Development of STEM-nuanced textbook to improve students' mathematical communication skill

M Asikin*, M F Nurhidayat, and A S Ardiansyah
Mathematics Department, Faculty of Mathematics and Natural Sciences of Universitas Negeri Semarang

*Corresponding author: asikin.mat@mail.unnes.ac.id

Abstract. This research is development research that aims to develop and to know the quality of Science, Technology, Engineering, and Mathematics (STEM)-nuanced teaching materials that meet the suitability of characteristics, validity, readability, and improvement of students’ mathematical communication ability. This research uses the stages of Research & Development, including potential and problems; data collection; product design; product test (readability test); trial test; and final product. The results showed that the teaching material met the suitability of the characteristics. The results of the validity test showed a percentage of 88.54%. The readability test results showed a percentage of 63.65%. Analysis of pretest and posttest showed that teaching materials increased mathematical communication ability with the n-gain score of 0.44 in the medium category. Thus, the development of Science, Technology, Engineering, and Mathematics (STEM) nuanced teaching materials is qualified because suitability in characteristics, valid to use, easily understand, and can increase students' mathematical communication ability.

1. Introduction
Education has an important role in equipping youth to compete in the future and be able to face the developments of the 21st century. Education is a foundation that can develop student abilities and prepare students for problem-solving, communication, and decision-making skills. Education is the most important aspect of country development [1]. In reality, Indonesia's position in the education and health sector is in the 100th position [2], which shows a decrease of 20 levels from the previous year. The results of the Program for International Student Assessment (PISA) study in 2018 [3] that the average scores on mathematics and science of Indonesian students are below the international average. Whereas, mathematics is a very important lesson, and useful in life [1].

One of the solutions to develop the education sector is developing teaching materials. Teaching materials are all forms of systematics materials used in the learning process [4, 5, 6]. Teaching materials are proven to be able to assist teachers in delivering material, as well as being able to improve learning outcomes and student motivation [7].

Teaching materials also can be integrated with the STEM approach. STEM is an acronym for Science, Technology, Engineering, and Mathematics. STEM is based on the achievement of science and mathematics and must be appropriate when combined with technology and engineering [8]. Integrated STEM means to combine two or more aspects of STEM in a single project [9]. The STEM approach has been developed in several countries [10, 11] and became a worldwide trend [6, 12]. Turkey's Ministry of National Education (MoNE) [8], and the United States NGSS [13] recommend the STEM approach
in learning to increase PISA scores [8, 13]. Besides, the STEM approach can improve students’ literacy skills [14], students’ creativity skills [15], and help students to be better at problem-solving, motivated in learning, show a more positive attitude, and increase achievement in mathematics and science [16]. [6] explained STEM is not a special concern in Indonesia. In fact, several studies about STEM in Indonesia has been done, and STEM has been developed in several fields [17].

Developing teaching materials ideally have to support 21st-century learning which includes creativity, critical thinking, collaboration, and communication [18]. Several studies proved that STEM-based teaching materials effective to improve students’ critical thinking [19], students’ creativity [20, 18], and problem-solving skills [21]. It was necessary to develop STEM-based teaching materials to improve other skills such as communication. Australia, China, Hong Kong, and Korea have established communication skills as one of the competencies in the curriculum [22]. In Australia, communication becomes the threshold of learning outcome for undergraduate mathematics and needs more attention to develop [11]. Through communication, students can manage, think, clarify their understanding [23], also can share and explain ideas fluently [24]. Someone with good communication skills on math, will support their problem-solving skills [25].

In this research, mathematical communication skill is students' competencies to use mathematics as a communication tool and communicate mathematical ideas in writing. The indicator of mathematical communication skill used in this study is a modification of the indicators of mathematical communication skill presented by Putri, Dwijanto, & Sugiman [26] namely 1) the ability to express mathematical ideas in writing; 2) the ability to use mathematical terms and notations to present ideas; 3) the ability to evaluate mathematical ideas in writing, and 4) the ability to express mathematical ideas in tables/graphs.

The learning model is needed to apply the developed STEM-nuanced teaching materials. Conventional teaching could not improve mathematical communication skills [27]. So, one of the learning models that can be applied is the Problem Based Learning (PBL) model. Based on an interview with a mathematics teacher at SMP Negeri 3 Patebon, the PBL model has been applied in learning. PBL is a model that uses real problems, where students are allowed to build their knowledge in solving the problem [28]. PBL be able to improve students' mathematical communication skills, interests, and motivation [25].

In this study, a phase modification of the PBL model was carried out. The modification was made because the learning process was conducted online, which includes: (1) student orientation to the problem; (2) organizing students to learn; (3) guiding individual investigations; (4) presents the work in writing; and (5) evaluating the problem-solving process.

Based on the background described above, it is necessary to research "the development of STEM-nuanced teaching materials to improve students' mathematical communication skills". This study aims to develop and to know the quality of STEM-nuanced teaching materials based on the suitability of characteristics, validity, readability, and improvement of students’ mathematical communication skills.

2. Research Methods

Research & Development (R&D) method in this study uses modified [29]’s method that consists of 7 stages, namely: potential and problems, data collection, product design, design validation, product test (readability test), trial test, and final product. This research was conducted in December 2019 - June 2020. The subjects in this study were students of VII-C of SMP Negeri 3 Patebon as the readability test class and VII-F of SMP Negeri 3 Patebon as the trial test class.

The design validation stage was tested with a questionnaire on the suitability and validity of STEM-nuanced teaching materials which were tested on 7 validators consisting of 5 teachers and 2 lecturers of the Mathematics Department of UNNES. The readability test was tested with the gaps test. Meanwhile, at the trial test stage, the n-gain test was carried out on the average pretest and posttest values obtained.
3. Result and Discussion

3.1. Potential and Problems
Based on the interviews with a mathematics teacher at school, the mathematics teaching material used was a book entitled "Matematika untuk SMP/MTs kelas VII Semester 2" published by the Ministry of Education and Culture. In the book, there are several examples of questions with STEM nuances, but they are not comprehensive and have not facilitated the improvement of mathematical communication skills. Even though mathematical communication skill is one of the abilities that students must have in learning. It becomes the potential to develop STEM-nuanced teaching materials as one of the learning alternatives to improve students' mathematical communication skills.

3.2. Data collection
Data collection started from core competencies, basic competencies, competency achievement indicators, learning objectives, concept maps, the benefits of the material being studied, and problems related to STEM. In this study, Basic Competencies of 3.7, 3.8, 4.7, and 4.8 were selected for the basic design. Furthermore, observations were conducted on several students' books in the Mathematics Department library of UNNES to obtain materials information to be developed.

3.3. Product Design
This STEM-nuanced teaching material is designed in A4 size. The basic design of the teaching materials was dominated by Times New Roman font and the size was 12-16 pt. The basic design of STEM-nuanced teaching materials consists of 22 pages, consist of the front page, preface, table of contents, core competencies, basic competencies, objectives of teaching materials, concept maps, benefits and linkages with other sciences, learning motivation, learning materials, let's summarize, test competencies, glossary, and references.

The contents of STEM-nuanced teaching material adjusted to the modified format of the student's book analysis from the Ministry of Education and Culture [30], including (1) aspects of the suitability of STEM-nuanced teaching material content with basic competencies; (2) the breadth, depth, current condition, and accuracy of the learning materials on STEM-nuanced teaching materials; (3) shows examples of learning materials (knowledge, factual, conceptual, and procedural) in each chapter of the student book related to STEM; (4) the suitability of learning activities in STEM-nuanced teaching materials; and (5) the assessment in the STEM-nuanced teaching materials.

3.4. Design Validation

3.4.1. Characteristics of STEM-nuanced Teaching Materials. The STEM-nuanced teaching materials met the suitability aspects of the characteristics and can be used in learning based on the validation results of 7 validators. Besides, five validators suggested revision in several contents. The validator's suggestions include adjusting the material with the first core competencies, adding apperception, and updating the material with the current condition. After the revision was made, teaching materials have had the characteristics according to the Ministry of Education and Culture's book analysis format [30].

3.4.2. Validity of STEM-nuanced Teaching Materials. The validity of teaching materials consists of 3 aspects, namely content, presentation, and language validity. The assessment of the validity of STEM-nuanced teaching materials was adopted from the assessment guidelines for mathematics textbooks published by the National Education Standards Agency (BSNP).

| Table 1. The Validity Score of STEM-nuanced Teaching Materials |
|-----------------------------|-----|----------------|
| Aspect of Validity            | P (%) | Criteria       |
| Content validity             | 88.09 | Excellent      |
| Presentation validity        | 89.61 | Excellent      |
| Language Validity            | 87.91 | Excellent      |
| Average                      | 88.54 | Excellent      |
Based on Table 1, it was obtained the validity of STEM-nuanced teaching materials had excellent criteria. The content aspect obtained excellent criteria. Teaching materials developed based on science concepts will be worthy [31]. The presentation aspect obtained excellent criteria because equipped with illustrations that support the learning material, so it makes students interested and loves the teaching materials [31]. The language aspect obtained excellent criteria. The use of Language-Enhanced Spelling (EYD) in STEM-nuanced teaching materials make it easy to understand [31]. Thus, the STEM-nuanced teaching materials on direct and inverse proportion was valid and can be used in the learning process.

3.5. Product Test (Readability Test)

The readability test was conducted on 26 students of the VII-C class of SMP Negeri 3 Patebon. Readability test obtained an average percentage score of 63.65% with easy to understand criteria. According to [32], the teaching materials has high level readability. It means that the teaching materials has good quality.

3.6. Trial Test

STEM-nuanced teaching materials applied in Problem Based Learning (PBL) models. In this study, learning was conducted online using the Google Classroom and WhatsApp in VII-F class of SMP Negeri 3 Patebon.

The prerequisite test was carried out in a normality test at the pretest and posttest. The normality test was carried out using the SPSS 24 application. The hypothesis used was

$H_0$ : Pretest and posttest data are normally distributed  
$H_1$ : Pretest and posttest data are not normally distributed

The pretest and posttest data are said normally distributed if the value of Sig. (2-tailed)/$> 0.05 = \alpha$. Based on the normality test, the value of Sig. (2-tailed) of the pretest is $0.186 > 0.05$ and the Sig. (2-tailed) of the posttest is $0.200 > 0.05$. Because of the Sig. (2-tailed) at pretest and posttest $> 0.05$, then $H_0$ accepted. It could be concluded that the pretest and posttest data are normally distributed.

The n-gain test results of pretest and posttest are shown in Table 2 below.

| Table 2. N-Gain Result |
|-------------------------|
| Average score | Pretest | 48.10 | Posttest | 71.05 | N-Gain | 0.44 | Criteria | Medium |

Based on Table 2, the n-gain score is 0.44, which indicates the improvement of mathematical communication skills with medium criteria. The improvement not only occurs in the overall average score but also occurred in each indicator of mathematical communication skill. The following picture is the pretest and posttest result of mathematical communication indicators.

![Figure 1. Graph of Mathematical Communication Indicators on Pretest and Posttest](image-url)
Furthermore, the N-Gain result of mathematical communication indicators is shown in Figure 2 below.

![Figure 2. The N-Gain Result based on the Indicator of Mathematical Communication Skills](image)

Based on Figure 2, the ability to express mathematical ideas in writing, the ability to use mathematical terms and notations to present ideas, and the ability to evaluate mathematical ideas in writing increased with medium criteria. Meanwhile, the ability to express mathematical ideas in tables/graphs increased with the high criteria.

These results indicate that STEM-nuanced teaching materials on direct and inverse proportion materials have a positive influence on improving mathematical communication skills. This supports the research of [21] that teaching materials with the STEM approach can improve the communication aspect in problem-solving skills.

### 3.7. The Final Product

The final product in this study is a STEM-nuanced teaching material on direct and inverse proportion materials and facilitated by mathematical communication indicators on each problem presented. In the end, the teaching material was registered as copyright at the Directorate General of Intellectual Property.

### 4. Conclusion

Based on the results and discussion, STEM-nuanced teaching materials on direct and inverse proportion had fulfilled the characteristic of student book guidelines published by Ministry of Education and Culture in 2018, STEM-nuanced teaching materials was valid and can be used in the learning process, easy to understand, and can improve students’ mathematical communication skill. It can be concluded that STEM-nuanced teaching materials was qualified. The recommendation of this study is further research about the development of STEM-nuanced teaching materials that contain other materials or other mathematical skills.

### References

[1] Millaturrahmah N, Mardiyana, and Pramudya I 2017 *AIP Conf. Proceeding* **1868** 050024
[2] World Economic Forum 2016 The Global Competitiveness Report 2016-2017 Geneva.
[3] OECD 2019 *PISA 2018 Insight and Interpretation* (Paris: OECD)
[4] V N Yulian 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **335** 012110
[5] Suharti et al 2020 *J. Phys.: Conf. Ser.* **1539** 012082
[6] Widayanti et al 2019 *J. Phys.: Conf. Ser.* **1155** 012021
[7] Al Azri R H, and Al Rashdi M H 2014 *Int. J. Sci. Tech. Research* **3**(10) 249
[8] Acar D, Tertemiz N, and Tasdemir A 2018 *Int. Electron. J. Elem. Educ.* **10**(4) 505
[9] Mtemngwa C and Oliver J S 2018 *Int. J. Educ. Math. Sci. Tech.* 6(1) 12
[10] Ritz J M, and Fan S C 2015 *Int. J. Technol. Des. Educ.* 25 429
[11] Poladian L, and Zheng C 2016 *Int. J. Innov. Sci. Math. Educ.* 25(5) 14
[12] Bell D 2016 *Int. J. of Tech. and Design Educ.* 26(1) 61
[13] Bahrun S, Wahid N, and Ibrahim N 2017 *Int. J. Aca. Res. Bus. Soc. Sci.* 7(6) 645
[14] Tati et al 2017 *J. Phys.: Conf. Ser.* 895 012157
[15] Conrady C, and Bohner F X 2020 *Smart Learn. Environ.* 7(26) 1
[16] English L, and King D 2015 *Int. J. STEM Educ.* 2(14) 1
[17] Sheffied et al 2018 *Int. J. Innov. Sci. Math. Educ.* 26(8) 67
[18] Heliawati et al 2020 *Int. J. Innov. Creat. Change* 13(7) 783
[19] Sayekti A, and Suparman 2020 *Int. J. Sci. Tech. Res.* 9(3) 3390
[20] Tahir S D W, and Anwar S 2018 *Int. Conf. Math. Sci. Educ.* 3 384
[21] Purwaningsih et al 2020 *J. Phys.: Conf. Ser.* 1481 012133
[22] Chung Y, Yoo J, Kim S W, Lee H, and Zailer D 2014 *Int. J. Sci. Math. Educ.* 14 1
[23] Sumaji et al 2019 *IOP Conf. Ser.: Earth Environ. Sci.* 243 012128
[24] Bicer A et al 2015 *Int. J. Contemporary Educ. Res.* 2(2) 69
[25] Hidayati et al 2020 *J. Phys.: Conf. Ser.* 1460 012047
[26] Putri L, Dwijanto, and Sugiman 2017 *Unnes J. Math. Educ.* 6(1) 97
[27] Nartani et al 2015 *Int. J. Innov. Res. Educ. Sci.* 2(4) 2349
[28] Mustaffa N et al 2016 *Int. J. Ac. Res. Bus. Soc. Sci.* 6(12) 490
[29] Sugiyono 2018 *Metode Penelitian Pendidikan* (Bandung: Alfabeta)
[30] Kemendikbud 2018 *Materi Penyegaran Instruktur Kurikulum 2013 SMP Mata Pelajaran Matematika* (Jakarta: Kemendikbud)
[31] Sari N, Sumantri MS, and Bachtiar IG 2018 *Int. J. Adv. Sci. Res. Engin.* 4(7) 162
[32] H Rusnayati et al 2019 *J. Phys.: Conf. Ser.* 1280 052010