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Development of PjBL-STEM Learning E-Modules with Jigsaw Strategy on Motion and Force Materials to Increase Student's Creativity and Communication Skills Class VII

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Abstract: This research aims to create a PjBL-STEM-based learning e-module that can improve student creativity and communication skills on motion and force materials. This research method uses Research and Development (R&D), ADDIE design which consists of 5 stages (Analiysis, Design, Development, Implementation, Evaluation). Class VII students were involved as research subjects taken with purposive sampling technique. Research data were collected through creativity test, performance test, student response questionnaire and observation sheet. Data processing techniques for the improvement of creative thinking and communication skills used paired sample t-test and then N-Gain test. The results of the analysis showed that after using the PjBL-STEM-based learning e-module there was a significant increase in creative thinking with an N-Gain value of 60% in the medium category and an N- Gain value of 61% for improving communication skills. Student testing of creative products based on display criteria, functional prototypes and technological accommodations fall into the good category. In addition, students gave a positive response to the learning e-module of 47.79% for very good criteria and 45.6% for good criteria. Thus, the PjBL-STEM-based learning e-module with Jigsaw strategy can be used in science learning in grade VII to improve students' creativity and communication skills.

Keywords: Communication skills; Creativity; Learning e-module development; PjBL-STEM; 21st century skills

Introduction

Education in Indonesia still faces great challenges in producing a superior generation that is ready to compete in the global era. To improve the quality of education, the application of technology and distance learning has begun. 21st century learning emphasizes critical thinking, creativity and collaboration, which are essential in facing the Industrial Revolution 4.0. The low creativity of students is often caused by the lack of learning targets and difficulties in the material, especially in science lessons. Teachers need to create a learning environment that stimulates new concepts to enhance creativity (Yusmar et al., 2023).

Innovative learning models, such as Project Based Learning (PjBL), are expected to help students develop creative thinking and problem-solving skills (Adhelacahya et al., 2023; Afriana et al., 2016). Research shows that PjBL is able to improve students' creativity by involving them in the learning process actively (Nababan et al., 2023; Nugraha et al., 2023). This model gives students the opportunity to explore and integrate new knowledge through real-life experiences, rather than just listening to the teacher.

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The application of STEM (Science, Technology, Engineering and Mathematics) approach in PjBL is also proven effective in improving students' creativity, communication and collaboration skills (Davidi et al., 2021). Several studies have shown that the combination of PjBL and the STEM approach can improve the learning process and student outcomes (Akrim, 2022; Ningrum et al., 2021). By using appropriate methods, it is hoped that education in Indonesia can be more optimal, preparing future generations to face global challenges and technological developments (Amin et al., 2022; Ayuningsih et al., 2022).

Effective PjBL-STEM learning requires the right strategy, and one that is used is the Jigsaw strategy (Hidayah, 2023; Kartikasari et al., 2019). According to Rahmi et al. (2023), Jigsaw is a group-based learning method that can be applied to various topics. The aim is to develop students' expertise through collaboration (Cholis et al., 2020; Potimbang, 2018; Rahmi et al., 2023; Sholihah et al., 2016; Solissa et al., 2023; Suryono et al., 2023). The model is divided into home groups and expert groups; students learn in expert groups and then share knowledge in home groups. The success of Jigsaw depends on students' reliance on sharing information, which promotes cooperation and deep understanding.

Many studies have shown that innovative learning enhances higher order skills, creativity and communication, which are 21st century skills. Communication and creativity can be enhanced through the final step in STEM, which is communicating the results of ideas, both oral and written (Fitriyah et al., 2021; Izzati et al., 2019). In addition, students' independent learning requires facilitation, including teaching modules that attract students' interest (Heliawati et al., 2020; Kartini, 2020). Based on observations, students prefer electronic books because of the ease of access. E-Modules are very relevant in the current technological context (Inayah et al., 2024; Jusup et al., 2021; Mawaddah, 2023; Megawati et al., 2022; Meidita et al., 2021). One of the e-module materials that can be raised in PjBL-STEM-Jigsaw-based learning is motion and force material, such as STEM-based car manufacturing. This research is entitled 'Development of PjBL-STEM-Jigsaw Learning E-Modules to Improve Creativity and Communication Skills of Grade VII Students on Motion and Force Material.

This study provides empirical evidence of the effectiveness of PjBL-STEM-based e-learning modules in improving students' problem-solving, critical thinking, and communication skills (Lasmiyati et al., 2014). This research also offers innovation in learning module development by integrating the PjBL-STEM approach into an electronic format, so as to increase student engagement and develop 21st century skills effectively.

Method

The research method used in the development of learning e-modules is Research and Development (R&D) with ADDIE design (Analysis, Design, Development, Implementation, and Evaluation) (Pitriani et al., 2021; Rafles et al., 2023; Ranuharja et al., 2021). The research subjects were class VII junior high school students totaling 36 students, the participants were taken by purposive sampling technique at one school in Bogor Regency. The research instruments used in this study include validation sheets, student response questionnaires, creativity question instruments and student presentation observation performance assessment sheets.

Analysis Stage

At the analysis stage, it is carried out by analysing the problems that exist in the school environment by conducting interviews with principals, teachers and students to see the level of student creativity as a guide in developing learning e-modules. Examining STEM Novelty on creativity in schools and using bibliometric studies using Vosviewer to see the gap in the distribution map of research objects. Conduct a creativity test to select the treatment to be used in the research.

Design Stage

In the design stage, designing story boards and visual design of learning e-modules that meet STEM criteria that accommodate creativity components.

Development Stage

The development stage begins with developing teaching materials and assessing the feasibility of learning e-modules by several teams of experts.

Implementation Stage

The implementation stage is used to implement STEM-based learning e-modules in learning in education units.

Evaluation Stage

The research subject were junior high school seventh grade students total 36 students, the participants were taken by purposive sampling technique.

Data Collection and Data Analysis

The research instruments used in this study include validation sheets, student response questionnaire sheets and creativity question instruments. The data analysis

technique used in this research is qualitative data analysis technique.

Research Instruments and Data Analysis Techniques

Research Instruments

The instruments in the research of developing STEM-based learning e-modules on force and motion material to improve creativity and communication skills are described in Table 1.

Table 1. Researchs Instruments

Data managed	Data collection techniques	Research instruments	Data source	Data processing
Needs analysis of teaching materials at school	Likert	Questionnaires using the Gform app	Teacher	GForm processing by looking at the percentage of answers
Student creativity	Creative thinking question rubric; Product creativity	PG questions that include creative thinking indicators; Product Scoring Rubric	Student	SPSS
Communication skills student	Performance Test	Rubric for Performance Test Work	Student	SPSS
Feasibility of STEM-based teaching modules: Presentation, Content, Language and Readability, STEM	Likert	Questionnaires that include STEM components in the teaching module	Teacher Validator	CVI CVR

Data Analysis

Validation Test

To test validation, Content Validity Ratio (CVR) and Content Validity Index (CVI) were used. CVR is used to calculate the percentage of items that are considered appropriate by experts, while to calculate the percentage of items that are considered relevant for each expert and then take the average percentage among experts using CVI. The results of CVR and CVI are used to determine the content validity of the teaching materials developed. The steps to analyse questionnaire data based on CVR.

Questionnaire data is converted into numeric form. Giving a certain score to each answer choice with the following conditions.

Table 2. Interpretation of Questionnaire Data

Validation result	Score
Yes	1
No	0

Calculate CVR with the formula:

$$\mathrm{CVR} = \left(\frac{\mathrm{ne} - \mathrm{N}}{2}\right) \Big/ \left(\frac{\mathrm{N}}{2}\right) \quad (1)$$

Description:

ne = Number of validators who answered 'Yes'

N = Total validators

Calculating the Content Validity Index (CVI) with the formula:

$$\mathrm{CVI} = \frac{\mathrm{CVR}}{\text{number of sub questions}} \quad (2)$$

Categories of CVR and CVI calculation results. The results of the CVR and CVI calculations are in the form of a 0-1 number ratio. This number can be categorized as follows.

Table 3. CVI Categorization

Range value	Category
0 – 0.33	not suitable
0.33 – 0.67	suitable
0.68 - 1	very suitable

1) 0–0.33 = not suitable
2) 0.33–0.67 = suitable
3) 0.68–1 = very suitable

Test of attractiveness, convenience and usefulness. To analyse the test of attractiveness, convenience and usefulness using a questionnaire instrument with four answer choices intended for students. The assessment score of each answer choice can be seen in Table 4.

Table 4. Criteria for Rating Answer Options

Attractiveness test	Ease test	Usability Test	Score
Very interesting	Very easy	Very useful	4
interesting	Easy	Helpful	3
Less interesting	Less easy	Less useful	2
Not interesting	Not easy	Not useful	1

The instrument used has four answer choices. The total assessment score was sought using the Formula 3.

$$\text{Total assessment score} = \frac{\text{number of scores}}{\text{max score}} \times 4 \quad (3)$$

The results of the assessment score were sought averaged from a number of trial samples and converted to assessment statements to determine the quality and level of attractiveness, convenience, and usefulness of

the products developed according to respondents. The conversion of scores into assessment statements can be seen in Table 5.

Table 5. Conversion of Scores into Assessment Statements

Score	Average score	Eligibility answer options
4	3.26< x ≤4.00	Very good
3	2.51< x ≤3.26	Good
2	1.76< x ≤2.51	Less good
1	1.00< x ≤1.76	Not good

Based on the table above, the researcher's development product will be completed if the assessment of the design of the STEM-based learning module has met the terms and conditions or has reached the 'feasible' criteria.

Effectiveness Test

The development of data analysis to test the effectiveness of the product was carried out by giving a post-test to students during the product trial. Then the post-test value is analysed to determine the effectiveness of the product in the form of teaching materials developed. Data analysis to test the effectiveness of teaching materials used Learning Objective Completeness Criteria (KKTP) in accordance with the research site at SMPN 1 Klapanunggal, Bogor Regency.

The analysis was carried out simply with the following stages: Tabulation of learning outcome test data.

Table 6. Transforming Learning Outcome Test Data with Learning Effectiveness Tables

% Completeness (p)	Qualification
0 ≤ p ≤ 41	Very Low
41 ≤ p ≤ 56	Low
56 ≤ p ≤ 66	Fair
66 ≤ p ≤ 80	High
80 ≤ p ≤ 100	Very High

Description:
P = Percentage of student completeness

$$= {}^{Pa}/_{Pb}\ x\ 100\% \quad (4)$$

Pa = number of students completed
Pb = Total number of students

Result and Discussion

The results of this study produced a PjBL-STEM-based flipbook-shaped science learning e-module related to motion and force, which aims to improve the creativity and communication skills of junior high school students in Grade VII. This e-module is equipped with images, animated videos, and digital comprehension tests to facilitate student understanding. This development is driven by the lack of technology utilization in learning. It is expected that teachers can be more effective in teaching, while students can learn independently, so that their creativity and communication skills increase (Kharisma, 2020).

The analysis stage was conducted by identifying existing problems in schools through interviews with principals, teachers, and students to evaluate students' creativity and communication skills as the basis for developing teaching modules. The research also included a study of the influence of STEM Novelty on creativity and communication skills in the school environment, as well as mapping using bibliometric studies through Vosviewer.

In the initial analysis, fundamental problems related to science teaching materials were found, namely the absence of teaching materials that integrate PjBL-STEM learning with easily accessible flipbook technology. Furthermore, student analysis was conducted to evaluate the advantages and challenges of the available teaching materials. Students have used textbooks from the government; however, there are no PjBL-STEM-based learning e-modules.

Analysis was also conducted on the characteristics of teaching materials that are still conventional, curriculum that is adjusted to learning independence, and materials related to student needs. The average of students' final grades shows that there is a need to develop e-modules to improve students' creativity and communication skills.

Concept analysis leads to the preparation of learning steps, including objectives, material presentation, and STEM practicum activities. While in task analysis, skills relevant to STEM learning were identified to include understanding of motion, speed and force.

Finally, learning objectives were formulated in accordance with the independent curriculum learning outcomes, where students are expected to be able to measure physical aspects and utilise a variety of movements and styles. All these stages focus on developing learning materials that can improve students' creativity and communication skills.

The design stage of the PjBL-STEM-based learning e-module for grade VII junior high school starts from the preliminary test findings. E-modules in the form of flipbooks with comprehensive features are designed to be easily accessible and interesting, and serve to train students' creativity and communication (Mardiana et al., 2022; Taufiqqurrahman et al., 2022). Students can access the e-module via mobile phones or internet-connected computers, increasing the flexibility of learning. The design process involved four main steps: test

development, media selection, format selection, and initial design. Test development includes multiple-choice questions that are in line with the measurement indicators. The learning media used was an e-module on motion and force. The format developed is portable (PDF) for easy access. Draft I of the presentation of materials and learning activities was prepared through an experiment to make a toy car. The development stage includes making draft I and evaluation by experts.

Expert Judgment, validation was conducted by four experts, followed by improvements based on the feedback received, resulting in draft II. This process aims to ensure the quality of teaching materials before they are presented to students. Data from the validation results are presented in an analysis table to support further development.

The validation of the learning e-modules involved four validators: one lecturer of material experts, one lecturer of media experts, and two teachers of material experts. The purpose of validation is to identify the strengths and weaknesses of the science e-module that has been developed. The analysis results showed an average percentage value of feasibility of 88.06%, in accordance with the opinion of Meidita et al. (2021) regarding the importance of feasibility elements. In preparing e-modules, there are five important scopes: introduction, learning activities, evaluation, glossary, and bibliography. The material expert provided input that was implemented in the revision.

Validation of the learning e-module by 8 science teachers assessed aspects of presentation, content, language, readability, and STEM. Five teachers provided assessments to determine the Content Validity Ratio (CVR) and Content Validity Index (CVI). CVI, which is the average CVR value for items answered 'Yes', indicates the validity of the e-module content. The validation results can be seen in Table 7.

Table 7. Feasibility Learning E-modules by Expert Judgment

Aspect	Average value	Percentage	Criteria
Presentation	27	96.4	Very feasible
Material content	23.5	97.9	Very feasible
Language and readability	24	100	Very feasible
STEM	16	100	Very feasible
Average		98.57	Very feasible

The advantages of the developed learning e-module are STEM-based projects, video features and quiz links for practice questions. The implementation phase of the PjBL-based STEM project was conducted offline with learning outcomes in 10 lesson hours. There are four important stages that have been 100% implemented, namely problem launching, knowledge building, problem solving, and product presentation with evaluation (Lugiati, 2020). The 'Activity 4.2' project challenged students to create toy cars, which stimulated their creativity and communication skills. Each group functioned as a team of experts in science, technology, engineering and maths, sharing their respective expertise. The results of the activities are presented in Table 8, showing the successful implementation of the STEM project.

Figure 1. Display of PjBL-STEM-based learning e-module

Table 8. STEM Project Implementation Stages

Meeting	STEM Stages	Description
1	Launching the problem	Completed 100%
2	Building of knowledge	Completed 100%
3	Solving problem	Completed 100%
4	Presenting product and evaluation	Completed 100%

Table 8 shows that the STEM stage was well implemented, with students completing worksheets that simplified concepts and discussion of reflection questions. Activity 4.2 required students to present the results of their project, followed by feedback from other groups.

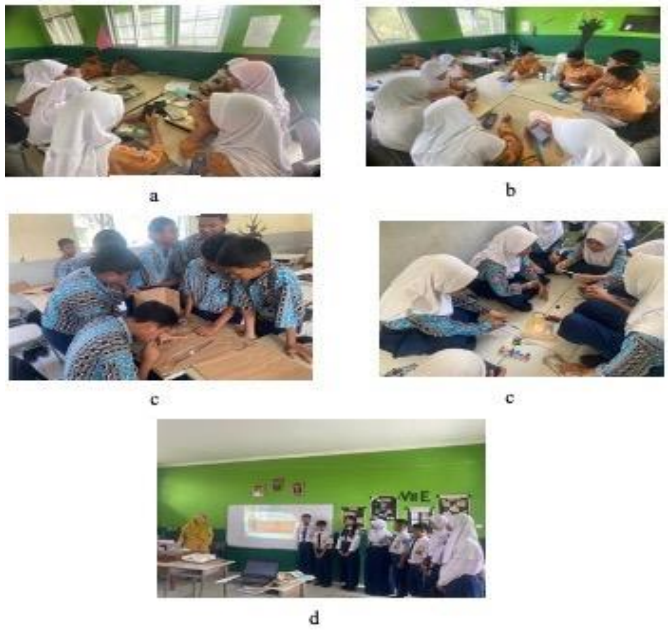

Figure 2. Stages of PjBL-STEM (a) Launching the problem, (b) Building of knowledge, (c) Solving problem, (d) Presenting product and evaluation

Figure 3. STEM project results made by students

The resulting toy-car product can be seen in Figure 3, where students are divided into 4 groups of 9 people each, following the steps in 'Let's Practice'. In addition, students also made a making video that will be uploaded to YouTube. The evaluation stage assesses the quality of the product and the learning process, including testing the e-module to improve students' creativity and communication skills. The development of PjBL-STEM-based learning e-modules has gone through a validation process and limited product tests to assess its effectiveness in improving students' creative thinking skills. The trial was conducted on 36 junior high school students in grade VII, with the average creative thinking N-Gain reaching 0.604, indicating a moderate category. The students' average score increased from 51.25 to 80.69 after using the e-module, indicating success in improving students' creativity.

The 'Let's Practice' practice in the e-module proved to be effective in stimulating students' creativity as well as helping in solving problems related to motion and force materials. Pretest and posttest data were analyzed using SPSS, which showed that the data were normally distributed. The homogeneity test showed that the data variances were not equal, so it was continued with a paired t-test. The test results showed a t-count of -11.601 with a significance value of 0.003, which means there is a significant difference between the pretest and posttest scores.

This finding confirms that the PjBL-STEM-based learning e-module is effective in improving students' creative thinking and creating an interactive learning environment. Creative thinking skills that are trained through the 'Let's Do It' activity can have a positive impact on learning (Yusuf et al., 2020). The N-Gain value data for each creative thinking indicator confirms the significant impact of the e-module implementation.

Table 9 shows the improvement of students' creative thinking skills after learning using e-modules based on PjBL-STEM, with moderate indicator categories (Oktavia et al., 2022). The lowest N-Gain value was found in originality (0.512), while elaboration achieved the highest N-Gain (0.698). This shows that the material in the e-module is presented completely, allowing students to ask questions and answers from different perspectives on motion and force material, in line with Fatma (2021) opinion regarding the importance of elaboration ability. However, the low originality ability indicates that students have not created new ideas. Although the e-module content is complete, the short learning duration hinders deep understanding. Fluency and flexibility showed effective N-Gain, especially through PjBL-STEM activities. Furthermore, the e-module development continued with limited product testing, resulting in an average assessment score of the good category, with the appearance and functionality of the prototype getting a score of 78, while technological accommodation obtained the lowest score (75), reflecting the limited understanding of grade VII students towards technology.

Table 9. N-Gain Results for Each Creative Thinking Indicator

Creative Thinking Indicator	Problem No	Pretest average	Posttest average	N-Gain
Fluency	1	52.32	79.19	0.563
	10			
	11			
	12			
	16			
	20			
	2			
	4			
Flexibility	6	45.56	82.22	0.673
	9			
	19			
	3			
	5			
Originality	7	60.18	80.56	0.512
	8			
	14			
	17			
	13			
Elaboration	15	41.67	82.41	0.698
	8			

The implementation of PjBL-STEM-based learning e-modules not only focuses on student creativity, but also communication skills (Nurhidayat et al., 2021). STEM-based learning encourages students to produce products that can be presented, so their communication skills can be measured. The analysis showed an increase in posttest scores compared to the pretest, with an N-Gain value of 0.61 which indicates a moderate category. This indicates that the e-module is effective in improving students' communication skills. Activities in the e-module, such as 'Activity 4.2', can stimulate students to present project results, contributing to the improvement of communication skills.

To ensure the significance of the results, normality and homogeneity tests were conducted using SPSS. The normality test results showed that the data were normally distributed with Sig values greater than 0.05. However, the homogeneity test showed the variance

was not homogeneous. Based on these results, a paired t-test was conducted, with a t-count value of -14.262 and a sig value of 0.001, which is smaller than 0.05. This signifies that there is a significant difference between the pretest and posttest scores, which supports previous research that shows the Jigsaw method can develop students' communication skills. Thus, the PjBL-STEM e-module plays an important role in improving students' communication skills, especially in motion and force materials.

Students' responses to the PjBL-STEM-based learning e-module showed positive results. Based on data from 36 students who rated 18 statements using a Likert scale of 1 to 4, there are several key findings. First, the function indicator has a very good average score of 49.22 and good 46.72, which indicates the e-module is effective in improving understanding of the concept of motion and force. Secondly, the quality indicator with an excellent average of 42.86 and good 50.88 indicates that the module presentation, language, and video tutorials are very helpful in the learning process. Third, the function indicator also shows an excellent score of 51.43 which reflects the attractiveness and increased enthusiasm for student learning. Finally, the display indicator with an average score of 49.12 shows that the design, colour composition, and illustrations on the e-module attract students, thus supporting better learning.

Result of research is in line with the reserach reported by Meidita et al. (2021), Fatma (2021), and Ayuningsih et al. (2022). It was stated that jigsaw-based PjBL STEM learning can improve students' creativity and communication skills (Safriana et al., 2022; Siswanto, 2018; Sutrisna et al., 2020; Triastuti, 2020; Widana et al., 2021; Zahirah et al., 2023).

Conclusion

The development of PjBL-STEM-based learning e-modules to improve students' creativity and communication skills is an innovation that is applied to science learning, especially Motion and Force materials. The results of the development of learning e-modules include PjBL-STEM-based learning e-modules have characteristics that have fulfilled aspects or criteria for learning modules such as: language feasibility, presentation feasibility, content feasibility, design, appearance and accommodate pedagogical aspects. The learning e-module materials developed are in accordance with curriculum needs and student characteristics. This learning e-module technology is to increase students' interest in understanding the material. The PjBL-STEM-based learning e-module is also equipped with STEM project making activities and practice questions so that it not only trains students' creativity and communication skills. Jigsaw-based PjBL-STEM-based e-modules show good feasibility from the aspects of presentation feasibility, content feasibility and language feasibility. The validation results of the three aspects have very feasible criteria. The PjBL-STEM-based learning e-module effectively improves students' creative thinking and communication skills with an average N-Gain value of 0.60 and 0.61 both in the medium category. PjBL-STEM based learning e-modules are well received by students, interactivity, aesthetic design and comprehensible content seem to increase understanding and interest in motion and force materials.

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Author Contributions

Conceptualization, methodology, A.A. and A.P.; software, A.A.; validation, A.P. and I.P.; formal analysis, investigation, resources, writing-original draft preparation, visualization, project administration, funding acquisition, A.A.; data curation, A.A., I.P., and A.P.; writing-review and editing, I.P. and A.P.; supervision, A.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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