Development of STEM Integrated PBL-Based Student Worksheets in Energetic Materials of First-Year Students

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Abstract. This study aims to produce STEM integrated problem-based student worksheets by looking at the validity, practicality and effectiveness of student worksheets in student learning activities. This research method is a research development using the Plomp’s model. The design of this study was the design of one pretest-posttest group. The research subjects were students of chemistry majors Padang State University 2019. The research instruments used were validation sheets, practicality sheets and observation sheets of learning activities. This research shows that worksheet has a very high level of validity, very high level of practicality by students and high by the lecturer. The results showed that overall the average student learning activities were very high. This shows that the worksheets that has been produced can be used as one of the teaching materials in the learning process on energetic material.

1. Introduction

Indonesia, which is one of the developing countries, has always carried out reforms and innovations in the field of education to produce competent generations in all fields. But there are some constraints experienced in relation to the quality of education including the limited facilities in schools, the uneven number of teachers, and the quality of the teachers themselves who are considered to be lacking. In learning, the approach used in the assessment is still not appropriate and effective. So it takes an innovation by a teacher in learning to prepare and produce the desired generation.

In the current era of the industrial revolution 4.0, global education globally responds to the challenges of the 21st Century skills a global goal of education. So is the case with education in Indonesia. 21st Century skills consist of three major components, namely Thinking, Acting, and Living in the World [1]. Components of thinking include critical thinking, problem solving, creating, and metacognition. Acting components include communication, collaboration, digital literacy, technology literacy, flexibility and adaptability, initiative and self-directing. Components of living in the world include social responsibility, global understanding, leadership, and career readiness [1].

Learning to realize 21st Century skills oriented education, including STEM education. STEM refers to four disciplines namely science, engineering technology and mathematics that are related to each other. Mathematics is used in science, science involves scientific methods and learning to discover and will continue to technology and be useful for engineering [2].

Learning with this STEM approach, in line with the demands of the desired competencies in the 2013 Curriculum which demands and trains students in critical thinking, creative, collaborating and
communicating in facing 21st century challenges. In the 2013 curriculum there are 4 learning models that can be applied in STEM approach learning, namely the problem based learning model, inquiry learning model, discovery learning model learning and project based learning model learning.

Problem-based learning (PBL) is a learning model that connects the concept of material with everyday life and is equipped with real-world problems, so that students will be active in learning because of the material that is poured in. teaching materials related to everyday life. In PBL learning consists of 7 stages, namely description, brainstorming, systematization, problem description, evaluation, knowledge collection and reporting [3]. The benefits of learning PBL models in chemistry education include creative thinking, self-study skills and self-evaluation. Furthermore, students' understanding of chemistry can be improved through PBL, because this learning model aims to improve students' generic learning skills such as collaboration, synthesis, communication and problem solving. PBL has the potential to link subject matter with other fields of science [3]. The steps carried out in PBL can be seen in Figure 1.

![Figure 1. Steps in problem based learning (PBL)](image)

In a problem-based learning environment, important STEM concepts are embedded in the context of interesting interdisciplinary problems. PBL engages students in solving interdisciplinary real world problems, thus encouraging them to invoke concepts and ideas drawn from multiple disciplines. PBL, in essence, tries to mirror the processes used by scientists to solve real-life problems [4]. Incorporating real-world problems into science learning allows teachers to guide, investigate, and challenge students to think. Students become independent, problems as investigations encourage them to explore, enabling them to make meaningful connections between disciplines. STEM problem based learning integrates four fields of knowledge through problem-based learning.

Figure 2, is an illustration of the relationship between PBL and STEM. There are 3 types of learning contained in PBL, namely cognitive learning, content learning and collaborative learning [5]. Cognitive learning is focused on the ability to think critically, creatively and innovatively. While collaborative learning is focused on collaboration, self and communication skills. And content learning focuses on knowledge between STEM disciplines, the use of technology as a tool and real life relationships that ultimately lead to higher-order thinking skills [5].
Figure 2. Illustration of the relationship between PBL and STEM

2. Research Methods

This type of research is a research development that aims to produce a new product in learning in the form of PBL-based student worksheets that are integrated with STEM. The development model used is the Plomp’s model, which consists of 3 stages, namely preliminary research, prototyping stage and assessment phase [6].

The research subjects were first year students majoring in non-educational chemistry in 2019 and lecturer in chemistry at the mathematics and natural sciences faculty, Padang State University. The object of the research was in the form of student worksheets for PBL-based energetic materials for STEM students for 1st year. This research was conducted in semester 1 of 2019/2020.

The type of data collected is validity data, practicality data and effectiveness data from student worksheets. While the instruments used to collect data are validation sheets, practicality test questionnaires and student worksheets effectiveness instruments in the form of student achievement tests and student activity observation sheets.

Data analysis techniques for validity and practicality based on a questionnaire lecturers and students using the Kappa Cohen’s formula. Then, analysis of student activities can be searched using a percentage approach with the following equation:

\[
\%A = \frac{\text{score obtained}}{\text{maximum score}} \times 100\%
\]  

(1)

3. Result and Discussion

3.1. Preliminary research

General chemistry course is a compulsory subject in the Department of Chemistry / Chemistry Education, Faculty of Mathematics and Natural Sciences, UNP which can be taken in semester 1 (one) and can be repeated every odd semester. According to several lecturers of General Chemistry of Chemistry Education, Faculty of Mathematics and Natural Sciences, UNP, currently in the learning process they only use textbooks and there is no such module or LKM that students can use to make it easier to understand the basic concepts of the material being studied on energetic material. Moreover, energetics material is one of the materials that is classified as complex and requires a strategy so that this material is easily understood by students.

Meanwhile, the results of a questionnaire from chemistry students who had taken general chemistry courses said that so far no LKM had been used. So far, only using textbooks. And from the suggestions
given by the average student states that an LKM is needed to make it easier for students to understand the concept of the material easily.

Teaching materials that must be mastered by students based on syllabus and Semester Learning Plan are 1) Atomic structure, 2) Periodic System of Elements, 3) Basic Laws of Chemistry, 4) Gas Laws, 5) Ion Bonds, 6) Covalent Bonds, 7) Chemical Nomenclature, 8) Metal Bonds and Intermolecular Interactions, 9) Stoichiometry, 10) Chemical Energetics, 11) Chemical Kinetics and 12) Substance Forms.

Then a student analysis was carried out to identify learning targets. This analysis was carried out by interviewing chemistry lecturers regarding the description of student characteristics, including academic ability, learning motivation, psychomotor and student age. Based on the results of interviews with lecturers, students' academic abilities vary depending on the pathway to college.

This analysis aims to identify learning targets, including the ability to meet criteria such as: attitude; knowledge; and skills expressed in the formulation of learning outcomes. By understanding student characteristics, it will facilitate the development of Student Worksheets that are suitable for use by students.

3.2. Prototyping phase
At this stage, student worksheets are designed. Starting with making a concept map, looking for the concept of energetic material, determining the formulation of results based on the syllabus and semester learning plans, then designing and creating a discourse containing real world problems that are in accordance with the formulation of learning outcomes. Student-generated worksheets are self-evaluated which aims to double-check the completeness of the components contained in the learning tools developed. Then, the results of the self-evaluation were analyzed and revised. Furthermore, student worksheets are validated by experts, namely UNP chemistry lecturers. This validation consists of content components, constructs, linguistic, and graph.

![Figure 3](image.png)

The results of student worksheet validation by the lecturer.

The results of student worksheet validation can be seen in Figure 3. For the content component the value of $k = 0.77$ (valid), the construct component $k = 0.93$ (very valid), the language component $k = 0.93$ (very valid) and the graphic component $k = 0.92$ (very valid). The average validation by the lecturer $k = 0.89$ (very valid).

Then continued with one to one evaluation with 3 students majoring in chemistry. The purpose of this evaluation is to identify possible errors such as poorly understood grammar, incorrect spelling, punctuation, unclear instructions, material systematics, ease of use, attractiveness and student satisfaction. The instrument used was an interview sheet. The results of the interview stated that the LKM had an attractive appearance, the steps for learning activities were clear and easy to understand.
After one to one evaluation, conducted a small group evaluation with 6 students. The purpose of group evaluation is to identify deficiencies in student worksheets. The instrument used was a questionnaire sheet. The results prove that, the worksheet were practical with a very practical category with $k = 0.82$. Questionnaire sheets were also given to lecturers. The results prove that, the worksheet were practical with a practical category with $k = 0.77$.

![Figure 4](image_url)  
**Figure 4.** The results of student worksheet practicality by the lecturer and student.

### 3.3. Assessment phase

At the assessment stage, a field test will be carried out. At this stage the effectiveness test is carried out. To test the effectiveness of student worksheets used learning outcomes tests and observation sheets of student learning activities. The learning outcome test is the pre-test and post-test scores. From the results of the pre-test and post-test, it was found that the post-test scores were higher than the pre-test scores.

The observation sheet is a sheet designed to see student activities during the learning process. The learning activities are 1) visual activities (reading and experimenting), 2) oral activities (asking and issuing opinions), 3) listening activities (listening to descriptions and discussions), 4) writing activities (summarizing and making reports), 5) drawing activities (making diagrams), 6) motor activities (such as designing and conducting experiments), 7) mental activities (solving a problem and analyzing), and 8) emotional activities (interested).

On the energetic material, there were 3 meetings. The activities of the 3 meetings are shown in Figure 5, 6 and 7. In the three meetings, each activity has almost the same percentage. At the first, second and third meetings, the average percentage of students who were active in each activity was 82.56 (very high), 82.27 (very high) and 82.85 (very high). A very high percentage of activity shows that student worksheets are very effective to be used in the learning process.

![Figure 5](image_url)  
**Figure 5.** Student activity at the first meeting
Figure 6. Student activity at the second meeting

Figure 7. Student activity at the third meeting

Figure 8. Average student activity of all meetings

Figure 8, shows that the average activity of the three meetings. The average percentage of learning activities is 82.56 which is included in the very high category and indicates that student worksheets are very effectively used in the learning process
4. Conclusion
In this research, it can be concluded that the development of STEM integrated problem-based learning student worksheets using the Plomp’s model development has a very high level of validity \( k = 0.89 \), very high level practicality by students \( k = 0.82 \) and high by lecturer \( k = 0.77 \). The average student learning activity was 82.56 which was in the very high category, with a very high activity category proves that student worksheets are very effective in the learning process.

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