The effectiveness of Problem Based Learning - physics module with authentic assessment for enhancing senior high school students’ physics problem solving ability and critical thinking ability

I W Suastra¹, N P Ristiatil, P P B Adnyana¹, and N Kanca¹

¹Universitas Pendidikan Ganesha, Jl. Udayana No 11 Singaraja Bali, Indonesia
E-mail: iwsuastra@undiksha.ac.id

Abstract. The ability to solve physics problems and the ability to think critically are important factors in this fourth industrial revolution era. These abilities can be developed in teaching and assessment. The aim of this study was to enhance senior high school students’ physics problems solving ability and critical thinking ability through the implementation of problem based learning (PBL) - based Physics module and authentic assessment. The study used a Posttest Only Control Group design by involving 78 twelfth grade students of SMA Negeri 4 Singaraja Bali who were distributed into an experiment class of 39 students and a control class of 39 students. The classes used had been tested for their equivalence with t-test. The data of the study were analysed using MANOVA. The students’ problem solving ability was measured with a problem solving test and their critical thinking ability with a critical thinking test. The results of the study showed that 1) the physics problem solving ability was higher for the students who learned by using PBL-based module with authentic assessment compared to that of those who learned by using PBL-based module and conventional assessment; 2) the critical thinking ability of the students who learned with PBL-based module and authentic assessment was higher than that of those who learned by using PBL-based module with conventional assessment; and 3) simultaneously, the problem solving ability and critical thinking ability of those who learned by using PBL-based module with authentic assessment were better than the problem solving ability and critical thinking ability of those who learned by using PBL-based module with conventional assessment.

1. Introduction
In this fourth industrial revolution, challenges in various sectors of life are increasingly tougher so that there is a need for preparing higher quality human resources. According to Gardner, to face the increasingly more complex challenges five kinds of thinking are needed for the future, namely disciplined thinking, synthesizing thinking, creative thinking, respecting thinking, and ethical thinking[1]. Furthermore, Tilaar says that globalization has to be “countered” with the development of creativity and entrepreneurship through transformative critical pedagogy in national education [2]. Hence, today’s education has to be directed to the improvement of the nation’s competitive advantage to be able to compete in the global competitions. This can be achieved if education at school is oriented not only to the acquisition and understanding of scientific concepts, but also to enhancing high order thinking ability, namely the ability to solve problems and critical thinking skill.
Departing from the gap that has been described above, then there is a need for improving instructional process, both in relation to a more innovative teaching model that is capable of developing the students’ problem solving ability and critical thinking ability and their assessment. One of the teaching models that does not only empower science as product but also empowers it as process, especially for improving problem-solving ability and critical thinking ability, is Problem Based Learning (PBL). This model was recommended to be implemented in the Curriculum 2013.

Arends states that PBL is a teaching model based on the understanding of constructivism in which the students themselves build up their knowledge through a real problem solving so that it can develop their high order thinking skill and self confidence [3]. Furthermore, Yew & Goh state that PBL has been adopted in the educational field to enhance critical thinking, problem solving in the real situation [4]. In the classes that used PBL, the students worked in teams to solve real problems. Ibrahim and Nur state that PBL is a model of learning that presents problems in authentic and meaningful situations that can provide facility for them to conduct an investigation and inquiry [5]. This model helps the students to develop their thinking in finding solutions to problems through data searching, so that a solution is found for a problem rationally and authentically.

In addition, the study done by Aji, et al showed that the PBL-based physics module in the topics “Balance and Rotation Dynamic” can improve senior high school students’ physics problems [6]. The study done by Dianawati, et al found out that PBL model has a positive and significant effect on the students’ critical thinking [7]. Furthermore, Mubuke, et al state that PBL model can improve cognitive and social factors [8]. A similar statement is expressed by Gorghiu, et al., who state that PBL is efficiently used in understanding science concepts [9]. Lestari1 states that senior high school students who learned with contextual physics module had a higher mean score than those who learned without a module [10]. It is clear that the use of PBL-based module gives a positive contribution to the students’ development of problem solving ability and critical thinking ability. In this study PBL model was presented in PBL - based teaching module that followed PBL steps. Module was used because it is effective in helping students learn.

The implementation of the Curriculum 2013 has the consequence in the change of assessment system. In the Curriculum 2013 the assessment of learning achievement covers the assessment of competence, attitude, knowledge and skill that is done proportionally. One of the assessments that is stressed is authentic assessment, that is, a form of comprehensive assessment done by the teacher in a sustainable way (Regulation of Ministry of Education and Culture No. 104 of 2014). However, in reality, teachers face problems in performing authentic assessment [11]. Authentic assessment is an integral part of science instruction [12]. The result of the study done by Al-Sadaawi showed that the science learning achievement of the group that was given performance assessment was better than that of those who were given a common assessment [13]. Hence, in the present study the effect of PBL-based module and authentic assessment (performance assessment) on their implementation in the classroom was investigated. Based on the explanation, the researchers would like to test the effectiveness of PBL-based module and authentic assessment on senior high school students’ physics problem solving ability critical thinking ability. The core characteristics of high school physics module based on problem based learning include two major stages, namely the starting new class and follow-up problem. In the first stage, starting new class students were provided with problems regarding physical material related to everyday life. The second stage, follow-up problems students are asked to solve problems by following the rules and recognize problems, identify solutions, make observations / tests, discuss solutions and alternative solutions, and make conclusions. All learning activities are assessed using authentic assessment, namely: assessment of the portfolio and performance assessment.

Based on the explanation that has been given, then the general statement of problem in this study is: Is PBL-based module with authentic assessment effective in developing problem solving ability and critical thinking ability in senior high school physics instruction, both simultaneously and partially?

2. Method
This study was aimed at testing the effectiveness of PBL-based module and was the final stage in the module development study. The testing was done with the twelfth grade students at SMA Negeri 4 Singaraja with the sample of 78 students assigned to experiment group of 39 students (using module with performance assessment) and control group of 39 students (using module with test assessment).
The study used the Posttest Only Control Group Design. The classes used in the study had been tested in terms of equivalence using t-test and the two groups were equivalent. To measure problem solving ability a valid essay test with a high reliability was used. The students’ critical thinking ability was measured with a multiple choice test of critical thinking ability. To test the hypotheses in this study one-way MANOVA test at 5% level of significance was used.

3. Result and Discussions

3.1 Results

Problem based learning based physics modules that have been developed have met the elements of validity and practicality. Modules have steps, namely: setting new problems where students in the group are given problems in the module and are asked to listen and understand the problems presented. Next, the next step is the follow-up problem, namely the student is asked to follow up on the problem at the stage of the new problem setting by filling in the fields provided. The column filled includes questions: what do you know about the problems you have read? what needs to be known so that you can solve the problem? Make a hypnotic of the problem! Arrange the results of the discussion and alternative solutions, and for conclusions. All questions and instructions are written in the module. Student performance in working on module assignments, discussions and presentations is assessed using the assessment rubric. Tasks in working on modules are assessed by portfolio assessment and performance in discussion and presentation of problem solving assessed using the performance assessment rubric. Thus, all aspects, both cognitive aspects and attitudes and skills of students can be assessed comprehensively through this authentic assessment.

Based on the results of descriptive data analysis the means for problem solving ability (PSA) and critical thinking ability (CTA) for each group, namely experiment group (the group of students who learned using PBL-based module with authentic assessment) and control group (the group of students who learned using PBL-based module without authentic assessment/conventional assessment) are as shown in Figure 1.

![Figure 1. Description of the students' problem solving ability and critical thinking ability](image)

Before Manova testing was carried out, prerequisite tests that comprised data distribution normality test, homogeneity test, and co-linearity test. All Manova test prerequisites have been fulfilled so that the hypothesis test can be continued.

In this study there were two problems to be answered, namely: (1) is there simultaneously any difference in problem solving ability and critical thinking ability between the students who learned by
using MPBAA and those who learned by using MPBCA and (2) is there partially any difference in problem solving ability and critical thinking ability between the students who learned by using MPBAA and those who learned by using MPBCA. Based on the results of analysis the following results as shown in Table 1 and Table 2 were obtained.

| Effect      | Value     | F       | Df | Sig   |
|-------------|-----------|---------|----|-------|
| Intercept   | Pilla’s Trace | .995    | 7617.628 | 2.00 | .001  |
| Group       | Pilla’s Trace | .417    | 26.852 | 2.00  | .001  |

The results in Table 1 show that simultaneously there is a difference in problem solving ability and critical thinking ability between the students who learned by using MPBAA and those who learned by using MPBCA (F= 26.852; p<0.05).

Based on the results of difference test partially the results as shown in Table 2 were found.

| Source       | Dependent Variable | df | F       | Sig   |
|--------------|--------------------|----|---------|-------|
| Corrected model | PSA | 1 | 33.024 | .001 |
|              | CTA | 1 | 20.967 | .001 |
| Intercept    | PSA | 1 | 13601.407 | .001 |
|              | CTA | 1 | 1756.915 | .001 |
| Group        | PSA | 1 | 23.024 | .001 |
|              | CTA | 1 | 20.067 | .001 |

Table 2 shows that, partially, the problem solving ability in physics learning of those who learned by using MPBAA and that of those who learned by using MPBCA are different (F = 33.024; p < 0.05). The table shows that the mean for problem solving ability of the students who learned by using MPBAA was 82.35 (high qualification), higher than that of those who learned by using MPBCA, i.e. 74.62 (high qualification). Similarly, the students’ critical thinking ability of those who learned by using MPBAA was 47.38 (high qualification), higher than that of those who learned by using MPBCA, i.e. 38.05 (high qualification).

3.2 Discussion
The result of the testing of hypothesis 1 in this study shows that simultaneously there is a difference in problem solving ability and critical thinking ability of the students who learned using BPBL-based module with authentic assessment and those who learned using PBL module without authentic assessment (only with a test) with F value of 26.85 (p < 0.05). After being testing partially it was also found out a not very much different result for hypothesis 2 in which there was a difference in physics problem solving ability of the students who learned using PBL-based module with authentic assessment and that of those who learned using PBL-based module without authentic assessment. The result of hypothesis 3 showed that there was a difference in critical thinking ability of those who learned using PBL-based module with authentic assessment and that of those who learned using PBL-based module without authentic assessment. Viewed from the means, the physics problem solving ability of the students who learned using PBL-based module with authentic assessment was 82.35 (high), higher than that of those who learned using PBL-based module without authentic assessment (i.e., 74.62 (high)). Similarly, the critical thinking ability of the students who learned with PBL-based module with authentic assessment was 38.05 (high). This result indicates that PBL-based module can enhance students’ physics problem solving ability and critical thinking ability, thus it fell into a high category. The contribution of PBL-based module is that it gives an opportunity to the students to learn by
themselves by following the PBL steps: clarifying terms and concepts that are not yet clear; formulating problems, organizing material systematically; formulating added information from other sources, and synthesizing (combining) and testing new information and writing it in a report form. Chen through an action research in media literacy found out that PBL can enhance critical thinking ability, academic performance, and positive perception in developing the model [14]. The finding of Masek, A & S. Yamin also indicated that PBL can enhance creative thinking ability and critical thinking ability of the students because of the stages in the PBL itself [15]. The result of study by Gorgiu et al that implemented PBL through 17 modules showed that both the teacher and students responded well and in addition, the students’ understanding about science concepts became better too [9].

Viewed from differences in assessment done, it turns out that those that used authentic (performance) assessment had problem solving ability and critical thinking ability that are significantly different from those who did not use authentic assessment (only using a test). This finding indicates that authentic assessment gives a positive contribution to the development of problem solving ability and critical thinking ability of the students. As explained by Harlen assessment is an integral part of teaching [12]. It means that assessment also determines students’ learning process and achievement. Enger & Yager explained that assessment is closely related to science teaching [16]. In learning science, the there are six dimensions of science that have to be assessed: concept, process, application, attitude, creativity, and nature of science. The concept of application consists of critical thinking ability and problem solving ability. Hence, authentic assessment can also develop critical thinking and problem solving ability. In addition, the steps in authentic assessment such as determining aspects to be assessed that have been known by the students; giving ample opportunities to the students to prepare themselves earlier in solving problems and accepting or rejecting other’s points of view guide the students in their learning. Their performances can be seen from their work, both individually and in group. The finding of Kinay & Bagceci showed that problem solving ability for the teachers who were given conventional assessment did not improve from the pretest to the posttest [17]. On the contrary, authentic tasks with constructive approach were more effective in developing students’ problem solving ability than tasks based on the curriculum especially those that used conventional assessment. Less authentic tasks were less effective in facilitating students’ thinking in solving problems [18]. Ward & Lee state that authentic assessment was more suitable for use in PBL module than conventional assessment since the latter used only standard tests that only assess factual knowledge [19]. Furthermore, the findings of Tai & Yuen showed that the development of students’ critical thinking ability can be observed and facilitated to be more effective [20]. The superiority of authentic assessment with portfolio was reported by Ling who stated that the use of portfolios in physics teaching gives positive academic contribution and their use can be considered [21]. A study by Suastra, et al found that the effect of authentic assessment was very real in senior high school physics teaching on the improvement of physics learning achievement [22]. Hence, it can be stated that in improving problem solving ability and critical thinking ability the teaching that is assisted by PBL-based module with authentic assessment is more effective than that by PBL module without authentic assessment. In other words, authentic assessment gives a real contribution to the improvement of students’ problem solving ability and critical thinking ability in senior high school physics teaching.

4. Conclusion

Students’ problem solving ability and critical thinking ability can be developed effectively through Physics teaching assisted by PBL module with authentic assessment. The PBL steps in the module can help students to think step by step in solving problems presented in the module from the stage of identifying real problems, collecting information, formulating hypotheses, investigating/testing, discussing to the stage of presenting the results. These activities will involve science process skill and in the end will enhance students’ problem solving ability and critical thinking ability. The module will help in making the use of time more efficient in the classroom in practices/tests and discussions. Systematic and sustainable implementation of authentic assessment through performance, product, portfolio and self-assessment also give positive contributions to the development of students’ problem solving ability and critical thinking ability. It is suggested to physics teachers that they develop and use
PBL-based modules and prepare authentic assessment rubrics and do authentic assessment every time they teach.

Reference
[1] Gardner H 2007 *Five Minds for The Future* (Jakarta: Gramedia Pustaka Utama).
[2] Tilaar H A R 2012 *Pengembangan Kreativitas dan Enterpreneurship dalam Pendidikan Nasional* (Jakarta: Penerbit Kompas).
[3] Arend R I 2007 *Learning to Teach* (New York: The MacGraw-Hill Companies, Inc).
[4] Yew H Y 2016 *Health Prof. Educ.* 2 75.
[5] Ibrahin M and Nur M 2000 *Pengajaran Berdasarkan Masalah* (Surabaya: Universitas Negeri Surabaya).
[6] Aji S D, Hudha M N, and Rismawati A Y 2017 *Sci. Educ. J.* 1 36.
[7] Dianawati N L P, Riastini P N, Pujwan K 2017 *Mimbar PGSD Undiksha* 5 1.
[8] Mubuuke A G, Louw A J N, and Schalkwyk S V 2016 *Health Prof. Educ.* 3 85.
[9] Gorghi G 2015 *Proced. Soc. Behav. Sci.* 191 1865.
[10] Lestari D P 2016 *J. Pembelajaran Fis.* 4 96.
[11] Suastra I W and Ristiati N P 2017 *Int. Res. J. Eng. IT Sci. Res.* (IRJEIS) 3 24.
[12] Harlen W 1991 *The Teaching Science* (London: David Fulton Publisher)
[13] Al-Sadaawi 2008 An Investigation of Performance-Based Assessment in Science in Saudi Primary School. *Paper presented at 34th IAEA Annual Conference*, Cambridge UK, September 2008
[14] Chen D L 2015 Developing Critical Thinking through Problem Based Learning: An Research for a Class of Media Literacy. *Thesis (Doctoral).* Faculty of Social Sciences & Health Duran University. www://etheses.dur.uk/1024.
[15] Masek A and Yamin S 2011 *Int. Rev. Soc. Sci. Humanit.* 2 215.
[16] Enger S K and Yager R E 2001 *Assessing Student Understanding in Science* (California: Corwin Press, Inc).
[17] Kinay I and Bagcici 2016 *J. Int. Stud.* 9 51.
[18] Kaya H I 2010 Effects of the Practice based on Constructivist Learning in Teacher Education on Teacher Candidates’ Tendencies of Problem Solving, Critical Thinking and Creative Thinking *Dissertation University of Attaturk*
[19] Ward J D and Lee C L 2010 *J. Family Consum. Sci. Educ.* 1 16.
[20] Tai G X and Yuen M C 2007 Authentic Assessment Strategies in Problem Based Learning. *Proceeding of the Ascilite.* 983.
[21] Ling M K 2016 *Int. J. Assess. Tool Educ.* 3 151.
[22] Suastra I W 2007 *J. Pendidik. Pengajaran Undiksha* 40 21.