed) is 0.086 so that the score $\frac{\text{sig} \text{ (2-tailed)}}{2} = 0.043 < 0.05$, then $H_0$ is rejected, so that $H_1$ is accepted. It means that the self-regulated learning data of the experimental class students is higher than that of the control class. Therefore, it is concluded that at $\alpha = 0.05$, the self-regulated learning of the students’ with e-learning assisted PBL is better than the students who received conventional learning. Two-way ANOVA test is used to discover whether there are differences in average scores of both groups based on SAC classification (high and low achievers). The calculation result is provided in Table 1.
Table 1. Results of two way ANOVA on the students’ self-regulated learning based on SAC.

| (I) SAC  | (J) SAC   | Mean Difference (I-J) | Std. Error | Sig.  | Lower Bound | Upper Bound |
|----------|-----------|-----------------------|------------|-------|-------------|-------------|
| HA Control | LA Control | 5.13                  | 1.734      | .020  | .60         | 9.67        |
| LA Experimental | HA Experimental | -12.11               | 1.750      | .000  | -16.68      | -7.53       |
| HA Control | LA Control | -6.97                  | 1.699      | .000  | -11.41      | -2.53       |
| LA Control | HA Experimental | 2.81               | 1.770      | .390  | -1.81       | 7.44        |
| HA Control | LA Experimental | -5.13               | 1.734      | .020  | -9.67       | -6.00       |
| LA Control | HA Experimental | 6.97               | 1.699      | .000  | 2.53        | 11.41       |
| LA Control | LA Experimental | 9.78               | 1.754      | .000  | 5.20        | 14.37       |
| HA Control | LA Experimental | -14.92              | 1.804      | .000  | -19.64      | -10.20      |
| LA Control | HA Control | -2.81               | 1.770      | .390  | -7.44       | 1.81        |
| HA Control | LA Control | -9.78                | 1.754      | .000  | -14.37      | -5.20       |

The error term is Mean Square (Error) = 38,223

In Table 1, it can be seen that almost all items have a sig score of 0.000, less than 0.05; this indicates that H0 is rejected and H1 is accepted: then there is a significant difference in average score of self-regulated learning among the two related groups. There is only one sig score of 0.390, more than 0.05, for low achievers of the experimental group and low achievers of the control group.

The results above can be interpreted that, based on SAC, it is discovered that there are significant differences between the self-regulated learning of high achievers and low achievers who received PBL with the help of e-learning. Furthermore, there are also considerable differences between the self-regulated learning of high achievers who received PBL with the help of e-learning and high achievers who received conventional learning. There are also significant differences between the self-regulated learning of low achievers who received PBL with the help of e-learning and high achiever who received conventional learning. However, there is not much significance between the self-regulated learning of low achievers who received PBL with the help of e-learning and that of a low achiever who received conventional learning. There are also considerable differences between the self-regulated learning of high and low achievers with conventional learning.

Santiuste (2015) states that “In e-learning, the students do not completely depend on the teachers, the student learns independently in discovering knowledge through the internet or other information technologies.” Moreover, PBL can create conducive classroom situation and integrate academic and social conditions among students and teachers. Research conducted by Severiens and Schmidt [11] reported that PBL produces a positive impact on academic and social integration when compared to conventional learning.

Self-regulated learning is a process which requires conditioning, strong determination since it is based on internal factors of each so that it is challenging to change it. Bude et al [12] stated that learning does not have to be directive since the students may lose their ideas in the reduction of self-regulated learning as well as learning motivation. Besides, Alyya Meerza and Beauchamp stated [13] that success of ICT in any learning institution, including at KHEIs, will depend on attitudes of undergraduates towards the use of ICT in their daily learning processes. One of them is like the use of Maple program to self-regulated learning.

In this case, PBL and e-learning have essential roles in facilitating students to condition themselves wherever and whenever by utilizing internet access, so that the students will be more motivated as e-learning has exciting features. Therefore, the self-regulated learning of high and low achievers who experienced e-learning assisted PBL is better than that of high and low achievers in conventional learning. This statement is in line with Sockalingam et al. [3] that in PBL, it is the students who take the responsibility to synthesize the content knowledge through self-directed learning and group discussion which is in turn determined by the nature of problems. Using e-learning, they can learn mathematics material-especially three dimensions-routinely and independently anywhere and anytime. The self-regulated learning of high achievement students develops further in searching mathematics material by
using e-learning. They can solve problem-solving questions easily. Nevertheless, there are still low achievement students who are not independent yet in their study. When given tasks in mathematics, they do not show initiatives in working the problems, so the task is not complete.

3.2. The influence of self-regulated learning on problem-solving skill.

It is seen that the determination coefficient \( R^2 \) indicates that there are influences from self-regulated learning on the problem-solving skill with the \( R^2 \) score at about 0.881. The influence percentage of self-regulated learning variable toward problem-solving skill is 88.1%, while other variables influence the rest (11.9%).

**Table 2. Linear Regression Coefficients.**

| Model                | Unstandardized Coefficients | Standardized Coefficients | T     | Sig. |
|----------------------|----------------------------|---------------------------|-------|------|
| (Constant)           | -24.356                    | 3.434                     | -7.092 | .000 |
| Self-regulated learning | 2.509 0.93 | .939                      | 26.936 | .000 |

Dependent variable: Problem Solving

Table 2 shows that the significance and coefficients of the linear regression equation \( Y = -24.356 + 2.509 \times X \). The equation’s self-regulated learning variable coefficient is positive. It means that increases in the independence of the student problem-solving skills have improved by a score of 2.509. Based on that, the students’ self-regulated learning also influences problem-solving skill. The higher the self-regulated learning of the high and low achiever students, the higher the problem-solving skill is. Ozcan's [14] study reported that there is a 24% relationship between self-regulated learning and student problem-solving abilities in Istanbul, Turkey.

An example of exploration task in e-learning for students that can lead to a conjecture: Given a chocolate cube with corners ABCD. EFGH, and a side length of 6 cm. The chocolate will be sliced through the BDG plane so that the small polyhedron/tetrahedron C.BDG is separated and will be given to his sister. How to formulate this situation to determine the distance from point C to the BDG plane?

![Figure 4](image1.png)

**Figure 4.** The formulation of situation.

![Figure 5](image2.png)

**Figure 5.** The solution of problem solving.

Figure 4 and Figure 5 show one example of the answers to the task given to students with PBL learning assisted by e-learning. In the picture, it appears that students understood the problem faced by modelling the contents of the story in the form of a picture of constructing a polyhedron, namely the cube; then the student made a frontal image of the construction of the polyhedron in the form of a flat plane, namely a right triangle so that the distance from the point to the plane on the polyhedron is in the form of a point to a line segment when a triangle is made. Students can plan strategies by formulating
six steps that must be done until the problem can be solved, and finally the student can solve the problem according to the plan that has been made.

E-learning functions as a complement, i.e., the material are programmed to complement the learning materials delivered to the students in the classroom. It can be said that e-learning material becomes an enrichment for high achiever students and remedial for low achiever students. They are provided opportunities to access e-learning materials. The sole purpose is to solidify students’ comprehension level toward the content provided by the teachers in the classroom. Therefore, during the PBL learning process, students can access e-learning, for example at Stage 3 (guiding individual and group investigations) based on the teachers’ instruction. After the learning has finished, the students can reopen e-learning materials wherever and whenever they are to understand more the learning materials.

High achiever students activity in learning is quite good as they argue that the PBL assisted e-learning strategy is more interesting than conventional learning, so they are motivated in completing the task. The high achiever students use e-learning to learn upcoming materials and repeat the materials for the low achiever students. Some of them even say that they intend to do the exercises for the next meeting. The most preferred facility is the material provided in the form of flash media player on e-learning. Some of them who find difficulties to imagine space are helped by flash player media that contains three-dimensional images so that they can understand shapes in the area.

However, this implementation of e-learning has not achieved optimal results. Some students, deficient achiever students, have not utilized this e-learning well. Results of Gunduz et al. [15] study reported that few students participated in the task and lacked strong collaboration resulting in weak communication among them.

4. Conclusion

Results of our study on the implementation of e-learning assisted Problem Based Learning (PBL) model in the mathematics education program at Universitas Pasundan, Bandung, Indonesia, showed a statistically significant increase in problem-solving skill and self-regulated learning. The mathematical problem-solving ability of high and low achievers who received e-learning assisted PBL was better than that of the students in conventional learning. Nevertheless, among the low achiever students, the increase in problem-solving ability was still relatively small compared to the high achieving students.

Similarly, the self-regulated learning of high and low achievers with e-learning assisted PBL was better than that of the students in conventional learning. Using e-learning, they did study mathematical material, especially three dimensions, regularly and independently anywhere and anytime. The self-regulated learning of high achievement students developed substantially regarding searching mathematical material using e-learning. They quickly solved problem-solving questions. Nevertheless, there were still students who were not independent yet in their study. When given mathematics tasks, they did not show initiative in doing the problems, so the works were not completed. It was found that there was an influence of self-regulated learning on mathematical problem-solving skill. The percentage of contribution of independent learning variables on the ability to solve problems is 88.1% while the remaining 11.9% may have been influenced by other variables that are not studied yet.

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