# The Development of High School Physics Teaching Material Based on STEM to Facilitate the Development of 21th Century Learning Skills

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**Abstract.** This study aims to develop high school physics teaching materials that facilitate the development of 21st century learning skills, consisting of critical thinking, creative, communication and collaboration known as 4C skills. Test the readability and feasibility of the developed teaching material. The method used is Research and Development (R&D). The research instrument consisted of tests, questionnaires and observation sheets. The results of the study show that the teaching material developed is suitable for use in learning and easy to understand. The results of the analysis of the development of critical thinking skills, creative, communication and collaboration, showed a high increase.

**Keywords:** STEM, 21th Century Learning Skills, Physics Teaching Material

## 1 Introduction

The competency standards set in the 2013 Curriculum for elementary and secondary education graduates, on aspects of skills integrated 21st century skills are creative, productive, critical, independent, collaborative and communicative [1]. Critical, creative, communicative and collaborative thinking skills are known as 21st century learning skills or 4C skills. 21st century learning skills can be developed through the Science Technology Engineering and Mathematic (STEM) approach. STEM-based learning can help students solve problems and draw conclusions and then apply them in science, technology, engineering and mathematics [2, 3], train students' reasoning abilities [4] and thinking skills high level [5]. The results of a survey of 150 Physics teachers who are members of the Musyawarah Guru Mata Pelajaran Fisika (MGMP), showed that 87% of the physics teachers MGMP members had not prepared STEM-based teaching materials, 92% had not facilitated the development of 4C skills. This problem must be addressed immediately so that the educational objective of producing graduates with 21st century skills is quickly achieved. This study aims to describe STEM-based teaching materials that facilitate critical thinking, creative, communicative and collaborative skills. Another aim is to test eligibility and readability.

MSCEIS 2019, October 12, Bandung, Indonesia

DOI 10.4108/eai.12-10-2019.2296350

## 2 Method

The research method used is research and development (R&D). Research trials using One Group Pretest-Posttest Design. The subjects were 180 students of grade X MIPA, who came from five high schools in the city of Semarang. The research procedure was divided into four stages, namely preliminary studies, planning, development and testing. The research instrument consisted of a written test which included an overlap test, a description, a questionnaire, and an observation sheet.

## 3 Results and Discussion

### 3.1 Description of Teaching Materials

The material in this study is about Impulse and Momentum for class XI high school / MA students. The physics teaching materials contain physics concepts that are presented using the STEM approach, in which there are 4C skills development facilities in the form of, inserting indicators of critical thinking, creative, communication and collaboration (4C) skills. The concepts of physics as part of science are packaged in teaching materials contextually related to their application in the fields of technology and engineering by utilizing mathematics as the language of science and technology. According to the research by [6], mathematics can provide convenience in interpreting things, so that they can be easily understood. Research [7], mentioning the integration of techniques into learning material can develop higher-order thinking skills and mastery of science concepts. STEM-based teaching materials can develop critical thinking skills and mastery of students' concepts. This is consistent with the results of research that states that the STEM integrative approach has a positive impact on student learning, especially on improving learning achievement and developing critical thinking skills [8, 9]. Teaching material developed, divided into three parts, namely introduction, content, and closing. The introduction consists of the Title Page, Preface, Table of Contents, Concept Map, Basic Competence (KD), and Learning Objectives. The contents section consists of physics material. The concluding section consists of Material Summary, Competency Test, Glossary, and Bibliography. STEM based teaching materials are printed using A4 paper (21 cm × 29.7 cm), Typography writing teaching materials using Times New Roman letters size 12 pt. Science as the most important aspect is integrated in the form of discussion of material in each sub-chapter as well as some information related to the application of concepts. Technological aspects are integrated in the form of discussion of the application of basic concepts. Engineering aspects are integrated in the form of design information and the workings of several technologies that apply physics concepts. Based on the results of research [7], the integration of engineering aspects into learning material can help students develop mastery of concepts and higher-level thinking skills. Mathematical aspects are integrated in each chapter in the form of using number symbols for counting and measurement. This can facilitate understanding and problem solving related to the concept of physics. According to [6], mathematics can make it easier to interpret things, so that they are easy to understand. The feasibility of teaching materials is reviewed from three aspects, namely content, presentation, and language. The results of the feasibility analysis of teaching materials are presented in Table 1.

Teaching materials developed meet the eligibility standards for print teaching materials set by the National Education Standards Agency [10], which states the feasibility of printed

teaching materials can be assessed based on aspects of content, presentation, and language. The category of eligibility is caused by the process of preparing teaching materials that have been adjusted to the guidelines set by the Ministry of National Education. The content eligibility aspect consists of elements of conformity, accuracy and updating of the material, STEM characteristics, and 4C capability. The feasibility aspects of the presentation of teaching materials, namely the technique of presentation, presentation of learning, and completeness of the presentation. The material in STEM-based teaching materials is presented coherently from general concepts as well as more specific concepts regarding the application of Impulse and Momentum. In addition, teaching materials are presented with various illustrations in the form of pictures that support learning material. According to [11], illustrations in teaching materials can help students absorb knowledge and understand concepts. Aspects of language appropriateness, namely conformity with the level of development, straightforward, communicative, and conformity with Indonesian rules. STEM-based teaching materials are prepared using straightforward, communicative Indonesian and pay attention to the rules of Enhanced Spelling. The components of teaching materials include readability, clarity of information, as well as conformity with good and correct Indonesian language rules.

Readability test results, obtained an average score of 84.67%. According to the Rankin & Culhane readability criteria, STEM-based teaching materials are in the easy to understand category. The sentence structure used in teaching materials is in accordance with the general rules of the Indonesian language, using the font type Times New Roman with a size of 12-14 pt.

**Table 1.** Analysis result of feasibility of teaching materials.

| No | Aspect | Percentage | Criteria |
|---|---|---|---|
| 1 | Content | 84,20 % | Very Feasible |
| 2 | Presentation | 85,62 % | Feasible |
| 3 | Language | 78,98 % | Feasible |
| | Average | 83,57 % | Feasible |

### 3.2 Critical Thinking Skills

The analysis results of critical thinking skills are presented in Table 2.

Teaching material developed, facilitating students to get used to studying a problem with higher-order thinking skills. The ability to reason is developed through the presentation of problems relating to life around so that they are able to imagine and think logically to find solutions to problems. The ability to analyze is stimulated because teaching materials present new information or an issue that creates curiosity to find a solution. The ability to analyze can develop, because when students receive little initial information, they can search for related information and look for continuity with learning material, so they are able to find theories that are the basis, then be able to describe the information that has been obtained, and produce a conclusion that is the answer to the feeling want to know them and a solution that has the right reasons. The development of critical thinking skills in this study using the STEM approach

proved effective, because with the STEM approach students learn subject matter through problem-solving activities that are associated with aspects of STEM and daily life.

**Table 2.** Results of critical thinking ability.

| Indicator | School code | Average score | | Gain test | Criteria |
|---|---|---|---|---|---|
| | | Pretest | Postest | | |
| Reasoning | S-01 | 46,88 | 96,98 | 0,94 | High |
| | S-02 | 48,63 | 98,07 | 0,94 | High |
| | S-03 | 37,50 | 83,48 | 0,75 | High |
| | S-04 | 35,63 | 79,93 | 0,74 | High |
| | S-05 | 38,63 | 78,93 | 0,73 | High |
| Analysing | S-01 | 35,65 | 80,93 | 0,76 | High |
| | S-02 | 34,38 | 90,09 | 0,92 | High |
| | S-03 | 53,31 | 90,83 | 0,80 | High |
| | S-04 | 49,48 | 85,78 | 0,68 | Medium |
| | S-05 | 46,68 | 94,88 | 0,93 | High |
| Give an effective reason | S-01 | 56,88 | 96,98 | 0,84 | High |
| | S-02 | 41,36 | 96,07 | 0,94 | High |
| | S-03 | 41,50 | 86,70 | 0,86 | High |
| | S-04 | 38,75 | 96,75 | 0,82 | High |
| | S-05 | 37,60 | 83,58 | 0,75 | High |

### 3.3 Creative Thinking Skills

The results of developing creative thinking skills are presented in Table 3. STEM-based teaching materials that are applied to learning physics can help students in developing creative thinking skills. STEM integrated learning has a major effect on students' creative thinking skills. Learning applied in the classroom presents problems, discussions and simple experiments so that it is more student-centered, as an effort to facilitate them to think creatively. The development of high creative thinking skills makes students learn through direct experience given during the learning process. This is consistent with the results of [12], creativity possessed by students will develop well if students learn based on the experiences they have experienced. The factors that influence students 'fluency in formulating ideas are students' knowledge insights related to understanding material not just remembering what they have learned. In STEM-related learning, students learn lessons through activities that require student activity such as

discussions and practical work, so that students' understanding of subject matter is not only limited to remembering.

**Table 3.** Results of creative thinking ability**.**

| Indicator | School code | Average score | | Gain test | Criteria |
|---|---|---|---|---|---|
| | | Pretest | Postest | | |
| Creating ideas | S-01 | 35,55 | 80,93 | 0,76 | High |
| | S-02 | 34,38 | 91,09 | 0,92 | High |
| | S-03 | 54,31 | 89,83 | 0,80 | High |
| | S-04 | 49,58 | 85,68 | 0,68 | Medium |
| | S-05 | 45,68 | 93,88 | 0,93 | High |
| Elaborate ideas | S-01 | 56,88 | 96,98 | 0,84 | High |
| | S-02 | 42,36 | 95,07 | 0,94 | High |
| | S-03 | 42,50 | 85,70 | 0,86 | High |
| | S-04 | 38,75 | 96,75 | 0,82 | High |
| | S-05 | 37,60 | 83,58 | 0,75 | High |
| Originality | S-01 | 35,65 | 80,93 | 0,76 | High |
| | S-02 | 34,38 | 90,09 | 0,92 | High |
| | S-03 | 53,31 | 90,83 | 0,80 | High |
| | S-04 | 49,48 | 85,78 | 0,68 | Medium |
| | S-05 | 46,68 | 94,88 | 0,93 | High |
| Realize ideas | S-01 | 53,31 | 90,83 | 0,80 | High |
| | S-02 | 35,65 | 80,93 | 0,76 | High |
| | S-03 | 34,38 | 90,09 | 0,92 | High |
| | S-04 | 41,50 | 86,70 | 0,86 | High |
| | S-05 | 34,38 | 90,09 | 0,92 | High |

### 3.4 Communication Ability

The results of communication ability are presented in Table 4. Communication skills for each indicator are well developed. Learning using STEM-related teaching materials, students learn through activities carried out through problem solving activities. Through problem solving activities, students find solutions related to the problems presented, then write reports on the results of problem solving that have been obtained, in the form of discussion reports, as well as practicum, so that written communication skills can develop. Through problem-based learning, written communication skills can develop. The written communication skills in this study were also developed through writing practicum reports. So, through the preparation of practical

reports, it can develop written communication skills. Learning uses STEM-related teaching materials, accustoming students to be active, through group discussions, questions and answers, practicums, and presentations. Through discussion, question and answer, practicum, and presentation activities, students are accustomed to actively speaking to convey their ideas, so that students' abilities in each indicator can develop properly.

**Table 4.** Results of communication ability.

| Indicator | School code | Average score | | Gain test | Criteria |
|---|---|---|---|---|---|
| | | Early | End | | |
| States the solution to the problem with a chart, table, picture or mathematical language | S-01 | 38,22 | 86,31 | 0,80 | High |
| | S-02 | 46,67 | 88,10 | 0,82 | High |
| | S-03 | 42,38 | 87,14 | 0,79 | High |
| | S-04 | 28,10 | 82,38 | 0,75 | High |
| | S-05 | 35,71 | 77,60 | 0,65 | Medium |
| Explain ideas, situations and physical relations | S-01 | 28,30 | 82,18 | 0,74 | High |
| | S-02 | 46,76 | 88,05 | 0,79 | High |
| | S-03 | 38,22 | 86,31 | 0,79 | High |
| | S-04 | 46,67 | 88,10 | 0,80 | High |
| | S-05 | 42,28 | 86,04 | 0,76 | High |
| Use physical language, symbols and thinking schemes appropriately | S-01 | 38,22 | 86,31 | 0,79 | High |
| | S-02 | 46,67 | 88.10 | 0,80 | High |
| | S-03 | 42,38 | 87,14 | 0,78 | High |
| | S-04 | 28,10 | 82,38 | 0,75 | High |
| | S-05 | 35,71 | 77,60 | 0,65 | Medium |

### 3.4 Collaboration Ability

The results of communication ability are presented in Table 5. Learning using the developed teaching material, students are directed in groups such as group discussions, practical work, and group presentations. Collaborative skills can develop optimally, because the teaching material developed near STEM is designed using collaborative learning, to facilitate the development of collaboration and collaboration skills. Discussions that occur in the classroom can strengthen students' arguments that students who work in groups produce far better arguments than students who work alone in mastering assignments. Collaborative learning is a foundation for building togetherness and collaboration skills. Students become confident conveying the arguments of their cooperation. In line with the results of research [13] collaborative learning models can increase student confidence. The stages in the collaborative learning model that can increase student confidence are at the sharing and creating stages. Because at this stage students are required to express their opinions and create new concepts or knowledge from the discussion. Collaborative learning results encourage the development of critical thinking through discussion, clarification of ideas, and evaluation of other people's ideas. Collaborative learning

can improve critical and analytical thinking. So the development of collaborative skills can also indirectly develop other 4C skills, including critical thinking skills, creative thinking, and communication. Through collaborative work students will interact with friends and together solve the problems presented. Interaction conducted by students in collaborative activities will develop communication skills and thought processes in problem solving. The study in group gives advantages to students in finding solutions to problems, in addition to that students are also able to remember material well from group learning rather than learning on their own. Learning is also supported by STEM-based teaching materials that contain the presentation of problems to be solved together. Knowledge is actively built by students themselves and learning is a shared experience not an individual experience. In some schools, the development of collaboration skills is still in the medium category.

**Table 5.** Results of collaboration ability.

| Indicator | School code | Average score | | Gain test | Criteria |
|---|---|---|---|---|---|
| | | Early | End | | |
| Work effectively | S-01 | 35,11 | 77,78 | 0,65 | High |
| | S-02 | 33,07 | 84,44 | 0,79 | High |
| | S-03 | 38,39 | 88,33 | 0,80 | High |
| | S-04 | 35,56 | 78,32 | 0,65 | Medium |
| | S-05 | 43,08 | 91,18 | 0,81 | High |
| Contribution to groups | S-01 | 38,39 | 88,33 | 0,80 | High |
| | S-02 | 35,56 | 78,32 | 0,65 | High |
| | S-03 | 35,11 | 77,78 | 0,65 | Medium |
| | S-04 | 33,07 | 84,44 | 0,79 | High |
| | S-05 | 38,39 | 88,33 | 0,80 | High |
| To be responsible | S-01 | 35,56 | 78,32 | 0,65 | Medium |
| | S-02 | 43,08 | 91,18 | 0,81 | High |
| | S-03 | 35,11 | 77,78 | 0,65 | Medium |
| | S-04 | 33,07 | 84,44 | 0,79 | High |
| | S-05 | 38,39 | 88,33 | 0,80 | High |

## 4 Conclusion

STEM-based teaching materials developed have characteristics to facilitate the development of 21st century learning skills known as 4C skills consisting of, critical thinking, creative, communication and collaboration. The subject matter in teaching material is Momentum and Impulse. The integration of STEM is shown in the discussion of the application of material in everyday life technology and the project of making technology products for the

application of the material being taught. 4C skills indicators are raised in each activity such as discussion, project, trial, questions and final evaluation. STEM physics teaching materials that facilitate the development of 21st century learning skills, are appropriate for use in learning and easy for students to understand. Moreover, it can develop critical thinking skills, creative, communication and collaboration, with high average criteria.

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