Problem based learning models based on science technology engineering and mathematics for developing student character

D Yulianti1,*, Wiyanto1, A Rusilowati1, S E Nugroho1 and K I Supardi2
1 Physics Department, Universitas Negeri Semarang, Indonesia
2 Chemistry Department, Universitas Negeri Semarang, Indonesia

*Corresponding author: yulifis04@yahoo.com

Abstract. This study aims to determine the implementation of Science, Technology, Engineering, and Mathematics (STEM) based Problem Based Learning (PBL) model, identifying increased knowledge achievement, character development, and skill enhancement. This research uses Quasi Experiment method while design uses one group pretest-posttest design. The instrument consists of an essay test for measuring the knowledge achievement and an observation sheet for measuring skills and character outcomes. Implementation PBL model based STEM on Impulse and Momentum materials, assisted by Student Worksheet, can improve knowledge achievement (cognitive) and skill (psychomotor), and also can develop the character of discipline, curiosity, communicative, and cooperation.

1. Introduction

Learning in the 21st century teachers skills called 4Cs (Critical Thinking, Creativity, Communication, and Collaboration) [1]. The Change Leadership Group of Harvard University and identify the competencies and survival skills needed in the 21st century are emphasized on the following seven skills [2]: (1) critical thinking and problem solving skills, (2) collaboration and leadership, (3) initiative and entrepreneur spirit, (5) able to communicate effectively both orally and writing, (6) able to access and analyzing information, and (7) have curiosity and imagination. Physics learning according to Indonesian curriculum (K13), aims to foster scientific attitudes, develop thinking skills and experience to formulate problems, propose and verify hypothesis, communicate experimental results, master the concept and principle of physics and develop science and technology [3].

The Indonesia Government has sought to improve the quality of education through the K-13 that has been implemented, but it seems to be in vain if students are not prepared to develop the knowledge, skills, and attitudes required by world of work in 21st century. Related to improving the quality of education in Indonesia as expected in the K-13, Science, Technology, Engineering, and Mathematics (STEM) is currently an alternative science learning that can build a capable generation for facing a challenging 21st century [4]. Another reason is that STEM education mostly combines problem solving, analysis, critical and creative thinking, teamwork, and communication skills as a pedagogical strategy [5]. Learning with STEM approach can be applied so that students can compete in the 21st century, because STEM is an important issue in education today [6, 7]. The purpose of this STEM integration is in line with the objectives of physics learning. STEM learning is an integration of science, technology, engineering, and math learning that is suggested to help the success of 21st century skills [1]. In addition, STEM is used to address real-world situations through a problem solving process-based design as used by engineers and scientists [8].
Based on Regulation of the Indonesia Minister of Education and Culture No. 103 years 2014 on learning in primary and secondary education explained that the learning model suggested in the K-13 are discovery learning, problem-based learning, project-based learning, and inquiry learning. Ministry of National Education since May 2, 2010 has launched the development of character education at all levels of education. The goal is to develop the potential of learners as human beings and citizens who have the values of the nation's character [9].

Observation results in one of the state high school in Semarang city, it is known that the students of 1st grade of mathematics and science class still have difficulty in solving problems related to everyday life especially identify the problem, thus resulted in low knowledge achievement. Meanwhile there is a learning model that can encourage cognitive achievement for students. Therefore, it needs to be implemented PBL model based on STEM. Students’ learning outcomes and problem-solving skills increased after the PBL model was applied [25]. It is also reveal that the integration of aspects of STEM have a positive impact on student learning, especially on improving student achievement in science and technology. The result of a research shows that the development of physics-based learning model of scientific character can improve students' honesty effectively [10]. This study aims to determine the implementation of STEM-based PBL model, to identify improvement of knowledge achievement, character development, and skill enhancement.

2. Methods
This research took place from October to November 2017. This research use Quasi Experiment method with research design using one group pretest-posttest design. The study was conducted in five classes in the high schools in the Semarang city, population and sample are all 1st grade mathematics and science students. There are two methods of data collection used in this research, namely: (1) method of essay test to measure knowledge achievement; (2) observation method to observe character development and skills enhancement. Analysis of research instruments using validity, reliability test, degree of difficulty and distinguishing power. While the analysis of research data include percentage analysis and test increase in the average (gain) to determine the increase in learning outcomes knowledge and skills and character development. Analysis of research data using gains test and test criteria of observation assessment. The N-gain test is used to determine the improvement of knowledge achievement, character development, and skill enhancement.

3. Results and Discussion
3.1. Implementation of STEM Based PBL Model
Prior to the implementation of the STEM-based PBL model, Student Worksheet has been prepared in which the work steps refer to PBL and STEM. On the student worksheet is integrated the characters values to be measured i.e. discipline, curiosity, communicative and cooperation. The teaching materials used are also oriented PBL and STEM, and there is integration of characters to be measured. Integrating character education in learning becomes very important. According to [15], states that the development of socialization skills and integration of character education becomes an important part of children's learning success.

Stages of implementing STEM-based PBL models consist of student-oriented problems, organizing students for learning, guiding individual and group investigations, developing and presenting the work, and analyzing and evaluating problem-solving processes.

The student-oriented stage on the problem, that is, students are introduced to problems in everyday life related to the material Impulse and Momentum which aims to improve learning motivation. This is in line with [16] statement that problem-based teaching helps students develop thinking skills, problem solving, and intellectual skills. The second stage is to organize the students to learn, which is to divide the students into groups and then distribute the Student Worksheet along with the experimental tools in each group. In the Student Worksheet there are projects that must be done in groups. Learning group or together can improve students' thinking sharpness. The third stage is to guide the individual/group experience, i.e. the teacher gives guidance to each group to discuss and experiment to solve the problems presented in the Student Worksheet. The fourth stage is to develop and present the work, i.e. the representation of each group is asked to present the work of the group and other group
members are welcome to ask or express an opinion. This is in line with the results of [16] indicating that the use of presentation models in front of the classroom enhances communicative skills. The fifth stage is to analyze and evaluate the problem-solving process, i.e. the teacher helps the students to reflect on the performance that has been done to unite the thinking to the right concept. The cognitive learning outcomes are presented in Table 1.

**Table 1. Average Knowledge Achievement**

| 1st Grade Math and Science Class | Average Pretest | Average Posttest | N-gain Test Result | N-gain Criteria |
|----------------------------------|-----------------|------------------|--------------------|----------------|
| 1                                | 50.75           | 83.13            | 0.657              | Medium         |
| 2                                | 48.97           | 84.34            | 0.644              | Medium         |
| 3                                | 49.66           | 83.99            | 0.605              | Medium         |
| 4                                | 53.03           | 81.34            | 0.599              | Medium         |
| 5                                | 52.44           | 85.34            | 0.648              | Medium         |

Overall the gain test results of each class showing moderate results, which means that the implementation of the STEM-based PBL model can improve the knowledge achievement even in medium criteria. This is consistent with the results of research stating that the STEM integrative approach has a positive impact on student learning especially on improving learning achievement and developing critical thinking skills [6,19]. Through this STEM-based PBL implementation, students are brought closer to the application of physics in daily life, thereby enhancing material understanding. The results of research [20] stated that linking physics learning with everyday life can make students more active when discussing, asking questions, and making suggestions. Application STEM can improve the academic and non- academic achievement of learners, STEM can increase knowledge mastery, apply knowledge to solve problems, and encourage learners to create something new [22,23].

3.2. Character Development

Character that is measured is discipline, curiosity, communicative and cooperation has increased. In this research, character education is integrated into Student Worksheets and teaching materials. This is one way of habituation that can be done through the instruction of every activity or task for learners. Characters development results are presented in Table 2.

**Table 2. Percentage of Character Development**

| Character        | Before | Criteria    | After | Criteria    | N-gain Test Result | N-gain Criteria |
|------------------|--------|-------------|-------|-------------|--------------------|----------------|
| Discipline       | 71%    | Begin Developing | 87.6% | Be Entrenched | 0.583              | Medium         |
| Curiosity        | 55.85% | Starting Visible | 76.8% | Begin Developing | 0.487              | Medium         |
| Communicative    | 56.5%  | Starting Visible | 77.7% | Begin Developing | 0.451              | Medium         |
| Cooperation      | 70.26% | Begin Developing | 87.85% | Be Entrenched | 0.623              | Medium         |

The development of the character of discipline occurs because students are directly involved in learning. They enter the classroom before teachers enter and order during the learning process at each meeting. Students are required to collect tasks such as Student Worksheet on time with the aim of training students' disciplinary attitudes. The character of discipline is included in the instructions of each discussion and practicum activity, this is in line with the results of research [18] which shows that integrating the character of discipline in teaching materials and worksheets in which there is discussion and practicum activities can improve the development of student character.
The character of curiosity also increases, because the activities are carried out in groups, group activities can improve students' curiosity and creativity. The existence of group activities causes interaction between students, exchanging information that causes students to find alternative solutions presented by teachers. In the teaching materials used there are discussion and experiment activities that can encourage the curiosity of students through asking in solving problems. In addition, the teaching materials also presents the case of natural phenomena associated with the concept of heat so that attract student’s curiosity to ask questions. The development of communicative character is caused by each problem based learning that is applied. The students communicate the result of discussion or practice and make the report so that it can develop the character of communication. PBL can improve the ability to communicate scientifically [26, 27].

Character of cooperation is also growth, this is because the learning activities are done in groups with the aim of fostering the attitude of cooperation among students in solving a problem. Group work is an increasingly important tool for teaching with some known benefits including the ability to improve learning experience, self-esteem, achievement and to strengthen knowledge, skills, and problem-solving skills [20, 21]. Working in a group is very advantageous because students can interact with their friends and can exchange opinions to get solution problems in the lab and discussion. In addition, students can also compare their work with other members. Habituation of this cooperation attitude brings a change of attitude to a better direction so communication, negotiation, collaboration, independence, confidence, decision making, because this character is a prerequisite for the effectiveness of a team

3.3. Psychomotor Development

Analysis result of psychomotor aspect are presented in Table 3.

| Table 3. Analysis Result of Psychomotor Aspect |
|-----------------------------------------------|
| Aspect                                      |
|                                              |
| Doing observation in the experiment          |
| Issuing opinion                              |
| Write out the report                         |
| Speaking in front of the class               |
| Average                                     |

| Aspect                                      | A   | B   | C   | D   | E   |
|---------------------------------------------|-----|-----|-----|-----|-----|
| Doing observation in the experiment         | 85.64 | 88.72 | 86.55 | 85.65 | 92.82 |
| Issuing opinion                             | 76.41 | 81.54 | 78.89 | 81.23 | 82.56 |
| Write out the report                        | 79.49 | 82.56 | 81.23 | 87.69 | 80.34 |
| Speaking in front of the class              | 82.56 | 82.78 | 87.05 | 86.92 | 84.67 |
| Average                                     | 81.03 | 83.85 | 83.43 | 85.33 | 85.05 |

The use of problem-based approaches in the learning process and at the time of the experiment, able to make students become more skilled. The use of problem-based approach in the learning process can improve experimental performance skills [22]. It shows that there is an increase of skill learning result after using Student Worksheet with scientific approach. It also shows that the use of character-based Student Worksheet using a scientific approach can improve skills [23].

PBL application is complemented by practical and experimental activities. On activities experiment, students observe and write experimental data according to results observations made, as well as presenting the results of group discussions. Aspect expressing opinions in discussions indicated the active activities and active involvement of students discussion, and respect for the opinions of others. Aspects write down the results of the discussion shown by students by writing the results of the discussion in a coherent and complete manner does not cause different meaning/meaning. In the aspect of speaking in front of the class shown students are fluently speaking and giving acceptable opinions with common sense. This is in accordance with the research of [26] which shows that practical methods can make students more active and creative. Experiment activities are carried out in group and the results are discussed with friends in the group, then presented in front of the class. The results of previous work of Yulianti [27] also shows that group discussion activities and presentations in front of the class will make students feel happy and active. The problem-solving process during the experiment able to make students become more skilled at finding answers, this is
consistent with Artikasari &amp; [24] which states that practicum activities can encourage students to find answers in detail and clearly.

4. Conclusion
Implementation of PBL model based STEM on impulse and momentum subject, assisted by Student worksheet can improve knowledge achievement (cognitive) and skill (psychomotor). It also can develop the character of discipline, curiosity, communicative, and cooperation.

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