Student worksheets based on Science, Technology, Engineering and Mathematics (STEM) to facilitate the development of critical and creative thinking skills

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Abstract. This study aims to describe STEM-based Student Worksheets, which facilitate the development of critical and creative thinking skills. Another aim is to test the level of readability, feasibility, and describe the improvement of critical and creative thinking skills after the Student Worksheet is applied. This research uses Research and Development (R&D) method as well as one-group pretest-posttest design. As research subjects were ten high schools in the city of Semarang. The results of the feasibility test indicate the criteria are suitable for learning by obtaining an average of 88.96% which means it is very feasible. In addition, the readability test showed that the worksheets were easily understood with an average of 91.66% and an analysis of improvement in critical and creative thinking skills was found to have high average criteria.

1. Introduction
The skills that must be trained to students, according to the 2013 curriculum include critical thinking and creative skills. Student worksheets are sheets containing assignments that must be done by students. Student Worksheets (LKS) are sheets of paper that contain material, summaries, and instructions for implementing learning tasks that must be done by students that refer to the basic competencies that must be achieved [1]. The results of a survey of 90 high school physics teachers in Semarang, 95% stated that they had never compiled an STEM-based worksheet and 94% had not facilitated the development of creative thinking and critical skills through worksheets. Thinking creatively and critically has also not been specifically trained for students. This is a problem because creative and critical thinking skills are required for students in the 21st century. This problem must be overcome immediately, if not it will cause new problems in the world of education in Indonesia.

STEM firstly appears in the United States echoed by NSF (National Science Foundation). The STEM approach is an educational approach that integrates Science, Technology, Engineering, and Mathematics in the process, and is also an approach to learning between two or more STEM components or between one STEM component with other disciplines. Another understanding of STEM defined by [2], is a term used to refer collectively to teaching and cross-disciplinary approaches, namely science, technology, engineering, and mathematics. This is in accordance with [3] which states that STEM has something to do with learning in the fields of science, mathematics, engineering, and technology. In the work of [4] regarding the effects of education STEM states that STEM is related to problems and real life. In addition, research results from [5] state that the application of STEM is suitable for use in science learning. This study aims to develop students' creative and critical thinking skills through STEM-based worksheets. Then, test the feasibility and readability and find out the development of critical and creative thinking skills after the developed worksheet is applied.
2. Methods

This study uses Research and Development (R&D) research, with research procedures including: (1) introduction, (2) design, (3) product development, (4) product testing. The research design of the trial was using Quasi Experimental Design in the form of one-group pretest-posttest design. Small groups of 32 students became the subjects of this study, while the large group consisted of 320 class XI high school students, who came from ten schools in the city of Semarang. The research instruments were validation sheets, overlap tests, questionnaires and tests. The data to determine the level of eligibility and readability were obtained from questionnaires and the mortar test, while the critical and creative thinking skills data were obtained from the understanding test, the development of critical and creative thinking skills were analyzed using the gain test.

3. Results and Discussions

The worksheet starts with various problems related to material and applications in daily life. In the worksheet there are facilities for discussion, practical work or experiments, as well as evaluations aimed at honing critical and creative thinking skills. The material presented in STEM-based worksheets is Simple Aircraft. The worksheets are attractive, illustrated with bright colour. Illustration of pictures and colours will attract and arouse the interest and attention of students. Worksheets are printed using A4 size paper, intended to make students easy to use them. The STEM approach is used in the worksheet as it contains things that can make students' creative and critical abilities develop, through the use of questions that use indicators of critical and creative thinking skills. This integration allows students to learn to apply it to real life problems [6]. Worksheet based on STEM integrates aspects of science, technology, engineering, and mathematics, as revealed by [7] that the STEM approach is an integrated approach to the learning and teaching process that integrates content and skills in science, technology, engineering, and mathematics.

Worksheet readability level was measured using a Cloze test on 320 people, coming from 10 high school students of grade XI. Table 1 presents readability test analysis results.

| No | School | Average score | Maximum score | Score (%) | Criteria |
|----|--------|---------------|---------------|-----------|----------|
| 1  | S-01   | 33            | 34            | 97,06     | easy to understand |
| 2  | S-02   | 29            | 34            | 85,29     | easy to understand |
| 3  | S-03   | 29            | 34            | 85,29     | easy to understand |
| 4  | S-04   | 33            | 34            | 97,06     | easy to understand |
| 5  | S-05   | 31            | 34            | 91,18     | easy to understand |
| 6  | S-06   | 29            | 34            | 85,29     | easy to understand |
| 7  | S-07   | 32            | 34            | 96,06     | easy to understand |
| 8  | S-08   | 31            | 34            | 91,18     | easy to understand |
| 9  | S-09   | 33            | 34            | 97,06     | easy to understand |
| 10 | S-10   | 31            | 34            | 91,18     | easy to understand |
|    | Total  | 319           | 340           | 916,6     | easy to understand |
|    | Average| 31,9          | 34            | 91,66     | easy to understand |

The readability test results show that the worksheet is easy to understand, this is because the presentation of the material in the worksheet uses language according to the ability of high school students, and uses clear sentence structure, so that it is easy to understand. Student worksheet with a
good readability will affect readers and increasing interest. Level of worksheet feasibility shows that the worksheet is suitable for use in learning, as presented in table 2.

| Table 2. Feasibility analysis results |
|--------------------------------------|
| **Aspect**                           | **Percentage (%)** | **Criteria** |
| Content                             | 89,59              | very feasible |
| Presentation                        | 88,53              | very feasible |
| Language                            | 88,52              | very feasible |
| STEM characteristic                 | 88,64              | very feasible |
| Facility to critical and creative skills | 89,62              | very feasible |
| **Average percentage**              | 88,90              | very feasible |

Simple discussion and experiment are two activities contained in STEM-based worksheets, so students can develop knowledge, attitudes, and skills through scientific observation, and have direct experience in solving a problem. The problem solving strategies presented can help students to foster critical and creative thinking skills and problem solving through direct involvement in real or simulated experiences. In a previous work, [8] research results show that students who used STEM learning had higher critical thinking scores and problem solving skills. The discovery of concepts and material is coherently presented from general concepts to more specific concepts. Worksheet is equipped with supporting material presentation, which is preliminary to contain facts and issues related to the business concept. Presentation of material and activities in the worksheet refers to the process skills and self-discovery of a concept (inquiry). As pointed out by [9] that one of the effective and efficient learning methods, where students who receive it tend to have greater creativity in solving problems and learning achievement increases, is called problem-based learning. Critical thinking abilities are presented in table 3.

| Table 3. The result of critical thinking ability |
|-----------------------------------------------|
| **No** | **School code** | **Average score** | **Gain test** | **Criteria** |
|        |                | **Pretest**  | **Postest**  |              |
| 1      | S-01           | 46,88       | 96,98        | 0,94         | High |
| 2      | S-02           | 48,63       | 98,07        | 0,94         | High |
| 3      | S-03           | 12,50       | 85,70        | 0,86         | High |
| 4      | S-04           | 18,75       | 96,75        | 0,92         | High |
| 5      | S-05           | 37,50       | 83,48        | 0,75         | High |
| 6      | S-06           | 35,63       | 79,93        | 0,74         | High |
| 7      | S-07           | 34,38       | 95,09        | 0,98         | High |
| 8      | S-08           | 53,31       | 90,83        | 0,80         | High |
| 9      | S-09           | 49,38       | 84,68        | 0,69         | Medium |
| 10     | S-10           | 46,88       | 95,88        | 0,94         | High |

Achievement of critical thinking skills shows high average results because worksheet facilitates the development of these abilities, so that it becomes a habit, the results of [10] stated that significant impact on the development of critical thinking in students due to the STEM research experience is supported through question-based collaborative learning strategies. The worksheets are arranged based on STEM
using the syntax of problem based learning, the results of [4] study stated that STEM education on problem solving found that students' critical thinking and problem solving had a significant effect. In addition, the application of the STEM approach influences attitudes, interests and motivation. [11] research results show that STEM education has good potential in developing critical thinking skills. Worksheets are arranged based on problem solving, [12] research results in STEM-based education for students, through direct experience and problem solving can develop critical thinking skills. Several studies [13,14,15,16,12,17,18] also show that there is an increase in student academic achievement when problem-based learning is applied. In line with the findings [19] that by applying STEM in learning there is a difference in the results of critical thinking skills both before and after the learning. In addition, students' critical thinking skills have improved.

| No | School code | Average score Pretest | Gain test | Criteria |
|----|-------------|-----------------------|-----------|----------|
| 1  | S-01        | 56.88                 | 0.84      | High     |
| 2  | S-02        | 41.36                 | 0.94      | High     |
| 3  | S-03        | 41.50                 | 0.86      | High     |
| 4  | S-04        | 38.75                 | 0.82      | High     |
| 5  | S-05        | 37.60                 | 0.75      | High     |
| 6  | S-06        | 35.65                 | 0.76      | High     |
| 7  | S-07        | 34.38                 | 0.92      | High     |
| 8  | S-08        | 53.31                 | 0.80      | High     |
| 9  | S-09        | 49.48                 | 0.68      | Medium   |
| 10 | S-10        | 46.68                 | 0.93      | High     |

The high average creative thinking achievement like presented in table 4 is due to the worksheets that are arranged based on problem solving, according to the research of [7] the positive and significant influence of STEM PBL, is on the affective development of creativity, including adventure, curiosity, imagination and challenge. Other research findings show that STEM activity increases students' scientific creativity. Similar findings are reported in the literature [20,21,22,23]. As pointed out by [24] that students who take STEM-based learning are creative people who can design projects creatively and produce solutions based on contemporary needs. In a publication by [25] they emphasize that students develop critical and creative thinking skills with design experience in engineering disciplines. Another view by [26] that there is an increase in creativity in grade 6 students because it uses a syllabus based on the STEM approach.

As pointed out by [27] that learning with the STEM approach can significantly improve students' creative thinking abilities with a 95% confidence level and an N-gain value of 0.57 in the medium category. Increasing the average value of pretest and posttest supported by worksheet involves students directly in learning such as discussions and simple experiments, making students better understand the material. This is in accordance with [28] research, simple discussion and practical activities can improve students' creative thinking abilities. These results are consistent with [29] which revealed that STEM-based worksheets are good in training creative thinking skills as seen from increasing creative thinking skills on each indicator. In line with these findings, [30] found that discussion activities and practicums with certain learning models can improve students' creative thinking abilities.

Learning using STEM-based worksheets can increase student knowledge. The worksheets used are also equipped with information technology and engineering so that students' knowledge increases. This
is consistent with research conducted by [31] that students who have extensive knowledge can have high creative thinking abilities. Curiosity makes students curious and encourages students to think. This is also appropriate with [32] research that curiosity can influence students' creative thinking abilities.

4. Conclusion

The worksheet starts with various problems related to material and applications in daily life. In the worksheet there are facilities for discussion, practical work or experiments, as well as evaluations aimed at honing critical and creative thinking skills. The worksheet is printed using A4 size paper, facilitating the use of the STEM approach to worksheets by integrating aspects of science, technology, engineering, and mathematics. The readability test results of Student Worksheets (LKS) are included in the easy to understand category. The results of the feasibility tests for the worksheets developed were in the proper category to be used as teaching material. From the results of tests on students from ten schools in the city of Semarang, the development of critical thinking and creative thinking skills through questions that use indicators of critical and creative thinking skills. The worksheet is printed using A4 size paper, facilitating discussion, practical work or experiments, as well as evaluations aimed at honing critical and creative thinking skills. The worksheet is printed using A4 size paper, facilitating the use of the STEM approach to worksheets by integrating aspects of science, technology, engineering, and mathematics. The readability test results of Student Worksheets (LKS) are included in the easy to understand category. The results of the feasibility tests for the worksheets developed were in the proper category to be used as teaching material. From the results of tests on students from ten schools in the city of Semarang, the development of critical thinking and creative thinking abilities is high on average.

References

[1] Prastowo A 2014 Panduan Kreatif Membuat Bahan Ajar Inovatif: Menciptakan Metode Pembelajaran yang Menarik dan Menyenangkan. (Yogyakarta: DIVA Press)
[2] Bybee R W 2013 The Case for STEM Education: Challenges and Opportunities (Virginia: NSTA Press)
[3] Gonzalez H B and Kuenzi J J 2012 Congressional Research Service 7 5700
[4] Yildirim B and Selvi M 2016 J. Human Sci. 13 3684-95
[5] Permanasari A 2016 Pros. Sem. Nas. Pend. Sains (Surakarta: Universitas Sebelas Maret)
[6] Zhbanova K S 2017 Journal of STEM Arts, Craft, and Constructions 2 1-14
[7] Lou S, Chou Y, Shih R, and Chung C 2000 EURASIA J. Math. Sci. Tech. Edu. 13 2387-2404
[8] Soros P, Ponkham K, and Ekkapim S 2018 AIP Conf. Proc. 1923 030045
[9] Gonzalez R and Batanero F 2015 Inter. J. Adv. Edu. Res. 3 14-31
[10] Duran M and Şendağ S 2012 Creative Edu. 3 241-250
[11] OonsimW and Chanprasert K 2017 Rangsit J. Educ. Stud. 4 54-59
[12] Cutucache C E, Luhr, Luhr J L, Nelson, Nelson K L, Grandgenett N F and Tapprich W E 2016 Inter. J. STEM Edu. 3
[13] Abanikamnda M O 2016 Int. J. Educ. Learn. Dev. 4 55-63
[14] Aidoo B, Boateng S K, Kissi P S, and Oforli I 2016 J. Educ. Pract. 7 103-108
[15] Argaw A S, Haile B B, Ayalew B T, and Kuma S G 2016 Eur. J. Math. Sci. Tec. Educ. 13 857-871
[16] Aziz M S, Zain A N M, Samsudin M A B, and Saleh S B 2014 Int. J. Acad. Res. Prog. Educ. Dev. 3 126-137
[17] Selcuk G S, Caliskan C, and Sahin M 2013 Int. J. New Trends. Educ. Impl. 4 154-164
[18] Zabit M N M, Karagaianidou E, and Zachariah T Z 2016 Int. J. Adv. App. Sci. 3 30-35
[19] Siregar Y E Y, Rachmadullah R, Pohan N, Rasmitadila and Zulema M S 2019 IOP Conf. Ser.: J. Phy.: Conf. Series 1175 012156
[20] Erdoğan N, Çorlu M S, Capraro R M 2013 Int. Online J. Educ. Sci. 5 19
[21] Knezek G, Christensen R, Wood T T and Periathiruvadi S 2013 Sci. Edu. Inter. 24 98-123
[22] Şahin A, Ayar M C and Adiguzel T 2014 Kuram ve Uygulamada Eğitim Bilimleri 14 297-322
[23] Siew N M, Amir N and Chong C L 2015 SpringerPlus 4 8
[24] Morison J 2006 TIES STEM Education Monograph Series: Attributes of STEM Education (Baltimore, MD: TIES)
[25] Lawanto O, Butler D, Cartier S C, Santoso H B, Goodridge W, Lawanto K N and Clark D 2013 J. STEM Edu. 14 15-27
[26] Cho B and Lee J 2013 Inter. Conf. Educ. Tech. (South Korea: Sejong University)
[27] Surya J P, Abdurrahman, and Wahyudi I 2018 *J. Komodo Sci. Edu.* 1 106-16
[28] Nuriyanah S 2015 *Pengembangan Kemampuan Berpikir Kreatif Siswa Melalui Praktikum Sederhana* (Skripsi: Universitas Negeri Semarang)
[29] Pertiwi R S, Abdurrahman and Rosidin U 2017 *J. Phys. Learn.* 5 11-9
[30] Rohim, Fathur, Hadi S and Ellianawati 2012 *Unnes Phys. Edu. J.* 1 1-5
[31] Sari I M, Sumiati E, and Siahaan P 2013 *J. Pengajaran MIPA* 18 60-8
[32] Rudyanto H E 2014 *Premiere Edu.* 4 41-8