Inovasi Matematika (Inomatika) DOI: 10.35438/inomatika.v6i2.463
Vol.6 No.2, July 2024, hal.120 – 141 https://inomatika.unmuhbabel.ac.id/index.php

Development of STEM-PjBL Learning Media to Improve Students' Critical Thinking Skills for Counting Whole Number and Fraction

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Abstrak

Penelitian ini bertujuan untuk mendeskripsikan proses dan hasil dari pengembangan perangkat pembelajaran berbasis PjBL terintegrasi STEM untuk meningkatkan kemampuan berpikir kritis siswa pada materi operasi hitung bilangan bulat dan pecahan. Penelitian ini merupakan penelitian pengembangan dengan model pengembangan Plomp untuk mengembangkan perangkat pembelajaran berupa Modul Ajar dan Lembar Kerja Proyek materi operasi hitung bilangan bulat dan pecahan dengan desain pembelajaran proyek terintegrasi STEM. Instrumen penelitian ini yaitu lembar kerja proyek, modul ajar, lembar respon siswa, dan lembar *pre-test* dan *post-test.* Teknik pengumpulan data menggunakan kuisioner (lembar validasi dan respon siswa) dan tes. Analisis data dilakukan dengan menguji kevalidan, kepraktisan, dan keefektifan perangkat pembelajaran. Hasil penelitian menunjukkan bahwa perangkat pembelajaran memperoleh kriteria kevalidan sebesar 87,9% untuk Lembar Kerja Proyek sedangkan 84,375% untuk validitas Modul Ajar dan masing-masing tergolong sangat valid. Untuk kriteria keefektifan diperoleh N-gain 0,7512 pada uji coba terbatas dan 0,7091 pada uji coba kelas dan masing-masing memperoleh kriteria efektivitas yang tinggi. Perangkat pembelajaran memeroleh kriteria praktis diimplementasikan dengan rata-rata perolehan respons siswa sebesar 79,3% dan 80,45% untuk desain pembelajaran proyek. Dengan demikian, perangkat pembelajaran dinyatakan valid, efektif, dan praktis untuk digunakan.

Kata kunci: Bilangan Bulat, Kemampuan Berpikir Kritis, Pecahan, PjBL, STEM

Abstract

This study aims to describe the process and results of the development of PjBL-based learning media integrated with STEM to improve students' critical thinking skills on the material of counting operations of whole numbers and fractions. This research is a development research with Plomp development model to develop learning tools in the form of Teaching Modules and Project Worksheets on arithmetic operations of whole numbers and fractions with STEM integrated project learning design. The instruments of this research are project worksheets, teaching modules, student response sheets, and pre-test and post-test sheets. Data collection techniques used questionnaires (validation sheets and student responses) and tests. Data analysis was conducted by testing the validity, practicality, and effectiveness of learning devices. The results showed that the learning devices obtained validity criteria of 87.9% for the Project Worksheet while 84.375% for the validity of the Teaching Module and each was classified as very valid. For the effectiveness criteria, the N-gain was 0.7512 in the limited trial and 0.7091 in the class trial and each obtained high effectiveness criteria. The learning tools obtained practical criteria for implementation with an average student response of 79.3% and 80.45% for project learning design. Thus, the learning tools are declared valid, effective, and practical to use.

Keywords: Whole Numbers, Critical Thinking Skills, Fractions, PjBL, STEM
Received: April 21, 2024/ Accepted: June 19, 2024/ Published Online: July 01, 2024

INTRODUCTION

In the 21st century, there are four basic abilities that students must have, namely critical thinking, creative thinking, communicating, and collaborating (Han et al., 2021; Weng et al., 2022; Yudha et al., 2023). One of the most important is critical thinking skills. Critical thinking skills refer to the process of actively conceptualizing, systematically analysing, synthesizing, and evaluating information to form logical judgments and decisions that can be made in solving problems (Hwang et al., 2018) Critical thinking skills allow students to think rationally in solving problems (Sumarni & Kadarwati, 2020) Furthermore, critical thinking skills will encourage students to think more deeply and be able to solve problems at school and in the context of everyday life because critical thinking skills are not only needed in the classroom but also in everyday life (Basri et al., 2019). In learning mathematics, critical thinking skills are important for students (Alexandra & Ratu, 2018). This is because critical thinking skills are used to analyze and evaluate specifically when solving mathematical problems (Cahyaningsih & Nahdi, 2021).

The core of critical thinking involves indicators such as interpretation, analysis, evaluation, inference, explanation, and self-regulation. Researchers chose the indicators put forward by Facione because they are in accordance with the definition of critical thinking skills referred to in this study, namely the ability to think critically in problem solving and based on cognitive skills and abilities. The six aspects of critical thinking according to Facione, namely the interpretation aspect is related to the way students identify problems; for the analysis and evaluation aspects are related to the way students solve problems; the inference aspect is related to the conclusions students draw after solving problems; the explanation aspect is related to the reasons for the conclusions drawn by students; the self-regulation aspect is related to rechecking the answers that have been produced (Benyamin et al., 2021).

PISA results in 2022 showed that Indonesia's position in mathematics was ranked 71 out of 81 countries where the mathematical abilities of Indonesian students were still low, one of which was critical thinking ability. The low critical thinking skills of students are due to the learning applied in schools that are still dominated by teachers so that they do not train critical thinking skills in students (Aminah & Ayu Kurniawati, 2018). Students' low critical thinking skills are also caused by their tendency to focus on memorizing learning materials (Sukma & Priatna, 2021). In addition, some factors that cause low critical thinking skills are

overcrowded classes, teachers prefer traditional teaching methods, textbooks do not support critical thinking (Arisoy & Aybek, 2021).

One of the junior high schools mathematics materials that still causes difficulties for students is whole number and fractions (Ramadianti et al., 2019). Difficulties in whole number material occur when students work on whole number problems due to an understanding of the concept of whole numbers that has not been maximized (Yanala et al., 2021). In addition, Fuadiah et al., (2016) found that students had difficulty in understanding negative numbers where there were 59% of research subjects unable to order negative numbers and as many as 95% of subjects in the study could not perform addition operations on negative numbers. Then the difficulty in understanding the concept of fractions also occurs when students are asked to estimate the results of fractions, for example if the basic concept of fractions is well understood, then when students are asked to estimate the size of the fraction $\frac{12}{13}$ they can imagine the size which is close to 1 (Deringöl, 2019). Students also experience difficulties in fraction material such as difficulties in understanding fractions, doing fraction exercises that express the relationship of fractions to other sets of numbers, ordering fractions, determining the steps of work in problems whose steps involve whole numbers (Çalışıcı, 2018).

Not only experiencing difficulties and mistakes in learning whole numbers and fractions, students also experience misconceptions in the material, namely misconceptions in basic arithmetic problems, especially in the concepts of: (1) subtraction of whole numbers where students assume that the result of subtraction must be smaller; (2) subtraction of fractions where students immediately subtract the numerators of the two fractions involved and calculate the denominators separately, (3) multiplication and division of fractions where students do not understand the procedural concepts of multiplication and division so that it has an impact on the steps of the process (La Hadi & Dedyerianto, 2020). In addition, a specific misconception of fractions arising from whole number refraction is that students often view the numerator and denominator as one entity and thus interpret fractions as one number such as adding both the numerator and denominator to two fractions (e.g., 2/3 + 4/6 = 6/9) (Namkung & Fuchs, 2019; Zhang & Rivera, 2021). Another misconception related to fractions is that students tend to compare the value of fractions by comparing the numerator or denominator as natural numbers separately (e.g. 8/9>7/6 because 8>7 and 9>6) (Reinhold et al., 2020).

From this description, many students have difficulties and misconceptions in whole numbers and fractions. In fact, counting operations of whole numbers and fractions are basic materials that must be understood by students because it are the foundation for learning other mathematical materials (Najwa, 2021). Based on these conditions, it is necessary to innovate student-centered mathematics learning so as to provide opportunities for them to improve critical thinking skills. Based on 21st century learning, the learning needed is learning that involves students in the learning process. Learning that involves students is intended by including students in learning activities.

One of the learning models that can be used is project-based learning. This learning model can support the 4C abilities that must be possessed in the 21st century, one of which is students' critical thinking skills (Diana & Saputri, 2021; Sagala et al., 2020). Through the PjBL syntaxes, the students are taught, trained and improved to think critically, including analyzing/formulating problems, giving logical arguments, doing deductive reasoning (C4), synthesizing/ conducting inductive reasoning (C5), and evaluating (C6) (Chen & Yang, 2019;Efendi et al., 2020; Guo et al., 2020; Issa & Khataibeh, 2021). In project-based learning, students can understand the concept through making products, while in STEM learning students will do the process of designing and designing products (Andi et al., 2019) . According to Andi et al., (2019) PjBL model integrated with STEM gives students freedom to explore learning activities, carry out projects collaboratively, and produce products that are solutive and creative.

Research by Rahmawati et al. (2022) shows that the STEM learning approach has a positive effect on students' critical thinking. Another study conducted by Siregar et al. (2019) that the STEM learning approach in addition to improving students' creative thinking also improves students' achievement in mathematics learning. With the STEM approach, students learn to connect 4 fields namely science, technology, engineering and mathematics so that they are able to generate new ideas, create original work that has not existed before through experimentation, and practical practice which is one of the critical thinking skills. In a subsequent study conducted by Ayuningsih et al. (2022), Oktadila et al., (2022), dan Sukmagati et al., (2020) also showed the results of an increase in creative and critical thinking in students with STEM-based Student Project sheets.

In the STEM approach, there is an Engineering Design Process (EDP) which plays an important role in the process and designing products (English & King, 2015). With EDP, students can gather many problem-solving ideas to produce a product through several processes (English, 2017). Research by (English, 2017) shows that five EDP processes,

namely 1) Problem Scoping; 2) Idea Generation; 3) Design and Construct 4) Design Evaluation; 5) Redesign. Activities include: understanding the context of the problem used in the project, brainstorming or thinking about problem-solving strategies, developing a model, and testing the model. STEM learning can be integrated in mathematics learning and has an important role, namely mathematical modeling, numeracy and socio-scientific issues, as well as sharpening 21st century skills, especially creative thinking, critical thinking, problem solving, and decision making (Maass et al., 2019). Engineering Design Process (EDP) is a series of stages carried out by researchers and designers in designing and manufacturing creative products to meet certain constraints and user needs by utilizing scientific, mathematical, and engineering knowledge (Han & Shim, 2019). EDP provides a real-world context that aims to connect the integral disciplines of math, technology, engineering, and mathematics with the real world to equip students to solve real problems (Putra et al., 2023). The stages of EDP are illustrated in the Figure 1.

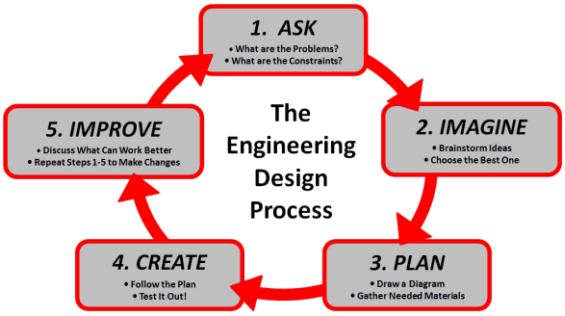


Figure 1. Process in EDP

Based on this Figure 1, the following is a description of each aspect of EDP according to Syukri et al., (2018) :

a. *Ask* (Identifying the problem)

   At this stage students in their groups identify and analyze a given problem.

b. *Imagine*

   At this stage students brainstorm various possible solutions to the problem. Students can conduct research through various sources of information that they consider relevant to help them in compiling various solution ideas.

c. *Plan*

   With the best solution determined, the next step is to model the solution in a design or sketch of a concrete picture of the proposed solution. In the design, students should be able to explain the parts of the design, the related functions of the parts, the materials used, and how their solution design will be able to answer the problem.

d. *Create*

Next, using the specified materials, students in their groups assemble the product according to their designs/sketches.

e. *Improve* (Uji coba)

At this stage, students will find out whether the solutions they design can answer the problems or challenges given at the beginning.

Research conducted by Mohd Hafiz & Ayop (2019) showed that EDP is effective in STEM learning. The next research was conducted by English & King (2015) on grade 4 students through the engineering problem of redesigning 3D model airplanes using engineering design in STEM learning shows that students are actively involved and can complete the initial design and redesign of model airplanes at various levels of sophistication. This shows that EDP has potential in STEM-based PjBL.Thus, researchers initiated the development of an integrated STEM learning tool using EDP to improve students' critical thinking skills

METHOD

This research is a type of development research used to develop a product. The development model used in this study is the Plomp development model with five phases, namely the Initial Investigation Phase, Design Phase, Realization / Construction Phase, and Test, Evaluation, and Revision Phase. Based on the Plomp development model, the research procedures carried out, namely:

1. Initial Investigation Phase

   In the initial investigation phase, the activities carried out are analyzing the needs for the development of STEM-based mathematics learning media.

2. Design Phase

   The design of teaching devices is carried out by collecting data on learning devices for teaching modules and STEM-based Project Worksheets. The stages in the design phase include:

   a. STEM learning design

      In the STEM learning design, what is done is to determine STEM activities and create an activity framework. The STEM activity developed is the "Daily Food and Drink Planner Project". This activity is carried out by observing the body condition of each student related to weight and height and find daily calories which are the basis for preparing a daily food and drink plan. The calorie context is not widely used even

though the context is interesting and close to students because calories are related to their health conditions (Bilgen et al., 2020).

b. Determining STEM aspects of learning activities

In the activities that have been determined, the STEM aspects can be explained in the following Table 1.

Table 1. STEM Components and Content

No.	Components STEM	Content STEM
1	*Science*	Daily calorie index (BMI, BMR, physical activity).
2	*Technology*	Daily Food and Drink Planner (BMI and BMR calculator, physical activity calculator).
3	*Engineering*	Techniques for making daily food and drink analyze, plan, cut and paste.
4	*Mathematics*	Operations on whole numbers and fractions.

c. Determine EDP (*Engineering Design Process*)

In this activity, EDP carried out in STEM-integrated PjBL learning activities is described in the following Table 2.

Table 2. Aspect EDP

No	Aspect EDP	Descriptions
1	*Ask*	Ask students questions about how to maintain ideal body weight? What do you need to consider in maintaining your ideal body weight?
2	*Imagine*	Ask students to think of a solution to the question. What is the solution and practical way to maintain the ideal body weight by paying attention to the calories in food and drinks.
3	*Plan*	Create the required diagrams or designs and agree on a manufacturing schedule.
4	*Create*	Realize the Daily Food and Drink Planner that has been analyzed and designed.
5	*Improve*	Reflect on the Daily Food and Drink Planner that has been done. Is it functional? Or is there anything that needs to be improved.

3. Realization/Construction Phase

The next stage is to realize or construct learning devices in the form of teaching modules and project worksheet. In addition, this phase also developed research instruments in the form of validation sheets, student questionnaires, and observation sheets.

4. Test, Evaluation and Revision Phase

The researcher will test the results of the device development to the validator to find out whether the teaching module and project worksheet are feasible to be tested on students. After being declared valid by the validator, the product in the form of learning devices will be tested on a limited basis to students.

This research was conducted in one of the junior high schools in seven grade. Data collection techniques in this study used validation sheets, student response sheets, and tests. Data collection also was carried out with two learning trial designs, namely limited trials and class trials. For the limited trial, six students were selected with two students each having high, medium, and low math abilities. As for the class trial, it was conducted with a sample of 27 students. Then, the following data analysis techniques were used.

a. Validity

The research instruments to be validated are teaching modules, project worksheets and are declared valid if they reach a minimum validity criteria ≥ 61.

Table 3. Validity Criteria

Range of Scores (100%)	Category
0 - 20	Invalid
21 – 40	Less Valid
41 – 60	Quite Valid
61 – 80	Valid
81 – 100	Very Valid

b. Practically

Practicality is seen from the student response sheet to the developed project worksheet and the implementation of the learning. The following is a calculation to determine the practicality category.

$$(\%)\ answer\ = \frac{frequency\ of\ answer}{number\ of\ respondents} \times 100\%$$

Table 4. Practically Criteria

Range of Scores (100%)	Category
0 - 20	Not Practical
21 – 40	Less Practical
41 – 60	Quite Practical
61 – 80	Practical
81 – 100	Very Practical

c. Effectiveness

Effectiveness in terms of improving critical thinking skills is known from the students' pre-test and post-test. The results of student work will be tested using N-Gain. The learning device is declared effective if it meets the criteria of medium or high

Table 5. Effectiveness Criteria

Skor gain	Kategori
$g < 0,3$	Rendah
$0,3 \leq g < 0,7$	Sedang
$g \geq 0,7$	Tinggi

RESULTS

The learning device development process refers to Plomp's development model which consists of the Initial Investigation Phase, Design Phase, Realization/Construction Phase, and Test, Evaluation, and Revision Phase (Plomp & Nieveen, 2013) . The following is a project worksheet that has been developed based EDP.

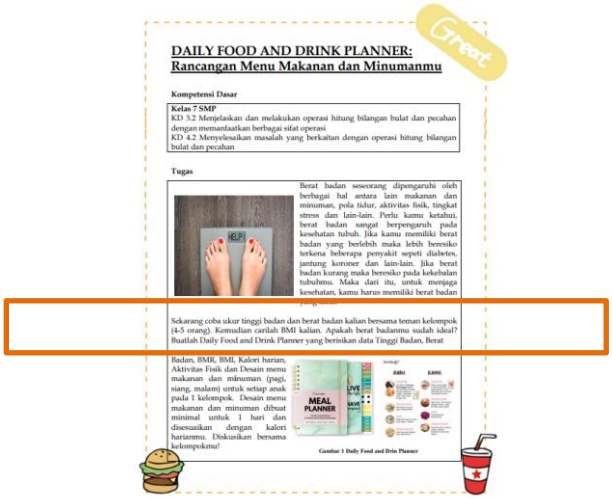


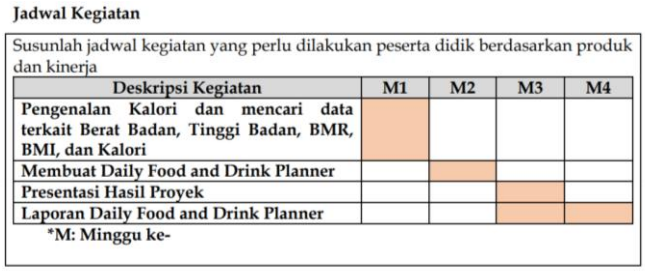
Figure 2. Aspect of Ask

In Figure 2 show that the aspect of ask in project worksheet is related to questions that students need to think about related to the concept of food and beverage menu design which is then related to the problems raised in this project.

Figure 3. Aspect of Imagine

In Figure 3 show that the aspect of imagine in project worksheet is related to the direction of solving or solving the problems raised in STEM learning. In this section, it is explained that to maintain or make ideal weight, you must pay attention to food and beverage

patterns. To design a food and drink pattern in order to maintain ideal weight, a Daily Food and Drink Planner is made that is adjusted to daily calories.



Jadwal Kegiatan

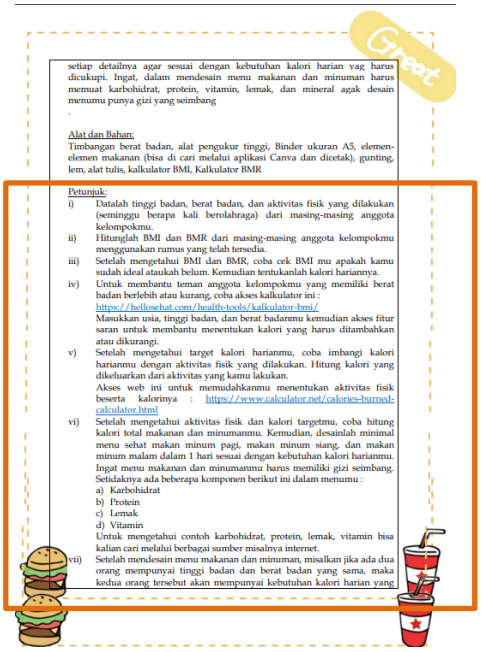
Susunlah jadwal kegiatan yang perlu dilakukan peserta didik berdasarkan produk dan kinerja

Deskripsi Kegiatan	M1	M2	M3	M4
Pengenalan Kalori dan mencari data terkait Berat Badan, Tinggi Badan, BMR, BMI, dan Kalori				
Membuat Daily Food and Drink Planner				
Presentasi Hasil Proyek				
Laporan Daily Food and Drink Planner				

*M: Minggu ke-

Figure 4. Aspect of Plan

In Figure 4 show that the aspect of plan in project worksheet is the preparation of a timeline of activities related to the implementation of the STEM project shown in the Figure 4. This section contains a project implementation plan described according to the activities and deadlines for implementing the activities.



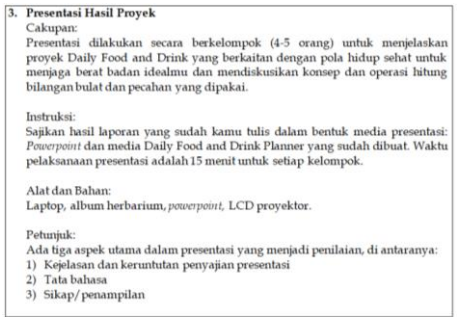
setiap detailnya agar sesuai dengan kebutuhan kalori harian yag harus dicukupi. Ingat, dalam mendesain menu makanan dan minuman harus memuat karbohidrat, protein, vitamin, lemak, dan mineral agak desain menumu punya gizi yang seimbang

Alat dan Bahan:
Timbangan berat badan, alat pengukur tinggi, Binder ukuran A5, elemen-elemen makanan (bisa di cari melalui aplikasi Canva dan dicetak), gunting, lem, alat tulis, kalkulator BMI, Kalkulator BMR

Petunjuk:
i) Datalah tinggi badan, berat badan, dan aktivitas fisik yang dilakukan (seminggu berapa kali berolahraga) dari masing-masing anggota kelompokmu.
ii) Hitunglah BMI dan BMR dari masing-masing anggota kelompokmu menggunakan rumus yang telah tersedia.
iii) Setelah mengetahui BMI dan BMR, coba cek BMI mu apakah kamu sudah ideal ataukah belum. Kemudian tentukanlah kalori hariannya.
iv) Untuk membantu teman anggota kelompokmu yang memiliki berat badan berlebih atau kurang, coba akses kalkulator ini : https://heliosehat.com/health-tools/kalkulator-bmi/ Masukkan usia, tinggi badan, dan berat badanmu kemudian akses fitur saran untuk membantu menentukan kalori yang harus ditambahkan atau dikurangi.
v) Setelah mengetahui target kalori harianmu, coba imbangi kalori harianmu dengan aktivitas fisik yang dilakukan. Hitung kalori yang dikeluarkan dari aktivitas yang kamu lakukan. Akses web ini untuk memudahkanmu menentukan aktivitas fisik beserta kalorinya : https://www.calculator.net/calories-burned-calculator.html
vi) Setelah mengetahui aktivitas fisik dan kalori targetmu, coba hitung kalori total makanan dan minumanmu. Kemudian, desainlah minimal menu sehat makan minum pagi, makan minum siang, dan makan minum malam dalam 1 hari sesuai dengan kebutuhan kalori harianmu. Ingat menu makanan dan minumanmu harus memiliki gizi seimbang. Setidaknya ada beberapa komponen berikut ini dalam menumu :
a) Karbohidrat
b) Protein
c) Lemak
d) Vitamin
Untuk mengetahui contoh karbohidrat, protein, lemak, vitamin bisa kalian cari melalui berbagai sumber misalnya internet.
vii) Setelah mendesain menu makanan dan minuman, misalkan jika ada dua orang mempunyai tinggi badan dan berat badan yang sama, maka kedua orang tersebut akan mempunyai kebutuhan kalori harian yang

Figure 5. Aspect of Create

The aspect of create aspect in project worksheet is found in the activity instructions for making the Daily Food and Drink Planner. This section presents the process or steps of project implementation carried out in the instructions for each activity description.



3. **Presentasi Hasil Proyek**
Cakupan:
Presentasi dilakukan secara berkelompok (4-5 orang) untuk menjelaskan proyek Daily Food and Drink yang berkaitan dengan pola hidup sehat untuk menjaga berat badan idealmu dan mendiskusikan konsep dan operasi hitung bilangan bulat dan pecahan yang dipakai.

Instruksi:
Sajikan hasil laporan yang sudah kamu tulis dalam bentuk media presentasi: *Powerpoint* dan media Daily Food and Drink Planner yang sudah dibuat. Waktu pelaksanaan presentasi adalah 15 menit untuk setiap kelompok.

Alat dan Bahan:
Laptop, album herbarium, *powerpoint*, LCD proyektor.

Petunjuk:
Ada tiga aspek utama dalam presentasi yang menjadi penilaian, di antaranya:
1) Kejelasan dan keruntutan penyajian presentasi
2) Tata bahasa
3) Sikap/penampilan

Figure 6. Aspect of Improve

The aspect of improve in project worksheet is found in the Project Results Presentation activity where in this activity, students and teachers together will carry out learning evaluation activities, namely providing case studies and reflections on projects that have been made. The results of the development of learning devices are reviewed from validity, practicality, and effectiveness. The results are described as follows:

A. Validity

a) Validity of Project Worksheet

Table 6. Project Worksheet Validation Results

No	Assessment Aspect	Expert Assessment		Average	Criteria
		Validator I	Validator II		
1	Content Appropriateness	57,5%	97,5%	77,5%	Valid
2	Language used	100%	90%	95%	Very Valid
3	Presentation	91,6%	91,6%	91,6%	Very Valid
4	Graphics	100%	75%	87,5%	Very Valid
Average				87,9%	Very Valid

The project worksheet validation results have an average of 87.9%. The average is included in the very feasible category by having aspects of content suitability, language used, presentation, and graphics. From these results, there were several inputs from the validators, including adjusting the terms in the teaching modules and project worksheets with the terms in the independent curriculum and correcting improper writing

b) Validity of Teaching Module

Table 7. Teaching Module Validation Results

No	Assessment Aspect	Expert Assessment		Average	Criteria
		Validator I	Validator II		
1	Purpose	50%	55%	52,5%	Quite Valid
2	Content Appropriateness	90%	80%	85%	Very Valid
3	Language Use	100%	100%	100%	Very Valid
4	Time	100%	100%	100%	Very Valid
Average				84,375%	Very Valid

Table 4 shows that validity criteria in the teaching module are obtained from the results of the assessment by the validator with the project worksheet assessment instrument. The teaching module instrument was prepared to look at the objectives, content feasibility, language use, and time of the teaching module. It can be concluded that the STEM-Based Teaching Module can be used in learning Counting Operations of Integers and Fractions.

B. Practicality

a) Students' Response to Project Based Learning "Daily Food and Drink Planner"

Table 8. Practicality of Learning

Aspect	Analysis of Percentage	Category
Project Learning "Daily Food and Drink Planner" can motivate students.	87,5%	Very Practical
"Daily Food and Drink Planner" Project Learning can improve students' understanding.	80%	Practical
Project Learning "Daily Food and Drink Planner" is interesting to do in learning.	82,5%	Very Practical
Project Learning "Daily Food and Drink Planner" helps students to think critically on the subject of Calculation Operations of Integers and Fractions.	82,5%	Very Practical
Project Learning "Daily Food and Drink Planner" helps students in solving daily problems on the subject of Calculation Operations of Integers and Fractions.	80%	Practical
Project Learning "Daily Food and Drink Planner" helps me to communicate my problem-solving ideas on the subject of Counting Operations for Integers and Fractions.	85%	Very Practical
"Daily Food and Drink Planner" Project Learning makes it easier for students to apply the concepts of Integer and Fraction Calculation Operations to real-world contexts.	80%	Practical
Project Learning "Daily Food and Drink Planner" is preferred over just listening to the teacher's explanation	72,5%	Practical
Average	81,25%	Very Practical

b) Students' Response to project worksheet "Daily Food and Drink Planner"

Table 9. Practicality of project worksheet

Aspect	Analysis of Percentage	Category
Project worksheet is easy to use	92,5%	Very Practical
The text on the project worksheet is clearly legible	77,5%	Practical
Project worksheet design is attractive	80%	Practical
The questions on the "Daily Food and Drink Planner" Project Worksheet are difficult to complete.	80%	Practical
The language used in the "Daily Food and Drink Planner" Project Worksheet is easy to understand.	77,5%	Practical
Images that support clarity of activities	75%	Practical
The image print is clearly visible	75%	Practical
Project worksheet makes it easier for students to learn the material of Calculation Operations of Integers and Fractions	90%	Very Practical
Project worksheet makes it easier for students to think critically on the material of Calculation Operations of Integers and Fractions	80%	Practical
Students like the project worksheet when used in learning	72,5%	Practical
The material on project worksheet is presented completely	85%	Practical
Average	80,45%	

Based on the table above, it was found that students' responses to the learning design and project worksheet, the majority of statement items received very practical criteria, which means that STEM learning is practical for improving critical thinking skills.

C. Effectiveness

Before starting learning with PjBL-based learning tools integrated with STEM, students are asked to do a pre-test to find out their understanding of whole number and fraction operation material before learning.

a) Limited test phase

In the limited trial phase, six students consisting of two students each with high, medium, and low mathematics abilities were selected. In the learning design, the six students were divided into two groups of one student each with high, medium, and low math abilities. From the pre-test, it was found that students had low critical thinking skills with an average of 56.6. In the five pre-test questions given, two students with high mathematical understanding fulfilled the critical thinking aspects of

interpretation, analysis, evaluation, and inference. Two students with moderate mathematical ability fulfilled the aspects of interpretation and analysis. Meanwhile, two students with low mathematical ability only fulfill the aspects of interpretation and analysis.

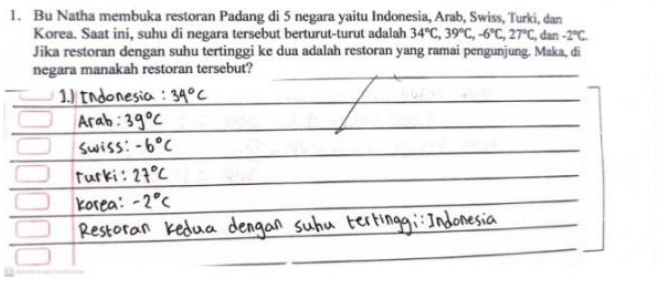


Figure 7. ARR Pre-Test Work

In the work of ARR pre-test questions according to the picture above, it is known that these students only fulfill the aspects of interpretation, analysis, and evaluation because the conclusions given are not correct and do not review.

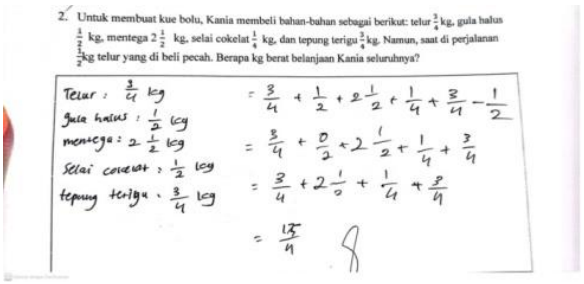


Figure 8. ARR Pre-Test Work

For problem number 2, ARR cannot solve the problem correctly. There is a calculation error in the numerator part of the fraction operation. This is because ARR did not review the solution.

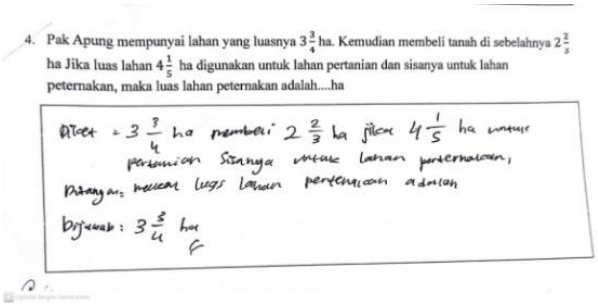


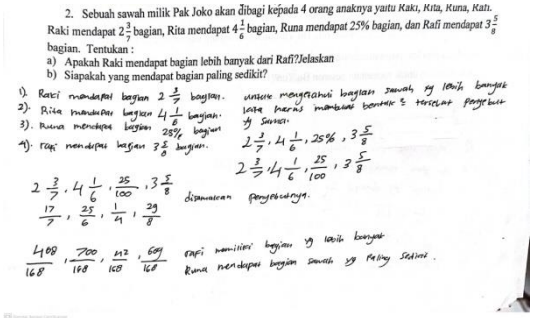
Figure 9. ARR Pre-Test Work

In fact, for question number 4, student ARR did not answer correctly. He stated that he did not understand the meaning of the problem given and had difficulty working on it. This indicates that students do not even fulfill this aspect of the case, it also happens to other students where they also have difficulty working on it.

From the pre-test results, it can be concluded that students' creative thinking skills are still relatively low with the majority of aspects of critical thinking skills that are fulfilled, namely interpretation and analysis. In fact, there were some questions students could not do at all. Then, researchers implemented the learning tools in the STEM learning design in the limited trial group. The learning design was carried out within two weeks with four meetings that had been listed on the Project Worksheet.

After the learning process, the students were given post-test questions to determine their critical thinking skills during the STEM-integrated project-based learning. The post-test results obtained an average of 85.8 which showed an increase of 29.23 points compared to the pre-test. The results of the critical thinking level began to increase, students began to think by writing down the known and questionable information (interpretation), making mathematical models in accordance with the problem (analysis), writing the problem solving appropriately (evaluation), drawing conclusions from the problem (inference), writing the final result correctly along with the reasons (explanation), and reviewing the problem solving (self-regulation).

In working on post-test questions, there was a significant increase in ARR students after doing STEM-integrated PjBL learning activities. If previously the questions were still limited to the aspects of interpretation and analysis, after participating in PjBL STEM learning he managed to solve the problem (evaluation) and inference in the material of Counting Operations of Integers and Fractions.


2. Sebuah sawah milik Pak Joko akan dibagi kepada 4 orang anaknya yaitu Raki, Rita, Runa, Rafi. Raki mendapat $2\frac{3}{7}$ bagian, Rita mendapat $4\frac{1}{6}$ bagian, Runa mendapat 25% bagian, dan Rafi mendapat $3\frac{5}{8}$ bagian. Tentukan :
a) Apakah Raki mendapat bagian lebih banyak dari Rafi?Jelaskan
b) Siapakah yang mendapat bagian paling sedikit?

1). Raki mendapat bagian $2\frac{3}{7}$ bagian. untuk mengetahui bagian sawah yg lebih banyak
2). Rita mendapat bagian $4\frac{1}{6}$ bagian. kita harus membuat bentuk" tersebut penyebut
3). Runa mendapat bagian 25% bagian yg sama.
4). Rafi mendapat bagian $3\frac{5}{8}$ bagian.

$2\frac{3}{7}, 4\frac{1}{6}, 25\%, 3\frac{5}{8}$

$2\frac{3}{7}, 4\frac{1}{6}, \frac{25}{100}, 3\frac{5}{8}$

$2\frac{3}{7}, 4\frac{1}{6}, \frac{25}{100}, 3\frac{5}{8}$ disamakan penyebutnya.

$\frac{17}{7}, \frac{25}{6}, \frac{1}{4}, \frac{29}{8}$

$\frac{408}{168}, \frac{700}{168}, \frac{42}{168}, \frac{609}{168}$ Rafi memiliki bagian yg lebih banyak
Runa mendapat bagian sawah yg paling sedikit.

Figure 10. ARR Pre-Test Work

From the work, ARR used the known information to solve the problems of whole number and Fraction arithmetic operations and answered correctly. He also presented a conclusion that was in accordance with the problem.

Table 10. N-gain calculation results of Limited Trial

Name	Pre-test	Post-test	N-gain
AHF	65	90	0.7142
ARR	50	80	0.6
AKR	55	85	0.6667
BRA	75	95	0.8
IAS	50	85	0.6
MCR	45	80	0.6363
	Average		**0.7512**

N-gain in the calculation is included in the high criteria, which is ≥ 0.7. These results indicate that the PjBL-based learning design integrated with STEM is effective in improving students' critical thinking skills on the material of arithmetic operations of whole numbers and fractions.

b) Class trial phase

After conducting a limited trial phase with six students, the researcher conducted a class trial with 27 students. In the learning design, students were grouped into six groups of 5-6 students. Before that, students were asked to do a pre-test consisting of five questions to measure students' critical thinking skills.

From the pre-test results, it was found that students still had low critical thinking skills. Then, the researcher conducted a two-week class trial related to the STEM-integrated project-based learning design on the material of arithmetic operations of whole numbers and fractions consisting of six meetings. After conducting the class trial, students were again asked to work on post-test questions to determine learning outcomes after conducting project learning activities. From the post-test results, it is known that there is an increase in results after conducting STEM-integrated project-based learning on the material of counting operations of whole numbers and fractions. The average post-test result was 84.1 and the pre-test was 43.7 with an increase of 40.4 points.

After obtaining the pre-test and post-test results, the next step is to calculate the N-gain to determine the effectiveness of this learning. Based on each calculation, the N-gain results ranged from 0.5 to 0.9 for 27 students. From the data, the final N-gain is 0.7091 which is included in the high criteria, which is ≥ 0.7. These results indicate that the PjBL-based learning design integrated with STEM is effective in improving students' critical thinking skills on the material of arithmetic operations of whole numbers and fractions.

DISCUSSION

Based on the results of the study, it is found that PjBL-based learning tools integrated with STEM can improve students' critical thinking skills on the material of Calculating Operations of Integers and Fractions because they have met the criteria of validity, effectiveness, and practicality. The following is a more complete discussion of the criteria for validity, effectiveness, and practicality

Validity

The validity criteria are obtained by validating learning tools in the form of teaching modules and project worksheets to validators. Based on the results of the validation filled out by media experts, it shows that the teaching module to be developed by researchers is included in the very feasible category with an average score of 84.375%. Then, the recapitulation of the validation sheet assessment for the project worksheet shows that the integration of STEM in the project worksheet in the form of "Daily Food and Drink" in class VII Mathematics lessons gets an average score of 87.9% with a very feasible category. So it can be concluded that the STEM integrated learning device is very feasible to use. This is in accordance with Ayuningsih et al., (2022) and Oktadila et al., (2022) that the development of Mathematics learning tools with the STEM-integrated Project Based Learning (PjBL) model is feasible and good for testing to users in the learning process.

Practicality

Learning tools are assessed as practical by collecting data based on student responses to project learning and learning tools used. The results showed that the implementation of project learning. Then, the project worksheet developed by the researcher is also included in the practical category with an average score of 80.45%. This is in accordance with Purwaningsih et al. (2020) that the development of Mathematics learning tools with the STEM-integrated Project Based Learning (PjBL) model is practically used in the learning process. In addition, research from Chen & Yang (2019), Han et al. (2014), Lee et al., (2019) showed that learning with STEM-based PjBl makes students more active and understand the concepts properly. Learning activities in PjBL are developed with the aim that students are actively involved in iterative learning designs (discussing and getting feedback), bridging so that projects can help solve problems, and stimulating social and knowledge construction with contextual learning (Beneroso & Robinson, 2021; Sagala et al., 2020; Winarni et al., 2022). In addition, the results of this study are also in line with the research of Lin et al. (2021) that the use of the EDP approach in STEM-based learning can clearly show the steps that students must take in the learning process, generalize alternative solutions to specific problems, so that

students can integrate knowledge in solving problems. Thus, STEM-PjBL-based learning tools are practical to use and learning using STEM-PjBL makes students more active.

Effectiveness

STEM-integrated project-based learning in the form of teaching modules and project worksheets "Daily Food and Drink Planner" can have an effect on improving students' mathematical critical thinking skills from the N-Gain test results of the pre-test and post-test. The learning tools are also effectively implemented in learning because it is evident from the increase in student learning outcomes in the material of arithmetic operations of whole numbers and fractions. Students who previously only fulfilled critical thinking in the aspects of interpretation and analysis could fulfill the aspects of critical thinking in the form of interpretation, analysis, evaluation, inference, explanation, and self-regulation after following this learning. This is supported by the results of research by Priatna et al., (2019) that learning with PjBL integrated with STEM allows students to exchange information, select information, and decide on actions to solve problems so as to train students' critical thinking skills in solving problems. In addition, the research results are in line with Fitriani & Kowiyah (2022) , Kellems et al. (2020), and Suciati et al. (2019) that learning using media is significantly better than conventional learning on the material of counting operations of whole numbers and fractions to improve students' critical thinking skills. So it can be concluded that STEM-integrated project-based learning can improve critical thinking skills and support each other's theories or previous research.

CONCLUSION

Based on the research that has been conducted, it can be concluded that the STEM-integrated PjBL learning media obtained have been validated with very valid criteria for four categories each in the project worksheet and teaching modules. STEM-integrated PjBL learning media in terms of pre-test and post-test implementation obtained an average N-gain of 0.7091 which states that this learning tool is effectively implemented to improve critical thinking skills. PjBL learning media integrated with STEM in terms of student response questionnaires obtained very practical criteria to be implemented.

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