

Physics Teaching Materials Based on Science Technology Engineering and Mathematics to Develop Communication and Collaboration Skills

Dwi Yulianti
Universitas Negeri Semarang
 Semarang, Indonesia
yul_ah@mail.unnes.ac.id

Wiyanto
Universitas Negeri Semarang
 Semarang, Indonesia

Ani Rusilowati
Universitas Negeri Semarang
 Semarang, Indonesia

Sunyoto Eko Nugroho
Universitas Negeri Semarang
 Semarang, Indonesia

Abstract—The 21st century skills must be possessed by students, including problem solving and communication skills. Teaching materials are learning tools that can help teachers in the learning process. The purpose of this study is to produce physics-based teaching materials based on Science, Technologi, Engineering and Mathematics (STEM) to develop communication skills. This study uses the Research and Development (R & D) method with procedures consisting of, introduction, design, product development, and testing. The trial design uses one-Group pretest-posttest design. Instrument level of feasibility and readability of teaching materials using questionnaires and close test. The results of the study show that teaching materials based on Science, Technologi, Engineering and Mathematics are appropriate to use and have a good level of readability and can improve communication skills.

Keywords: *teaching material, STEM, communication, collaboration*

I. INTRODUCTION

Graduates' competency standards listed in Act No. 20 of 2016 include attitudes, knowledge and skills. On the skill dimension, the expected competency is to have thinking and acting skills, including creative, productive, critical, independent, collaborative, and communicative. In accordance with graduate competency standards, to prepare people who are able to compete in the global era, Curriculum 2013 (K-13) emphasizes some of the 21st Century skills or abilities students have, namely 21st Century learning skills or 4C skills (Critical thinking and problem solving, Communication, Collaboration, Creativity and

innovation). One of the skills needed in the 21st century is communication and collaboration (Kemendikbud, 2017). The results of a survey of sixteen High Schools (SMA) in the city of Semarang at the end of 2018 showed that physics learning was still teacher-centered, so that it did not provide opportunities for students to develop specifically communication and collaboration skills. As'ari's (2016) found that the application of K-13 in schools has not yet developed 4C skills in the learning process. The teacher also has never compiled teaching materials that facilitate the development of communication and collaboration skills. One of the efforts made to develop 4C skills in the implementation of K-13 is to use an integrative approach. The integrative approach is a learning approach that is carried out using more than one scientific discipline, one of which is the STEM approach (Science, Technology, Engineering, and Mathematics) which integrates the basic themes and concepts of science, technology, engineering, and mathematics (Beers, 2011). The research results of Dewi et.al, (2018) approach of STEM (Science, Technology, Engineering, and Mathematics) on learning can improve problem solving abilities, the impact of learning becomes more meaningful so that it is appropriate to be used as an alternative to addressing educational problems in Indonesia. The results of the study by Pangesti et.al, (2017) revealed that learning using STEM-based teaching materials can improve students' concept mastery. McDonald (2016) also found that 237 STEM application studies in learning, both practical and pedagogical, have proven effective in increasing student interest, motivation, and achievement and can develop 21st century skills. The purpose of this study is to describe STEM-based physics teaching materials that are facilitate the development of communication and collaboration skills, test readability and feasibility and analyze the development of communication and collaboration skills after the teaching material developed is applied.

II. METHODS

The research method used is Research and Development, using procedures consisting of, introduction, design, product development, and testing. The research subjects were five high schools in the city of Semarang totaling 180 students. The trial design uses one-group pretest-posttest design. To test the instrument's level of eligibility and readability of teaching materials, questionnaires and the mortar test were used, to measure collaboration skills and oral communication using observation sheets, and to test written communication using a description test. Student learning outcomes are measured using written test instruments.

III. RESULTS AND DISCUSSION

A. Description of Teaching Materials

Teaching material developed is about Newton's Laws, the contents consist of elements of facts, concepts, principles, and procedures. Teaching material is divided into three parts, namely introduction, content, and closing, in addition to the index and glossary that contains 53 pages.

The introduction, consisting of the front page, preface, table of contents, instructions for using teaching materials, concept maps, basic competencies and indicators as well as learning objectives. The contents section contains learning objectives, apperception of material related to daily activities and simulations to find concepts. In the contents section consists of 5 sub-topics. In each sub-chapter there are problems, problem analysis, and sample problems. In addition, this teaching material is also equipped with "Look for", "Come on Discussion", "Independent and Group Assignments" and "Simulation" which can train students to develop communication skills. The concluding part of teaching materials consists of a summary, evaluation, and bibliography. Evaluation contains multiple choice questions and description questions that can train students to conduct evaluations and make appropriate decisions. At each presentation the sub-chapter is inserted with aspects of communication and collaboration. In the contents and end of the teaching material developed there is a facility to train students to improve indicators of communication and collaboration skills.

The letters used in this teaching material are Arial Black type with sizes 26, and 34, Century Schoolbook with sizes 11, 24 and 100, Adobe Casion Pro Bold size 24 and Adobe Gothic Std B size 18. Teaching materials have height and width of 29 cm and 20.5 cm using Arial type letters with size 12. These teaching materials have a lot of pictures aiming to make it easier for students to understand the material contained in teaching materials.

Feasibility Test Results

Table 1. Analysis Results of Teaching Materials Feasibility

No	Aspect	Score (%)	Criteria
1	Content	89,85	Very Feasible
2	Presentation	86,78	Very Feasible
3	Linguistic	83,68	Very Feasible
Average Score		86,70	Very Feasible

1. Readability Test Results

The result of data readability analysis was 87.89%, meaning that it was at a high criterion. This shows that the teaching material developed is easy to understand. This is because the use of language is in accordance with the user's language ability level. In addition, it is also caused by writing quite interesting. Writing instructional materials using typeface, font size and line density according to the rules. According to El-Masri (2010), the level of language proficiency affects the level of understanding and encourages students to be more active in developing their abilities. Dewi (2018) claimed that reading with a good level of readability will influence readers in increasing interest in learning and memory, increasing speed and reading efficiency.

2. Communication Skills

Written communication skills are obtained through a matter of description, while oral communication is obtained through observation. Observation activities are carried out when the learning process takes place in class. Improvement of written communication skills, measured using the value of pretest and posttest. The analysis results of improvement in written communication skills are presented in Table 2.

Table 2. Analysis Results on Improvement of Written Communication Skills

No	School	Pretest (%)	Posttest (%)	Enhancement every aspect (gain test)	Category
1	School A	57,22	82,74	0,53	Medium
2	School B	73,26	89,23	0,59	Medium
3	School C	52,95	78,47	0,54	Medium
4	School D	65,54	99,3	0,86	High
5	School E	53,85	79,47	0,53	Medium
Average				0,63	Medium

Written communication capability indicators consist of stating problem solutions using pictures, charts, tables and algebra, explaining ideas, situations and physical relations in writing, using physical language, symbols and schemes, re-expressing or making conclusions in writing using their own language. Writing communication on average is in the

medium category. This is because students are not accustomed to explaining ideas in writing, students are easier to convey directly and some students do not understand the material. According to Chung (2016) increasing written communication skills can stimulate student reasoning and build social knowledge. Prameswari (2018) states that students who can communicate ideas or thoughts about a material will increase their understanding of the material. Most students are not quite right in writing symbols. According to research Supriadi (2016) states that many students are less precise in writing symbols and take a long time to work on problems so that the thinking scheme is not right. There is one school that is in the high category, this is because in the learning process students are trained to be able to express opinions or make their own conclusions about the results of the questions they have done in accordance with the understanding of physics concepts. Although the average gain test results for increasing written communication skills have not yet reached the high category, it can still be said that there has been an increase in written communication skills after using STEM-based teaching materials developed. Communication skills are needed in this life, to find relationships and establish cooperation. Communication skills, especially oral communication are very important for students' personal and professional success in the future (Morreale et.al, 2017). The results of the analysis of oral communication skills are presented in Table 3.

Table 3. Results of Oral Communication Skills Analysis

School	Before (%)	After (%)	Enhancement every aspect (gain test)	Category
School A	57,22	82,74	0,53	Medium
School B	53,26	89,23	0,59	Medium
School C	52,95	78,47	0,54	Medium
School D	55,14	89,3	0,61	Medium
School E	43,85	79,47	0,63	Medium
Average			,58	Medium

Hernandez & Moralez (2016) also states that communication skills in various languages and teamwork are the competencies needed to succeed in an individual's position on a job. Research Hidayat et.al, (2017) found that learning with discussion activities have a positive influence on students and increase student motivation. In the learning process students are motivated to be able to communicate their work. The research of Yulianti et.al, (2019) revealed that learning accompanied by presenting problems and communicating the results of discussions or making reports, could develop the character of student communication. Indicators of oral communication skills consist of, accuracy of pronunciation, delivery

of material content, use of appropriate sentences, clarity and fluency and mastery of the topic of conversation. Improvement in verbal communication skills, because the use of STEM-based teaching materials optimizes students' participation in the learning process by conducting discussions, presentations in the form of delivering the results of discussions to their peers and the ability to analyze an issue that is closely related to daily life. In accordance with Sugito's (2017) opinion that learning by conducting discussions is more effective to improve oral communication skills so students can use effective words, form sentences that can be grammatically understood and use appropriate sounds and intonation when listening and speaking. In addition, learning in this study applies a project model. In project-based learning, students have many opportunities with their groups to practice explaining and justifying their ideas verbally and in writing. Students are allowed to use words or drawings, depending on students' needs. Whatever the reason, students get the opportunity to express what, how and why they think what they think and express their ideas.

3. Collaboration Skills

Table 4. Results of Collaboration Skill Analysis

No	School	(%)	Category
1	School A	92,74	High
2	School B	89,23	High
3	School C	91,47	High
4	School D	90,30	High
5	School E	89,47	High
	Average	90,62	High

Collaboration skills obtained are high on average as shown in Table 4. This is because students have often done group work in the previous learning process. This is consistent with the results of Jensen's et.al, (2012) research through collaborative work with colleagues who already know each other will make students comfortable in groups so that the process of completing the task feels more enjoyable. Student collaboration skills can be developed at school through group work activities. Through collaborative work or group work students will learn together and develop their collaboration skills specifically on project-based assignments (Scott, 2015, p.5). It is hoped that students with good collaboration skills will indirectly have the ability to interact positively and respectfully with others, the ability to lead or work in a team and to relate to others in various contexts, the capacity for sensitivity to problems and related processes by collaborating across cultures, as well as the ability to collaborate across networks using a variety of information and communication technologies (C21 Canada, 2012, p.10). According to

Nurhayati et.al. (2019) research, group learning 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. According to The Ontario Ministry of Education (2016, p.13) collaboration can also develop students' collective intelligence. Of course in learning students are expected to achieve effective collaboration, effective collaboration according to Wilcox et.al. (2017) requires the ability to listen to other people's ideas, the ability as flexible individuals, the ability to appreciate the contributions of other members in the team, the ability to share responsibility, recognition of team achievements, ability to compromise, and ability to respect others.

Learning that is carried out is more centered on students, involves students in organized discussion activities by forming learning groups, and conducting simple experiments encourages students to take responsibility in their work so that learning material can be understood properly. Thibaut, et al. (2018) states that knowledge is actively built by students themselves and learning is a shared experience not an individual experience. Woodland & Hutton (2012) claimed that collaboration can produce greater innovation while conserving resources to achieve common goals. Collaboration can be used as a step to solve problems, not only in the scope of education and business, but also in government agencies. Meiner & Gala (2016) mentioned that collaboration facilitates the overall performance of institutions and supports those involved in overcoming complex social problems. According to Van Leeuwen (2015) that by means of collaboration or group work completing assignments, students are challenged to share ideas, express their thoughts, and engage in discussion. Collaboration skills can be possessed by any individual who is able to work in a team. Rippner (2017) explains that collaborative activities are easy to start but difficult to do well and sustainably so that efforts are needed to improve collaboration.

IV. CONCLUSION

Based on the feasibility test, the developed teaching material is very suitable for learning Newton's Laws, and has a high level of readability. After applying teaching materials developed, the average communication skills develop on medium criteria. The ability of collaboration also develops and is in the high category. Further research is needed to analyze the development of communication skills and further collaboration.

REFERENCES

[1] As'ari A.R. (2016). Menjawab Tantangan 4C's Melalui Pengembangan Kurikulum dan Pembelajaran Matematika. *Prosiding Seminar*

Nasional Pendidikan Matematika. Malang: Universitas Negeri Malang.

[2] Beers, S. (2011). 21st Century Skills: Preparing Students for Their Future. Retrieved from https://cosee.umaine.edu/files/coseeos/21st_century_skills.pdf

[3] Chung Y., Yoo J., Kim S.W., Lee H., Zeidler D.L. (2016). Enhancing Student'Communication Skills In The Science Classroom Through Socioscientifics Issues. *International Journal of Science and Mathematics Education*, 14(1): 1-27.

[4] Dewi M., Kurniawati I., Suwarma I.R. (2018). Penerapan Pembelajaran Fisika Menggunakan Pendekatan STEM untuk Meningkatkan Kemampuan Memecahkan Masalah Siswa pada Materi Listrik Dinamis. *Prosiding Quantum #25 Seminar Nasional Fisika dan Pendidikan Fisika*. Yogyakarta: Universitas Ahmad Dahlan.

[5] Dewi N.R., Arini F.Y. (2018). Uji Keterbacaan pada Pengembangan Buku Ajar Kalkulus Berbantuan Geogebra untuk Meningkatkan Kemampuan Pemecahan Masalah dan Representasi Matematis. *Prosiding Seminar Nasional Matematika*, 1(1): 299-303.

[6] El-Masri Y., Vlaardingerbroek B . (2010). Science Textbook Readability in Lebanon: A Comparison Between Anglophone and Francophone Learning Milieux. *Mediterranean Journal of Educational Studies*, 15(1): 109-124.

[7] Hernandez M., Morales R. (2016). Current Trends In Competency Based Education. *World Journal of Engineering and Technology*, 4: 193–199.

[8] Hidayat W.N., Basri M., Arif S. (2017). Pengaruh Metode Diskusi Kelompok Terhadap Motivasi Belajar Sejarah Siswa. *Jurnal Universitas Negeri Lampung* 5(5).

[9] Jensen M., Mattheis A., Johnson B. (2012). Using Student Learning and Development Outcomes to Evaluate A First-Year Undergraduate Group Video Project. *CBE Life Sciences Education*, 11(1), 68-80.

[10] Kemendikbud. (2017). Modul Penyusunan Soal Higher Order Thinking Skill (HOTS). Jakarta: Dirjen Pendidikan Dasar dan Menengah Kemendikbud.

[11] McDonald C.V. (2016). STEM Education: A Review of the Contribution of the Disciplines of Science, Technology, Engineering, and Mathematics. *Science Education International*, 27(4): 530-569.

[12] Meiner M.A.K., Gala N.M. (2016). *Collaboration: Definitions and Explorations of An Essential Partnership*. Odyssey : New Directions in Deaf Education.

[13] Morreale S.P., Valenzano J.M., Bauer J. N. (2017). Why Communication Education Is Important: A Third Study On The Centrality Of The Discipline's Content And Pedagogy. *Journal Communication Education*, 66(4) : 402 – 422.

- [14] Nurhayati D.I., Yulianti D., Mindyarto B.N. (2019). Bahan Ajar Berbasis Problem Based Learning pada Materi Gerak Lurus untuk Meningkatkan Kemampuan Komunikasi dan Kolaborasi Siswa. *Unnes Physics Education Journal*, 8(2), 208-218.
- [15] Ontario. (2016). Towards Defining 21st Century Competencies for Ontario: 21st Century Competencies. Retrieved from http://www.edugains.ca/resources/21CL/About21stCentury/21CL_21stCenturyCompetencies.pdf.
- [16] Pangesti K.I., Yulianti D., Sugianto. (2017). Bahan Ajar Berbasis STEM (Science, Technology, Engineering, and Mathematics) untuk Meningkatkan Penguasaan Konsep Siswa SMA. *Unnes Physics Education Journal*, 6(3): 53-58.
- [17] Prameswari D.I., Siswono T.Y.E. (2018). Profil Kemampuan Komunikasi Matematika Siswa Dalam Pengajaran Masalah Berdasarkan Informasi Verbal dan Gambar. *MATHEdunesa*, 1(7).
- [18] Rippner J.A. (2017). State P-20 Councils and Collaboration Between K-12 and Higher Education. *Educational Police*, 31(1) : 3 - 38.
- [19] Scott C. (2012). An Investigation of Science, Technology, Engineering and Mathematics (STEM) Focused High Schools in the U.S. *Journal of STEM Education: Innovations and Research*, 13(5) : 30 – 39.
- [20] Scott C.L. (2015). *Educational Research and Foresight: Working Papers (The Futures of Learning 2: What Kind of Learning for the 21st Century?)*. Paris: UNESCO.
- [21] Sugito S., Susilowati S.M.E., Hartono H., Supartono S. (2017). Enhancing Students' Communication Skills through Problem Posing and Presentation. *International Journal of Evaluation and Research in Education*, 6(1): 17-22.
- [22] Supriadi N., Damayanti R. (2016). Analisis Kemampuan Komunikasi Matematis Siswa Lamban Belajar dalam Menyelesaikan Soal Bangun Datar. *Jurnal Pendidikan Matematika*, 7(1): 1-9.
- [23] Thibaut L., Ceuppens S., De Loof H., De Meester J., Goovaerts L., Struyf A., Boeve-de Pauw J., Dehaene W., Deprez J., De Cock M., Hellinckx L., Knipprath H., Langie G., Struyven K., Van de Velde D., Van Petegem P. and Depaepe F. (2018) Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Journal of STEM Education*, 3(1) : 1–12.
- [24] Van Leeuwen A., Janssen J., Erkens G., Brekelmans M. (2015). Teacher Regulation of Cognitive Activities During Student Collaboration: Effects of Learning Analytics. *Science Direct*, 90: 80-94.
- [25] Wilcox D., Liu J. C., Thall J., Howley T. (2017). Integration of Teaching Practice for Students' 21st Century Skills: Faculty Practice and Perception. *International Journal of Technology in Teaching and Learning*, 13(2): 55-77.
- [26] Woodland R.H., Hutton M.S. (2012). Evaluating Organizational Collaborations : Suggested Entry Points and Strategies. *American Journal of Evaluation*, 33(3) : 366-383.
- [27] Yulianti D., Wiyanto, Rusilowati A., Nugroho S. E., Supardi K.I. (2019). Problem Based Learning Models Based on Science Technology Engineering and Mathematics for Developing Student Character. *IOP Conf. Series: Journal of Physics: Conf. Series* 1170