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STEM-PjBL Worksheet : Ways to Improve Students' Collaboration, Creativity, and Computational Thinking

Shifa Alkautsar, Moh. Mirza Nuryady, Husamah, Poncojari Wahyono, Fuad Jaya Miharja*
Biology Education Department, Faculty of Teacher Training and Education, Universitas Muhammadiyah Malang
***Corresponding Author. Email: fuad.jayamiharja@umm.ac.id

Abstract: This study aims to develop STEM-PjBL worksheets to improve students' collaboration, creativity, and computational thinking skills. This development research uses the ADDIE model by implementing all stages of development. The research instruments were student collaboration observation sheets, student creativity observation sheets, computational thinking assessment sheets, pretest and posttest questions, teacher interview sheets, and validation sheets. Data analysis techniques using qualitative and quantitative descriptive analysis. The product validation results show that the STEM-PjBL-based worksheet is categorized as very feasible based on the validation value obtained by the expert validator. Collaboration, creativity, and computational thinking skills scored respectively 83, 81, and 82 with very good level of achievement category. Non-parametric test results show a significance value (<0.05). These results indicate that the STEM-PjBL worksheet is very feasible and recommended for use in learning.

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Introduction

Improving the quality of learning in schools must be carried out by prioritizing the skills needed in the future so that students are able to compete and face the realities of the 21st century (Maas et al., 2018; Nuvitalia et al., 2022; Scott, 2015). The 21st century learning is defined as learning that provides skills to students, which include critical thinking and problem solving, communication, creativity, and collaboration (Aji, 2019; Bellanca et al., 2010; Lai, 2011). These skills need to be integrated in such a way in learning through the application of innovative models (Dwyer et al., 2014; Wiartis, 2021), which is carried out steadily and consistently (Shukri et al., 2020).

Several studies have shown that students' high-level thinking skills are still low, one of which is influenced by the absence of innovative models used, or the use of these innovative models is not optimal (Changwong et al., 2018; Ika Noviyanti et al., 2019; Miharja et al., 2019). As a result, students often find difficulty in exploring ideas, resulting in difficulties in solving problems (S. P. Sari et al., 2019). More specifically, it also influences students' creativity in understanding and solving the problems they face (Binkley et al., 2012). The tendency towards a lack of student proficiency in learning can also be caused by a lack of student collaboration (Keast & Mandell, 2014; Le et al., 2018; Mamahit et al., 2020). On the other hand, computational thinking skills as an indicator of critical thinking skills and problem solving have not been widely studied (Fields et al., 2021; Fitriani et al., 2021; Güven & Gulbahar, 2020). Research on computational thinking skills still focuses on learning mathematics (Barcelos et al., 2018; Gadanidis et al., 2017; Sung & Black,

2020) and has not been widely measured in other learning such as learning science (Weintrop et al., 2016).

Strengthening the competence of 21st century students is in line with the objectives of the independent curriculum which includes science learning (Artawan, 2022; Indarta et al., 2022; Sari et al., 2020). In practice, learning science in junior high schools still often faces obstacles, especially students' difficulties in understanding abstract concepts that should be assisted by contextual learning (Desouza, 2017; Hsieh & Tsai, 2017; Yunarti, 2021). The use of teaching materials sourced from books and the internet cannot necessarily be used in learning because they are not necessarily in accordance with student learning needs (Du et al., 2018; Irdalisa et al., 2023; Sari et al., 2020). It is ultimately the reason why lectures still dominate during the learning process so that many student collaborations are also not optimally developed (Keast & Mandell, 2014; Le et al., 2018). In this case, the teacher needs to map students' abilities to innovate and develop the necessary teaching materials according to the characteristics of students and contexts that are relevant to the material being studied. Contextualization of this material needs to be designed in such a way that it is integrated into teaching materials (Su'udiah et al., 2016; Suryawati & Osman, 2018).

STEM learning brings material closer to the context of problems in everyday life through a multidisciplinary approach (English, 2016; Kennedy & Odell, 2014). STEM modifies learning through the integration of science, technology, engineering, and mathematic frameworks in solving contextual problems (Teo et al., 2021). STEM learning has been extensively researched and developed in Indonesia in the last ten years. More specifically, STEM research focuses on the development of learning innovations in the context of everyday problems that are relevant to the material, both in the form of media and teaching materials, as well as integration with innovative learning models (Handayani, 2020; Smith et al., 2022; Sturyf et al., 2019).

One of the learning models that can be applied in the learning process with the STEM approach is project-based learning (PjBL) (Aksela & Haatainen, 2019; Fiteriani et al., 2021; Siew & Ambo, 2018). Some researchers say that PjBL has a syntax that can support contextual learning and 21st century skills (Afriana et al., 2016; Ardiansyah et al., 2020; Avery & Reeve, 2013; Reeve, 2011). Furthermore, STEM has also been heavily integrated with PjBL through systematic project completion of contextual problems that occur daily (Lou et al., 2017; Ngoh, 2013; Tseng et al., 2013). The completion of the project is carried out according to student worksheets designed by the teacher and specifically aimed at improving students' 21st century skills. This study aims to develop student worksheets based on STEM-PjBL to increase students' creativity, collaboration skills, and computational thinking.

Research Method

This development research uses the ADDIE model by implementing all stages of analysis, design, development, implementation, and evaluation (Branch, 2010). The analysis phase is carried out by identifying student learning characters, the relevance of everyday contextual problems to learning materials, as well as the potential and resources they have. The design stage is carried out by designing worksheets and teaching materials, preparing evaluation instruments and expert validation. The development stage is carried out by developing worksheets that have been designed through the validation of material experts, teaching materials experts, and science teachers. The results of the expert validator's assessment form the basis for product revision. Products that have been revised and are suitable for use enter the product trial stage. Product trials were carried out at the implementation stage involving 29 class VII students of SMP Muhammadiyah 1 Malang who had studied environmental pollution as research subjects. The final stage is carried out by evaluating the products that have been tested.

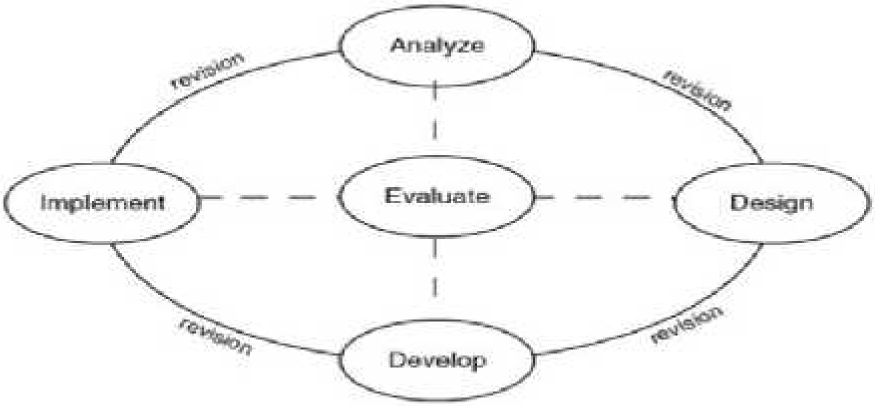

Figure 1. ADDIE design development model

Product validation was carried out to measure the validity of STEM-PjBL-based worksheets on students' collaboration skills, creative thinking skills, and computational thinking. The validation instrument was developed using a Likert scale with four criteria including very good, good, fair, and poor. Scores are analyzed to obtain an average questionnaire to determine the feasibility of the worksheet by experts. The criteria for the validity level of the worksheet developed are described in Table 1. The results obtained will be calculated based on the score obtained for each answer with the maximum score (Hulukati & Djibran, 2018).

Table 1. Criteria for the level of validity

Average Score	Criteria
0 – 25	Invalid
25 – 50	Less valid
50 – 75	Valid
75 – 100	Very valid

Data collection techniques were used with tests and non-tests in the form of interviews, questionnaires and observations. Measurement of students' collaboration skills, creative thinking skills, and computational thinking were carried out with student observation assessment sheets, student creativity observation observation assessment sheets, and computational thinking assessment sheets.

Data analysis techniques uses qualitative and quantitative descriptive analysis. Evaluation at the trial stage is carried out by developing evaluation questions that are given through the pretest and posttest. This evaluation score is made based on indicators of creative thinking skills and computational thinking. The results of the pretest and posttest evaluations were then analyzed by means (Table 2) and using a gain score (Table 3) (Ridha et al., 2022).

Table 2. Level of achievement category

Level of achievement	Category
76 – 100	Very good
51 – 75	Good
26 – 50	Low
0 – 25	Very low

Table 3. N-gain score category

N-gain score	Category
g > 0.7	High
0,3 ≥ g ≥ 0.7	Moderate
g > 0.3	Low

The validity of the pretest and posttest of evaluation items was measured using the product moment correlation. The results of the item validity test showed that 15 out of 30 items were declared valid, while the reliability test was carried out using alpha cronbach. The results of the reliability test showed a Cronbach's alpha value of 0.813 (ri > 0.70) with a total of 30 item

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items in the category of very high degree of reliability or reliable (Table 6) (Yusup, 2018). The normality test in this study used the *Kolmogorov-Smirnov* and *Shapiro-Wilk* with a sig normality score (>0.05). Furthermore, non-parametric test by comparing the average pretest and posttest values during trials with a significance <0.05 (Ghasemi & Zahediasl, 2012).

Tabel 4. Reliability index criteria

Reliability Index	Criteria
0 – 0.19	Very low
0.20 – 0.39	Low
0.40 – 0.59	Moderate
0.60 – 0.79	High
0.80 – 1.00	Very high

Results and Discussion

The development of the STEM-PjBL worksheet is carried out by referring to the needs of students, aspects of the material, and its contextualization in the daily problems faced by students. In the early stages, the analysis was carried out by observing classroom learning and interviews with science teachers and students as also (Kiplagat et al., 2012). It is to analyze how the students learn, as well as possible assistance that needs to be prepared by the teacher (Smith et al., 2022). The observation results show that student learning independence is still at a level that needs to be improved, especially in science learning students tend to only memorize theory. On the other hand, even though teachers have implemented many innovative learning models such as problem-based learning (PBL) and PjBL, sometimes the duration of study time is still dominated by lectures while the duration of student collaboration still tends to be less.

Some of the obstacles when learning is the gap between the subject matter and the context of the problems faced by students in everyday life (Illeris, 2009; Poortman et al., 2011; O.-S. Tan, 2003). Furthermore, the module used has many shortcomings because it is not fully developed according to the needs of students (Ajizatunnisa et al., 2018; Irwan et al., 2019; Maryani et al., 2017). It causes teachers often face obstacles in designing the best learning for students, so teachers need to develop learning tools that suit students' needs and can help students learn independently through contextual learning (Viro et al., 2020).

Contextualization of learning materials according to the STEM framework needs to be supported by relevant issues (Asrizal et al., 2018; Farida et al., 2017). It needs to be analyzed at the beginning to ensure that the problems raised in class discussions are complex, persistent, and extended problems (Tan et al., 2019). For example, the problem of environmental pollution. This environmental pollution is a common problem faced by almost all regions in Indonesia, such as soil (Muslimah, 2017; Pangestu et al., 2017; Ramadhan, 2018), air (Lussetyowati, 2011), and water pollution (Devianto et al., 2019; Salahuddin et al., 2012). However, the context of the problems faced by each region varies according to the characteristics of each region so that the solution for solving them may vary. In this case, the device development carried out raises the problem of water pollution at several river points in Malang.

The problems raised in this study are discussion modalities for students in order to find the best solution. The discovery of the best solution cannot be found immediately without systematic steps (Hollweg et al., 2012). In this case, the device development carried out in this study is embodied in worksheets and teacher guides by integrating STEM-PjBL as a learning model (Aksela & Haatainen, 2019; Honey et al., 2014). The STEM-PjBL worksheet was also developed by integrating students' collaborative and creative activities to

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try to solve problems in an orderly pattern that can train computational thinking, so that learning in class becomes more meaningful and can direct students to contextual learning.

The design of the STEM-PjBL worksheet begins with designing and establishing the linkages between basic competencies, learning materials, module design (refers to independence curriculum), and designing the steps outlined in the worksheet according to the needs analysis that has been carried out (English, 2016; Neubert et al., 2015). This stage also prepares student evaluation instruments during trials and validation instruments that will be submitted to material validation experts, worksheet teaching material validation experts, and science teachers. The basic competencies used are environmental pollution and its impact on ecosystems (KD 3.8) and finding problem-solving ideas (KD 4.8). The contents of the material include the characteristics of water pollution, water pollution factors, the impact of water pollution, and efforts to prevent or overcome water pollution.

The STEM-PjBL worksheet contains the design of the interconnection between science, technology, engineering, and mathematics (Teo et al., 2021) that students learn through problems concerning water pollution (Figure 2). The interconnection illustrates the tendency of the activities carried out in learning. In this case, the STEM activities carried out tend to be solution-centric because a water filter is a solution that has been used to filter dirty or polluted water (Teo et al., 2021). However, these solutions need to be evaluated to get the best filter design that may be used for various user needs, apart from of course according to the characteristics of the problems encountered (Tan et al., 2019).

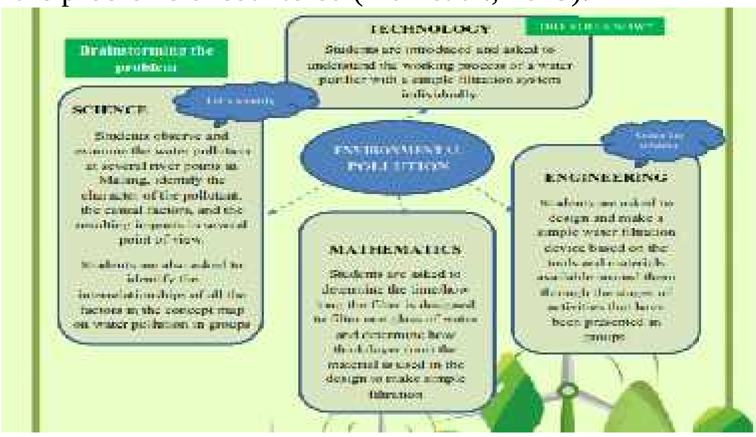

Figure 2. STEM interconnection

The issues raised in the lesson are presented by adding related news articles (Figure 3) and supporting pictures from several river points in Malang City (Figure 4). Furthermore, other things that are done in the worksheet design are background displays, collaborative activity steps, creative thinking activities, and computational thinking. This STEM-PjBL worksheet was developed according to the level of junior high school students.

Figure 3. Related news articles about river pollution in Malang

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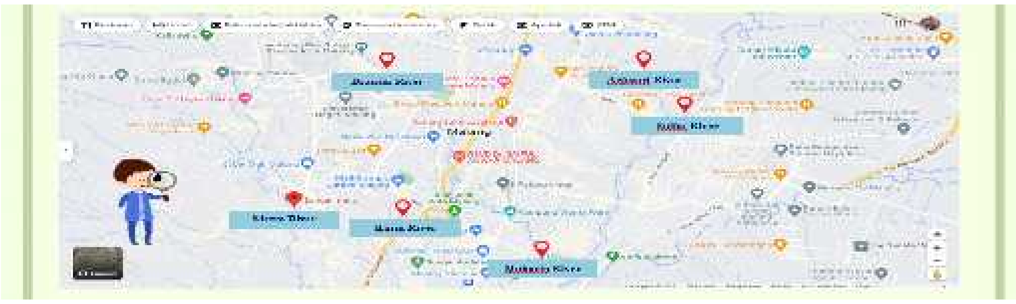
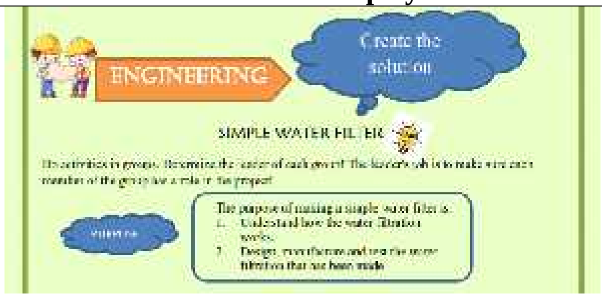
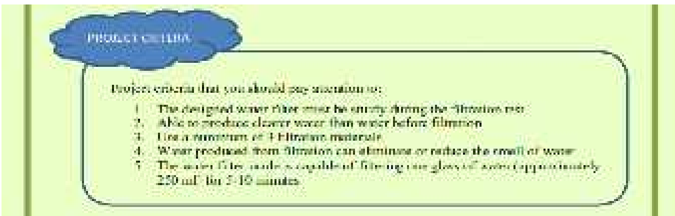


Figure 4. Several points of river pollution in Malang

Creative thinking and computational thinking skills are developed through a series of solution-finding activities. Students are asked to develop a simple water filter using the tools and materials that have been prepared. But in practice, students are asked to evaluate what kind of tools and materials need to be used with certain considerations they have. In this case, the teacher provides space for students to find out for themselves how their version of the best water filter is arranged. Solution discovery activities as described in Table 5.

Table 5. Display in the STEM-PjBL worksheet

No	Worksheet display	Explanation
1		This section is a guide for students to find a solution to the problem of dirty water or polluted water by making a water filter. Each group was also asked to determine the role of each member in the team before the project was carried out.
2		This section is an introduction that explains the role of students in solving water pollution problems. This narrative contains the application of theories related to water pollution which are important for students to understand and study further.
3		Project criteria are terms and conditions set by the teacher and must be considered by students during project work.
4		This section is the stages carried out by students in working on projects. The stages of activity carried out refer to the PjBL from designing solutions, implementing solutions, to reviewing solutions.

There are three categories of experts to test the validity of the STEM-PjBL worksheet including material experts, teaching materials experts, and class VII science teachers. Each category of validation is carried out by two expert validators. The results of the worksheet validation are shown in Table 6. The validation results show that the material expert's assessment is 95 and 94 (very valid). Furthermore, the expert assessment of teaching materials was 91, while the science teacher's assessment was respectively 84 and 95 (very valid). All the results of the validators' assessments show a very feasible category; however, adjustments and improvements need to be made in accordance with the revision notes.

Table 6. Expert validation results and suggestions for improvement

Experts Validator	Score	Category	Improvement Suggestions
Material expert 1	95	Very valid	Use the Law of the Republic of Indonesia No. 32 of 2009 concerning the Environment as a reference.
Material expert 2	94	Very valid	The writing format needs to be considered for revision by using an attractive font.
Teaching material expert 1	91	Very valid	Supporting images such as problem identification need to be added.
Science teacher 1	84	Very valid	Student activities in identifying water filtration techniques need to be deepened with literacy activities that stimulate student inquiry.
Science teacher 2	95	Very valid	1. If possible, when developing solutions, students need to be given more applicable projects 2. If possible, students should be invited to find creations to create new filtration devices

At this stage, the revised STEM-PjBL worksheet is piloted in schools. The trial was carried out involving 29 students. Before learning is carried out students are asked to do a pretest before being taught with the STEM-PjBL worksheet. The teacher gives directions according to the instructions in the worksheet during learning. Furthermore, during learning the teacher acts as a facilitator who controls the flow and activities of student learning such as determining heterogeneous groups and preparing tools and materials to be used by students in groups. At the last meeting after learning was carried out, students took a posttest to measure student learning outcomes after studying with the STEM-PjBL worksheet. Comparison of pretest and posttest results is presented in Figure 5.

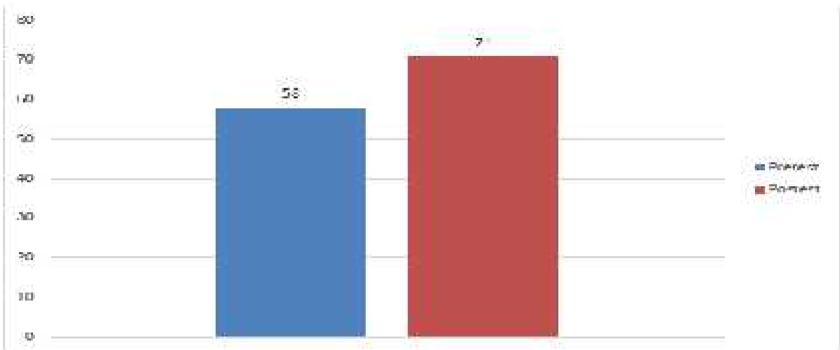


Figure 5. Comparison of students' pretest and posttest scores

Student collaboration and creativity can be observed during problem identification activities (Scager et al., 2016; Zulkarnaen et al., 2017). Students in groups try to find the best water

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filter composition and arrangement solutions through dialogue and collaboration (Figure 6). Students share roles starting from studying the theory of filtration, the characteristics and functions of each tool and material used, to paying attention to the thickness of each layer of the water filter and testing the product they are designing to see if it complies with the required project criteria (Figure 7).

Figure 6. Student collaboration

Figure 7. Students test the product designs they have designed

The N-gain score obtained is 0.31 (moderate). These results indicate that the use of the STEM-PjBL worksheet is able to make a difference between before and after learning. Kennedy and Odell (2014); Yu et al (2015) stated that learning using the project model can encourage students to be more active and better understand the concepts of the material provided through project activities in learning. Honey et al. (2014); Sung and Black (2020); Wang et al. (2021) also stated that learning using the PjBL model of the STEM approach was able to have a positive impact on the learning process, especially increasing learning outcomes and helping students to better understand the concept of material provided through contextual learning.

On the other hand, the observations of collaboration skills, creativity, and computational thinking skills are at a very good level with a score above 80 (Table 7). It shows that learning with STEM-PjBL worksheets can stimulate collaboration skills, creativity, and computational thinking through inquiry activities during project completion. The results of the observations are in line with Hossain et al. (2018); Mamahit (2020) which state that STEM-PjBL learning can trigger students' intellectual development during collaborative activities with other students who share information and exchange ideas. Fiteriani et al. (2021); Shukri et al. (2020) also state that learning with PjBL has a significant influence on students' creativity and collaboration abilities because project-based learning makes the learning process more active, creative, fun, and able to improve students' abilities in transferring knowledge so as to provide a positive learning experience. Furthermore, learning science with computational thinking is able to train students to think critically, structured and logically (Hershkovitz et al., 2019; Weintrop et al., 2016).

Table 7. The average score of learning outcomes

Learning outcomes	Average
Collaboration	83
Creativity	81
Computational Thinking	82

Table 8. N-gain score analysis

	Posttest - Pretest
Z	-4.903
Asymp. Sig. (2-tailed)	.000

The significance of learning with the STEM-PjBL worksheet using the non-parametric sign test (Table 8) shows a significant score (<0.05). This shows that learning with STEM-PjBL worksheets is also significantly able to improve students' cognitive. These results indicate that the resulting creativity is the impact of good cognitive understanding (English, 2016). Gasiewski et al. (2012) show that the PjBL model with the STEM approach provides a significant increase in learning outcomes in mastering science and mathematics.

On the other hand, these results also show that the STEM-PjBL worksheet is able to make it easier for students to understand water pollution material through structured activity in the worksheet with the STEM approach and PjBL stages that link real-life problems (Carlina & Djukri, 2018; Smith et al., 2022). Furthermore, activities carried out in groups in completing projects also improve students' collaborative skills (Sahin et al., 2014). The groups dialogue as well as training computational thinking during the learning process (Kafai et al., 2020; Malyn-Smith et al., 2018). The same results were shown in the research by (Hossain et al., 2018) which stated that learning with the PjBL model of the STEM approach makes the learning atmosphere in class more interesting by directly involving students in the process of designing and building projects in problem solving. So thatstudents are not only interested in learning, but also more easily map problems, find patterns, and make algorithms in decision making.

Conclusion

STEM-PjBL worksheets can improve students' collaboration, creativity, and computational thinking skills through structured learning activities. Furthermore, the STEM-PjBL worksheet is highly recommended to be developed and utilized as teaching materials to support learning and can improve students' collaboration, creativity, and computational thinking skills.

Recommendation

Further research needs to be carried out on a larger scale with more consistent implementation. Obstacles in this study for maximum results need to be explored factors that influence interest in learning such as internal factors which include curiosity and attention in learning as well as external factors including family aspects, community aspects and school aspects. This is necessary because it can affect the results given.

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