PERIÓDICO TCHÊ QUÍMICA
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DESENVOLVIMENTO DE MATERIAIS DE ENSINO-APRENDIZAGEM DE FÍSICA BASEADOS EM TECNOLOGIA CIENTÍFICA DE ENGENHARIA E MATEMÁTICA PARA DESENVOLVER HABILIDADES DE APRENDIZAGEM DO SÉCULO XXI

DEVELOPMENT OF PHYSICS LEARNING TEACHING MATERIALS BASED ON SCIENCE TECHNOLOGY ENGINEERING AND MATHEMATICS TO DEVELOP 21ST CENTURY LEARNING SKILLS

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RESUMO

O aprendizado baseado na tecnologia científica de engenharia e matemática (STEM) foi amplamente implementado no aprendizado para ajudar os alunos a entenderem o aprendizado no século XXI. O desenvolvimento de materiais de ensino é uma maneira de implementá-los, mas esses materiais de ensino devem estar de acordo com as competências do currículo de 2013 e aplicar os valores e conceitos contidos na aprendizagem no século XXI. Este estudo teve como objetivo descrever as características do material didático de aprendizagem de física baseado em STEM para desenvolver habilidades de aprendizado do século XXI e testar a legibilidade e a viabilidade. Esse estudo foi dividido em quatro etapas (estudos preliminares, planejamento, desenvolvimento e testes). O design do teste usa o *One Group* Pré-Teste e Pós-Teste. Os sujeitos dos ensaios em pequenos e grandes grupos foram estudantes do quinto semestre do Programa de Estudos em Educação Física *Universitas Negeri Semarang*. Os materiais de ensino apresentam dados sobre os antecedentes da importância das habilidades de aprendizagem STEM e do século XXI, material STEM e habilidades de aprendizado do século XXI, STEM e exemplos baseados no ensino de aprendizagem de física. Os resultados do teste de viabilidade, utilizando um questionário, mostraram que o material didático estava na categoria viável. Os resultados dos testes de legibilidade, usando um teste de *cloze* e um gráfico de *Raygor*, mostraram que o material didático estava incluído na categoria de fácil compreensão.

Palavras-chave: *STEM, materiais didáticos, legibilidade, viabilidade, materiais didáticos de aprendizagem.*

ABSTRACT

Learning based on Science Technology Engineering and Mathematics (STEM) has been widely implemented in learning to assist students in understanding learning in the 21st century. Developing teaching materials is one way to implement them, but these teaching materials must be in accordance with competencies in the 2013 curriculum and apply the values and concepts contained in learning in the 21st century. This study aimed to describe the characteristics of physics learning teaching material based on STEM to develop 21st Century Learning Skills and testing readability and feasibility. This study was divided into four stages (preliminary studies, planning, development, and testing). The trial design uses One Group Pretest-Posttest. The subjects of the small and large group trials were students of the fifth-semester Physics Education Study Program Universitas Negeri Semarang. The teaching materials showed data about the importance of STEM and 21st-century learning skills, STEM material, and 21st Century Learning Skills, and Physics Learning Teaching based STEM and examples. The results of the feasibility test using a questionnaire showed that the teaching material was in the category of feasible. Readability test results using a cloze test and Raygor graphic showed that the teaching material included in the easy to understand category.

Keywords: *STEM, teaching materials, readability, feasibility, learning teaching materials.*

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1. INTRODUCTION:

The 21st-century learning and innovation skills, known as 4C skills, are soft skills that need to be developed in every individual. Kivunja (2015) states that 4C is a super skill which is the core skill because it can help students to develop and demonstrate a good understanding of career skills, information, media, and technology. The Ministry of Education and Culture of the Republic Indonesia has adopted the concept of 21st-century education, in developing the 2013 curriculum for Senior High Schools (SMA) and Madrasah Aliyah (MA), namely 21st Century Skills (Trilling and Fadel, 2009). The US-Based Partnership for 21st Century Skills (P21) and (Beers, 2011) identify the competencies required in the 21st century, namely Communication, Collaboration, Critical Thinking, and Creativity, which is abbreviated as "the 4C".

Lundeberg & Jacobson (2016) mentioned that communication as a gate of 21st-century skills. Communication skills become one of the important considerations in the world of education and work. Metusalem *et al*. (2017) states that the importance of communication skills for personal, academic, and professional success is recognized in the elements of current standards and educational practices. According to Hoon, Fadzlin, & Singh (2017), communication skills and class management can influence the success of class activities and student learning. Collaboration is expressed as a coordinated and synchronous activity that is the result of ongoing efforts to build and maintain a shared conception of an issue (Rosen, Ferrara, & Mosharraf, 2016). Collaboration is carried out to achieve common goals. Lai *et al*. (2017) revealed that collaboration and teamwork focus on the process of interacting and requiring individuals to work together towards shared goals. The role of collaboration in learning is stated by Ronfeldt, Farmer, McQueen, & Grissom (2015) that can provide benefits for students. Students will get better achievement if they study in a strong collaborative environment. Woodland & Hutton (2012) states that collaboration can produce greater innovation while conserving resources to achieve common goals.

Critical thinking has a role in the world of education, especially for students. The benefits in students according to Bassham, Irwin, Nardone, & Wallace (2010) that it can help them do better learning in class by increasing their ability to understand, build, and criticize an argument. Critical thinking skills in students influence their learning outcomes. Siburian, Corebima, Ibrohim, & Saptasari (2019) stated that students' critical thinking skills need to be empowered in learning, so students get more optimal learning outcomes. Creative thinking skills are very necessary in life. Creative thinking is a high-level thinking ability (Kotzer & Elran, 2012). Creative thinking skills are needed for someone to be able to innovate. The benefits of creative thinking skills are also mentioned by Siburian *et al*. (2019) that it has tangible benefits for improving students' understanding of concepts, which can ultimately contribute to cognitive learning outcomes.

The development of 21st-century learning skills can be implemented through the Science Technology Engineering and Mathematics (STEM) approach (Bybee, 2010; Elliot *et al*., 2001; Gülhan and Şahin, 2016; Kennedy and Odell, 2014; Morrison, 2006; Olivarez, 2012; Roberts, 2012; Sahin *et al*., 2014; Yamak *et al*., 2014). STEM is an acronym for Science, Technology, Engineering, and Mathematics, which was introduced by the National Science Foundation (NSF) in the 1990s (Bybee, 2013). STEM is an approach to education that aims to integrate the four disciplines of science (S), technology (T), engineering (E), and mathematics (M) (Ercan, Altan, Taştan, & Dağ, 2016). The STEM approach not only focuses on the interdisciplinary integration of S, T, E, and M, but also focuses on systematic thinking, openness to communication, ethical values, research, production, creativity, problems, intersection of knowledge and skills in science, technology, engineering, and mathematics (Çengel, Alkan, & Yildiz, 2019). The advantage of integrating STEM into all class-level curricula was mentioned by Meyrick (2011) that STEM provides students with the experience and knowledge to determine their future careers, understand the principles of engineering design for completing problem-based projects and deepen students' understanding of 21st-century skills.

This means that in the 2013 curriculum, the STEM approach can be applied specifically to physics learning in schools. The achievement of the learning and competency objectives expected by the 2013 curriculum requires model innovation, approaches, and learning strategies, this means that physics teachers are required to be able to design learning that can deliver students to achieve the expected competencies. In order for teacher candidates to teach physics using the STEM approach to develop 21st-century learning skills, teaching materials needed for learning STEM-based Physics are integrated into

21st-century learning skills. This study aimed to describe the characteristics of Physics Learning Teaching Material Based on Science Technology Engineering and Mathematics (STEM) to develop 21st Century Learning Skills, and testing readability and feasibility.

2. MATERIALS AND METHODS:

The research was conducted at the Department of Physics Education FMIPA Universitas Negeri Semarang. The research subjects were 150 of fifth-semester students who were taking Basic Courses and Learning Processes in Physics I. The subjects of this research were divided into four classes consisted of 35-40 students. The subjects were all classes or population studies and chosen because they will get material about Learning Teaching Methods. When taking research data, classes are held in parallel so that the time and conditions are the same. The research method used was research and development (R & D). The research procedure used is four stages, namely the preliminary study planning, development, and trial phases. The preliminary study phase analyses the Semester Learning Plan and observes the material on the teaching materials used in the lecture process. The planning stage compiles a draft of teaching materials to be developed. The development phase includes the process of preparing STEM-based physics learning teaching materials to develop 21st-century learning skills. The trial phase consisted of small and large scale trials, including readability, feasibility. The validation sheet is used to determine the feasibility of teaching materials using a Likert scale. The Cloze test is used to determine the readability of teaching materials, Raygor graphic, to determine the level of readability.

3. RESULTS AND DISCUSSION:

Learning materials Science Technology Engineering and Mathematics (STEM) integrated learning skills of the 21st century. STEM-based learning materials developed, consisting of five chapters, numbered 63 pages and is divided into three parts: introduction, content, and closing. The introduction consists of the title page, preface, table of contents, Graduates Learning Subjects, and Learning Objectives. The body consists of five chapters, cover consisting of a Bibliography, Glossary, and Index. Printed materials use A4 paper (29.7 cm × 21 cm) because it has a size that fits the needs of learning. According to (Prastowo, 2015), paper size to print learning materials should be able to accommodate the needs of the learning that has been set. Typography writing materials using Times New Roman font size 12 pt. According to (Mudzakir, 2009), one of the components of the consummation of learning materials print is 12-14 pt font size for this type of Times New Roman or comparable to the type of the other. Learning materials, special titles, and subchapters, type, and size of letter customized to your needs.

Readability level measurement results using Raygor graphic indicates that the materials are appropriate for the level of the fifteen and above, which means according to the university level. As Gyasi (2013) states, readable text produces greater comprehension, retention, reading speed, and motivates readers. (Muslich, 2010) preparation of the textbook should pay attention to the linguistic elements related to the readability. In this formula the readability, sentence length and word difficulties identified as the main determinant of the readability of the text (Zamanian and Heydari, 2012). The readability of a text depends on how easy the text it is understood by the reader (Fry, 2002). There are a variety of methods and different approaches that can be used to assess the level of readability of reading materials. The most common approach in assessing the readability is the use of the formula. These formulas give educators the estimated difficulty of books and other texts. Most readability formulas are combining two components of semantic difficulty and the difficulty of the syntax (Freahat, 2014).

The appropriateness of materials from seven aspects, i.e. the content, the presentation of the material, component 4C, STEM skills, physics-based STEM learning components, completeness of presentation and language. The results of the analysis of the feasibility of the learning materials are presented in Table 1.

Based on the results of the analysis of the test of feasibility, materials-based STEM meets the eligibility standard print materials that are set by the Badan Standarisasi National Pendidikan (BSNP). Standard assessment defined (BSNP, 2014); the feasibility of the print materials can be assessed based on aspects of content, presentation, and linguistic. The achievement eligibility categories can also be caused by the process of the preparation of learning materials that have been adapted to the guidelines set forth by the Department of national education.

Aspects of the feasibility of the content

consist of elements of completeness, depth of content, the accuracy of the facts, and the concept of developmental science, fitness, and contextual. Materials physics-based STEM learning consistently presents material associated with the approach of the STEM and 21st-century learning skills. STEM-based learning, able to develop the ability to think creatively and improve the creativity of students (Lestari, 2018; Pertiwi, 2017).

Aspects of the presentation of the material consists of concept, systematics, user-centered, and coherence as well as motivation. The content in the materials presented in order from the general concept headed to more specialized concepts regarding the application of the approach STEM. In addition, the materials are presented with examples of illustration that comes in the form of images that support the learning material. According to (Cook 2008), illustration in the learning materials can help students absorb knowledge and understand concepts.

Aspects of component skills 4C consists of the urgency of skills and 4C aspect. This needs to be supplied to the candidates because of the role of teachers in the 21st century should be shifted from the patterned "planter of knowledge," leading to a role as mentors, directors discussion and measuring student learning progress (Hampson, 2011). (Luthvitasari, 2012) research shows that project-based learning can improve aspects of critical thinking skills, creative thinking, and generic skills of students. Research results (Duran and Sendag, 2012), learning associated with aspects of the STEM can develop critical thinking ability significantly. Critical thinking ability evolves because supported by the existence of the problem presented in the materials, including the questions and discussions. The problems are presented with customized aspects of STEM students and facilitate discussions to find a solution to any problem. Research results (DeJarnette, 2012), collaborating learning problems and aspects of the STEM can attract and train the ability of critical thinking.

Aspects of STEM components consist of the urgency approach STEM and elements in the STEM learning materials. This is important because its existence in learning materials suitably (Reeve, 2013), as an interdisciplinary approach on STEM learning, direct students to use science, technology, engineering, and mathematics in the context of a real-time to connect between school, work, world, and globalized world, so develop a STEM literacy delivering learners able to compete in the knowledge-based era. STEM materialized in certain situations when learning science (including physics) involves activity the authentic problem-solving in the context of social, cultural, and functional (Roberts, 2012).

Aspects of physics-based STEM learning component, consisting of the physics-based STEM learning and examples of learning physics-based STEM. In the example presented episodes of learning materials to high school students who have tested the feasibility and readability. On the learning materials, students are invited to discuss, create projects, problem-solving. According to research (Yuliati, 2011), several activities such as discussing and making projects can improve student learning outcomes. The result is also supported by the results of research (Roberts, 2012), which reveals a STEM-based learning can add to the learning experience through practice and apply the General principles of the material being studied, so growing creativity, curiosity and encourage cooperation among students. Moreover, Yildirim's research results (2016) approach to STEM has a positive impact on learning outcomes in school, students 'interests and motivation, critical thinking skills, problem-solving skills, students' attitudes toward learning, and also scientific process skills. In addition, learning using the STEM approach based on Sari, Alici, & Şen's (2017) research has proven to be effective in the learning process carried out and helps students to develop 21st-century skills, create a more pleasant classroom atmosphere, increase student interest in the engineering profession, and help students choose their future careers.

Aspect of completeness in presentation consists of the cover, table of contents, evaluation questions, bibliography, glossary, and index. The linguistic aspect consists of the appropriateness of the sentence structure, the term of the word, the meaning of wholeness, connecting between the chapter and the section later, correctness of grammar, spelling, and its terms. Materials are organized using a straightforward Indonesian Language, communicative, and pay close attention to the spelling rules of the Ejaan Bahasa Indonesian (EBI). It is in accordance with the terms of the advanced materials (Depdiknas, 2008); materials components include readability, clarity of information, as well as conformity with the Indonesian language rule, which is good and correct.

Based on the results of the analysis of the

test data readability, obtained an average score of 82.17% readability. According to the criteria of readability Rankin & Culhane, materials physics-based STEM learning included in easy to understand categories. According to (Lucy, 2014) readability resulting from the interaction between the various factors that make the text can be understood, while according to (Jatnika, 2007), the level of readability is influenced by two factors, namely: the language regarding word choice, waking up sentence, the order of the paragraphs and other grammatical elements, as well as factors relating to the form of the grammar of the letters or typography. In General, the structure of the sentences used in the learning materials in accordance with the rules of Indonesian Language and the ability of students.

According to (Suryadi, 2007) that in general, causal factors in the level of readability in learning materials consists of word choice, sentence, the order of the paragraphs, and other grammatical elements, as well as the form of the letter such as grammar is concerned the size of letters, the density of the lines, the width of the pias, and other visual layout elements. According to (Graves and Graves, 2003), factors that affect the readability of the text including the complexities of vocabulary; sentence structures and texts; text length and elaboration; coherence and unity; knowledge of the content and a required background; the suitability of the audience; the quality and passion of writing; and interest.

4. CONCLUSIONS:

The characteristics of teaching materials, containing material about the background of the importance of STEM and 21st-century learning skills, STEM material and 21st Century Learning Skills, STEM-based Physics learning teaching and examples. The results of the feasibility test using a questionnaire show that the teaching material is in the category of proper use. Readability test results using a ride test and Raygor graph show the teaching material included in the easy to understand category. Physics learning materials based STEM to develop 21st-century learning skills can be used by students (university level). Besides, learning materials developed viable to use and easy to understand.

5. REFERENCES:

1. Basham, J.D., Israel, M., and Maynard, K. *Journal of Special Education Technology*, **2010**, 25(3): 9 – 19.
2. Beers, S. *21st Century Skills: Preparing Students for Their Future*. **2011.**
3. BSNP. *Instrumen Penilaian Buku Teks Pelajaran Tahun 2014*, Badan Standar Nasional Pendidikan: Jakarta, **2014**.
4. Bybee, R.W. *Tech. Eng. Teacher*. **2010**, 70, 30-5.
5. Çengel, M., Alkan, A., and Yildiz, E.P. International Journal of Higher Education, **2019**, 8(3): 257-267.
6. Cook, M. *Electronic J. Sci. Educ*. **2008**, 12(1), 39-54.
7. DeJarnette, N. *Educ*. **2012**, 133(1), 77-84.
8. Depdiknas. *Panduan Pengembangan Bahan Ajar*, Depdiknas: Jakarta, **2014**.
9. Duran, M. and S, Sendag. *Creative Educ*. **2012,** 3(2), 241-50.
10. Elliott, B., Oty, K., McArthur, J., and Clark, B., *Int. J. Math. Edu. Sci. Tech*., **2001**, 32(6), 811-816.
11. Ercan, S., Altan, E.B., Taştan, B., and Dağ, I. *Journal of Turkish Science Education*, **2016**, 13: 30-43.
12. Freahat, N.M. *Theory Prac. Lang. Studies,* **2014**, 4(10), 2042-2050.
13. Fry, E. *Reading Teacher*, **2002**, 56(3), 286-291.
14. Graves, M.F. and Graves, B.B. *Scaffolding Reading Experiences: Designs for Student Success*. Norwood, MA: Christopher-Gordon, **2003**.
15. Gülhan, F. and Şahin, F. *Int. J. Hum. Sci*., **2016**, 13(1), 602-620.
16. Gyasi, W.K., *J. Research and Method in Edu*, **2013**, 2(1): 09-19.
17. Hampson, M., Patton, A., and Shanks, L. *Ten Ideas for 21st Century Education*, Innovation Unit: London, **2011**.
18. Hoon, T.S., Fadzlin, N., Singh, P. *Asian Journal of University Education*, **2017**, 13 (1): 67-78.
19. Jatnika, A.W. *J. Sosioteknologi*, **2007**, 10(6), 192-200.
20. Kennedy, T.J. and M.R.L. Odell. *Sci. Edu. Int*., **2014**, 25(3), 246-258.
21. Kivunja, C. *Exploring the Pedagogical*

Meaning and Implications of the 4Cs "Super Skills" for the 21st Century through Bruner's 5E Lenses of Knowledge Construction to Improve Pedagogies of the New Learning Paradigm, **2015**.

22. Kotzer, S., and Elran, Y. Learning and teaching with Moodle-based E-learning environments, combining learning skills and content in the fields of Math and Science & Technology. 1st Moodle Research Conference, **2012**.
23. Lai, E., DiCerbo, K., and Foltz, P. Skill for Today: What We Know About Teaching and Assessing Collaboration. Pearson: London, **2017**.
24. Lestari, T.P., Sarwi and Sumarti, S.S. *J. Primary Educ*., **2018**, 7(1), 18-24.
25. Lucy, S. *South African J. Childhood Educ*. **2014**, 4(2), 154-175.
26. Lundeberg, and Jacobson, V. *Educational Leadership and Administration: Teaching and Program Development*, **2016**, 27, 82-100.
27. Luthvitasari, N., N, Made D.P., and Linuwih, S. *J. Innov. Sci. Educ*., **2012**, 1(2), 92-97.
28. Metusalem, R., Belenky, D.M., and DiCerbo, K. *What We Know About Teaching and Assessing Communication*. Pearson: London, **2017**.
29. Meyrick, K.M. *Meridian K-12 School Computer Technologies Journal*, **2011**, 14 (11).
30. Morrison, J. *TIES STEM Education Monograph Series: Attributes of STEM Education*, MD TIES: Baltimore, **2006**.
31. Mudzakir, A.S. *J. Bahasa dan Sastra*, **2009**, 9(1), 34-46.
32. Muslich, M. *Text Book Writing: Dasar-Dasar Pemahaman, Penulisan, dan Pemakaian Buku Teks*, Ar-Ruzz Media: Yogyakarta, **2010**.
33. Olivarez, N., *Doctoral Dissertation*, Texas A & M University, Texas, **2012**.
34. Pertiwi, R.S., Abdurrahman and Rosidin, U. *J. Pemb. Fisika*, **2017**, 5(2), 11-19.
35. Prastowo, A. *Panduan Kreatif Membuat Bahan Ajar Inovatif*, Diva Press: Yogyakarta, **2015**.
36. Reeve, E.M. *Implementing Science, Technology, Mathematic and Engineering (STEM) Education in Thailand and in ASEAN*, Institute for the Promotion of Teaching Science and Technology: Bangkok, **2013**.
37. Roberts, A. *Tech. Eng. Teacher*, **2012**, 71(8), 1-5.
38. Ronfeldt, M., Farmer, S.O., McQueen, K., and Grissom, J.A. *American Educational Research Journal*, **2015**, 52 (3): 47 – 514.
39. Rosen, Y., Ferrara, S., and Mosharraf, M. *Handbook of Research on Technology Tools for Real World Skill Development*. IGI Global: Hershey PA (USA), **2016**.
40. Sahin, A., Ayar, M.C. and Adiguzel, T. *Educ. Sci. Theory Prac*., **2014**, 14(1), 309-322.
41. Sari, U., Alici, M., and Şen, Ö.F. *Electronic Journal of Science Education*, **2017**, 22(1): 1-20.
42. Sen, C., Ay, Z.S., Kiray, S.A. *Research Highlights in STEM Education*, **2018**, 81-100.
43. Siburian, J., Corebima, A.D., Ibrohim, and Saptasari, M. *Eurasian J. Educ. Res.*, **2019**, 81: 99-114.
44. Suryadi, A. *J. Sosioteknologi,* **2007**, 6(10), 196-200.
45. Trilling, B., and Fadel, C. *21st Century Skills: Learning for Life in Our Times*, Jossey-Bass: San Fransisco, **2009**.
46. Woodland, R.H., and Hutton, M.S. *American J. Evaluation*, **2012**, 33(3): 366-383.
47. Yamak, H., Bulut, N., and Dundar, S.*J. Gazi Educ. Fac*., **2014**, 34(2), 249-265.
48. Yildirim, B. *J. Edu. and Practice*, **2016**, 7(34): 23-33
49. Yuliati, D.I, Yulianti, D., and Khanafiyah, S. *J. Pend. Fisika Indonesia*, **2011**, 7, 23-27.
50. Zamanian, M., and Heydari, P. *Theory Prac. Lang. Studies*, **2012**, 2(1), 43-53.

Table 1. *The analysis result of the feasibility of learning materials*

No	Aspect	Results	Criteria
1	Contents	84.80%	Feasible
2	Presentation of material	85.12%	Very feasible
3	4C component skill	83.30%	Feasible
4	STEM component	84.30%	Feasible
5	Physics-based STEM Learning	85.62%	Very feasible
6	Completeness of Presentation	85.67%	Very feasible
7	Language	82.43%	Feasible
	Average	**84.40%**	**Feasible**