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The Implementation of Project-Based Learning (PBL) with ADDIE Model to Improve Students' Creative Thinking Ability

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Abstract

Creative thinking ability is one of the thinking concepts used to find ideas that people are starting to be interested in. Creative thinking can be used as a relevant tool in building innovation and as a method for building innovation models, one of which is a learning model. The project-based learning model is a solution that influences students' activeness and creativity in learning. The purpose of this research is to apply a project-based learning model that is expected to improve students' creative thinking abilities on creative product and entrepreneurship subjects on the Internet of Things material. The development model used in this research is ADDIE (Analyze, Design, Development, Implementation, Evaluation) with a One Group Pretest-Posttest research design. Based on the research results, there are several conclusions, including the following: 1) Students' creative thinking abilities by implementing the project-based learning model can be seen from the average pretest score of 38.24 and the average posttest score of 70.15. 2) The normalized gain test results obtained a mean of 0.517 with the "Medium" criteria, which means there is a difference in creative thinking abilities after the treatment process. There are four aspects given when giving the TAM questionnaire to students, namely the user's perception of usefulness with a percentage of 86.67%, the user's perception of ease of use with a percentage of 84.71%, attitude towards use with a percentage of 83.53 and attention. With a percentage of 86.27%, and the average obtained for the four aspects was 85.29% in the "Very Good" category.

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INTRODUCTION

Creativity is a complicated concept that can be conveyed in a variety of ways, including verbal [1], musical [2], mathematical [3], spatial [4], kinesthetic [5], interpersonal [6], and possibly intrapersonal intelligence. Torrance [7] described creativity as the process of recognizing problems, deficiencies, or gaps in knowledge, identifying challenges, searching for solutions, forming and testing hypotheses, and finally communicating the results. When a person possesses creative thinking abilities, their creativity will naturally emerge. Creative thinking is demonstrated through the discovery of new ideas, original inventions, and the development of innovative solutions to challenges. It involves generating diverse and unique concepts [8]. Critical thinking is a crucial skill that schools should impart to students, as it becomes a fundamental learning objective across all disciplines [9]. In today's world, where global competition is intense, creative thinking is vital due to the increasing complexity of modern life [10], [11], [12]. It requires activity in both hemispheres of the brain [1], balancing intuition with reasoning. The ability to think creatively enables individuals to approach real-world problems from various perspectives. Understanding the importance of creative thinking, the authors aim to clarify its significance.

Students who think creatively are more likely to gain deep knowledge through effective learning [13], leading to the generation of new ideas, knowledge, or products. Figures like Bill Gates, Steve Jobs, and Mark Zuckerberg exemplify this, as they introduced groundbreaking ideas and founded Microsoft, the iPhone, and Facebook, respectively. Creativity can also offer novel solutions to problems, as seen with Elon Musk, who revolutionized money circulation with PayPal, demonstrating that innovative methods can surpass traditional ones.

Project-based learning (PBL) is an inquiry-driven instructional approach where students engage in meaningful projects and create real-world products [14], [15]. Krajcik and Shin [15] identified six key elements of PBL: a central question, focus on learning goals, active participation in educational activities, student collaboration, use of scaffolding technologies, and the creation of tangible outcomes. Review studies, such as Helle et al. [16], have largely examined PBL in higher education, discussing its practice and impact on student learning. Ralph [17] reviewed studies on PBL in STEM education and found that it enhances both knowledge and skills, with students feeling encouraged to collaborate, though some reported a lack of motivation for teamwork. PBL is often seen as an alternative to traditional, teacher-led education. According to Chen and Yong [18], it has a moderate to large positive impact on academic achievement compared to traditional methods. However, it's important to note that PBL cannot fully replace traditional education. Through PBL, students work to solve and evaluate problems [19], present their findings, and acquire essential life knowledge and skills [18]. It emphasizes student autonomy, cooperation, communication, and reflection in real-world contexts [20]. Specifically, PBL allows students to explore solutions, ask questions, debate ideas, design plans, and communicate with others [21]. It fosters collaboration among students, with teachers serving as guides during the projects [22]. PBL is effective in developing 21st-century skills, such as critical thinking, problem-solving, interpersonal communication, information and media literacy, collaboration, leadership, creative problem-solving, flexibility, and originality [23], [24]. It also enhances students' abilities, skills, attitudes, and values necessary to navigate global challenges in a rapidly changing economy [25]. Students must plan and evaluate the completion of their tasks [26], which helps them deepen and broaden their knowledge, integrate it into a cohesive system, and realize its meaning and purpose. PBL is recognized as a valuable tool for engaging students, interestingly presenting educational content, acquiring new knowledge, and developing the personal qualities necessary for collaboration and problem-solving [27], [28]. It creates a strong link between student engagement in projects and their learning outcomes [29].

METHODS

This research uses the Research & Development (R&D) method. Educational research and development (R& D) is used to develop and validate educational products. The steps of this process are usually referred to as the R&D cycle, which consists of studying research findings pertinent to the product to be developed, developing the product based on the findings, field testing it in the setting where it will be used eventually, and revising it to correct the deficiencies found in the field testing stage. This indicates that the product meets its behaviorally defined objectives [30]. The research design used was pre-experimental, which is One-Group Pretest-Posttest. The experimental class was given an initial test (pretest) before carrying out the learning and given a final test (posttest) after being given treatment. The results of pre-experimental research are dependent variables, not influenced by independent variables. So, this stage will focus on treating one group. The research development model used is ADDIE (Analyze-Design-Develop-Implementation-Evaluate). Figure 1 is the development flow using the ADDIE model according to Branch [31].

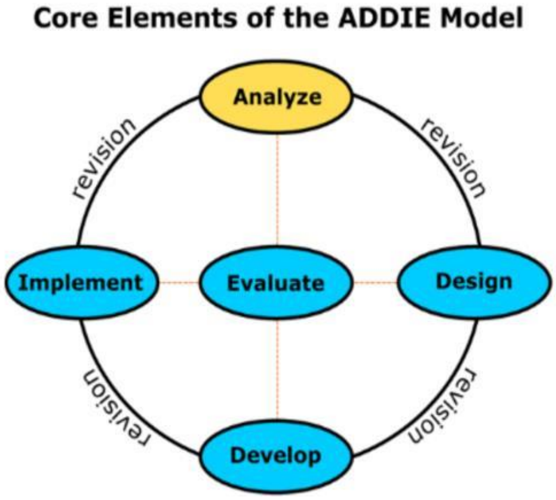

Figure 1. ADDIE Development Model

The following are the stages of research development using the ADDIE model:

Analyze

The analysis stage aims to find information related to needs that will be used in developing teaching materials. This stage is done by searching for literature sources related to the topic taken and conducting interviews with teachers of related subjects to obtain valid data.

Design

In the design stage, start designing the product that will be developed based on the results of the analysis stage. After analyzing the literature and interviews, then create plans such as product designs, teaching modules, questions, and questionnaires according to the data obtained. The stages carried out are creating learning media specifications, creating material content to be delivered, creating question instruments and evaluations, and creating a flowchart.

Develop

The next stage is the development stage of the product design that has been created. This stage aims to develop a learning media product for the research. The media is based on the flow diagram that has been created. After the media is built, validation will be carried out, and the results will be tested by experts. If there are errors or deficiencies in the media, improvements will be made before being tested on students. The media will be tested by two media and material experts who are Lecturers in Computer Science Education at the Indonesian Education University (UPI). In conducting the media expert test, we use the Learning Object Review Instrument (LORI) instrument, which consists of nine aspects which are divided into two categories, namely Media Validation (Presentation Design, Interaction Usability, Accessibility, Reusability, Standard Compliance) and Material Validation (Content Quality, Learning Goal Alignment, Feedback and Adaptation, and Motivation). LORI users will give a score for each dimension based on a certain scale (eg 1-5 or 1-7), where a higher score indicates better quality. Evaluators can also provide qualitative comments to provide more in-depth feedback on the advantages and disadvantages of the learning media.

Implementation

Next is the implementation stage; in the research conducted, the researchers began to apply the media developed to students. Before applying the media, researchers will give a pretest related to subjects to determine students' initial abilities. Then, students are given treatment, namely, carrying out project-based tasks. Next, students will be given post-test questions to find out the results of project-based learning and make comparisons with previous data.

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Evaluate

The final stage is the evaluation stage, where we analyze the data that has been obtained during the research. In addition, researchers also collect learning media assessment data from students. The overall data will be adjusted to the formulation of the problem that has been explained previously to find out whether the learning media is appropriate or not based on the formulation. The results at the evaluation stage will be developed into valid data so that conclusions from the study can be drawn. Furthermore, the data processing process is carried out on the pretest and posttest results at the data analysis stage. The analysis technique used is the n-gain test (normalized gain), which aims to measure the increase in student abilities before and after treatment. The n-gain test is useful for seeing how much increase (gain) in learning outcomes after the learning process is applied. This metric is normalized to consider the potential for improvement available based on the maximum possible score achieved. A formula was used according to Hake [32] to calculate the n-gain value, which is as follows:

$$g = \frac{T^2 - T^1}{T^3 - T^1} \qquad (1)$$

where,
g = Gain Indeks
T1 = Pretest Score
T2 = Posttest Score
T3 = Maximum Score

From the results of the formula above, it will be classified based on the results of increasing n-gain before and after the treatment process is carried out. Table 1 is a classification of the gain index that will be used as follows.

Table 1. Gain Index Classification

Percentage Score	Criteria
$g \geq 0.7$	High
$0.3 < g < 0.7$	Medium
$g \leq 0.3$	Low

Based on Table 1, the results of the n-gain score can be classified into several criteria. If the gain value is more than or equal to 0.7, then the gain criterion result is "High". If the gain value is in the middle, namely $0.3 < g < 0.7$, then the gain criterion result is "Medium". If the gain value is less than or equal to 0.3, then the gain criterion result is "Low". Based on the classification shown in Table 1, the results of the pretest and posttest comparison can be distinguished to determine how significant the increase is after using the project-based learning model. The significance of these results lies in their ability to provide a more objective picture of the effectiveness of the learning intervention. If the n-gain test results show a value in the medium or high category, this means that the learning intervention has a positive impact on improving students' abilities, while if the value is low, the intervention may require further adjustment. The results of the then-gain test in this study showed an average of 0.517, which is included in the "Medium" criteria, indicating that there was a significant increase in students' creative thinking abilities after treatment using project-based learning media and models.

RESULT AND DISCUSSION

A clear presentation of experimental results obtained, highlighting any trends or points of interest. The results should not be repeated in both tables and figures. The discussion should relate to the significance of the observations. The content must be arranged in the following format if it contains sub-chapters.

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Analyze Result

At the analysis stage, the researcher made initial observations, namely field studies and literature studies. The field study was conducted by interviewing teachers at the BPI Vocational High School in Bandung. Based on the results of the interview, it can be concluded that during learning creative products and entrepreneurship, the application of the Internet of Things is used in the practices available in the syllabus to produce a product. These subjects are available in grades 11 and 12. Furthermore, students still need teacher guidance to develop their abilities in product design in creative product and entrepreneurship subjects. Each lesson uses the Internet of Things for beginners curriculum from Github and uses sensors that are appropriate to the curriculum. The obstacle that occurs during learning activities is that students' desire to modify Internet of Things devices is still lacking, and every learning activity needs to be encouraged by the teacher. Lastly, during the assessment, the teacher mapped it out in advance for each semester so that in the following semester, no student's grades would decrease.

Design Result

At the design stage, there is a process of creating material instruments such as teaching modules, pretest-posttest questions, evaluations, and student worksheets, which are taken and adapted to the learning outcomes in the applicable independent curriculum. Next, the pretest-posttest instrument is used to measure students' creative thinking abilities before being given the treatment process and after being given the treatment. The material was developed to hone students' abilities and understanding of Internet of Things material and creative thinking. At this stage, a flowchart is obtained for the learning media that will be designed. Figure 2 explains the flowchart flow of the learning media being developed.

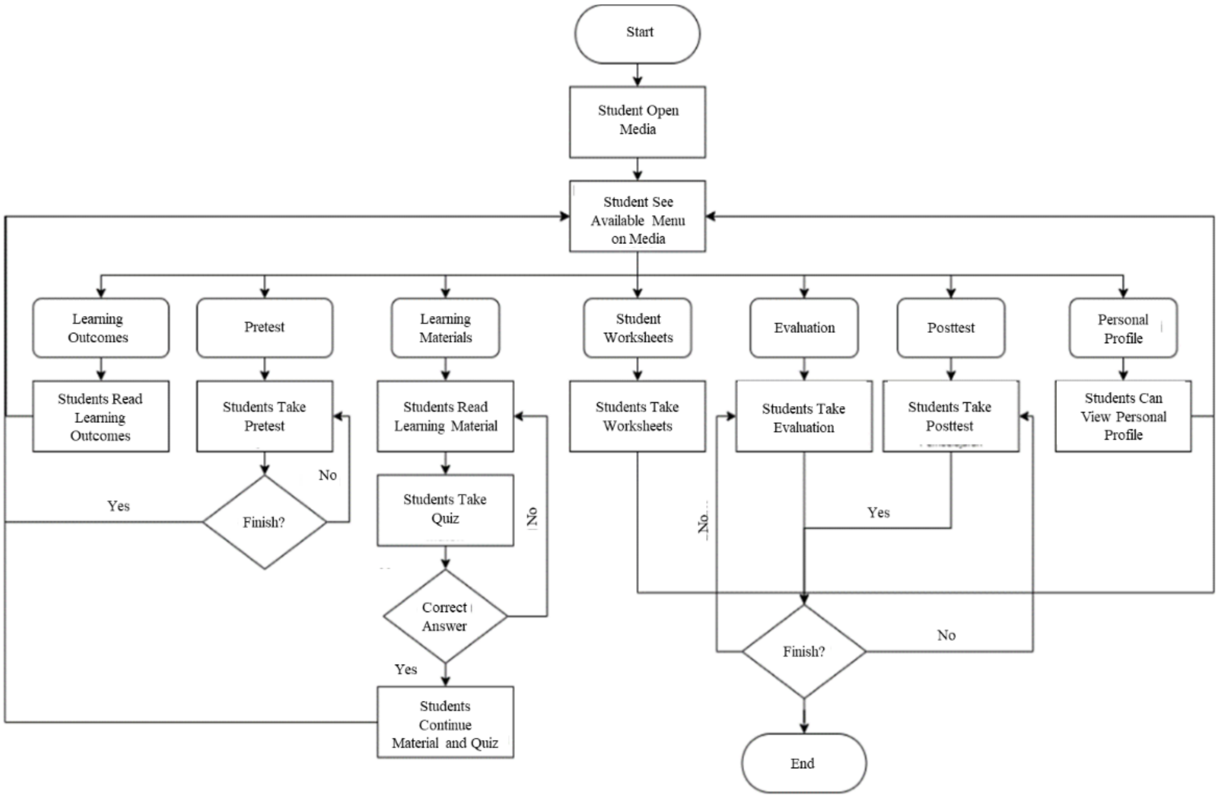

Figure 2. Learning Media Flowchart

Based on Figure 2, when students open learning media, there will be a start button to go to the next page. Users will be presented with various menu options such as learning outcomes, pretest, learning materials, student worksheets, evaluations, posttests, and personal profiles. When students select the learning outcomes menu, reading will appear related to the learning outcomes they are aiming for. Next, students will be asked to take a pretest to hone their initial skills in creative thinking. The next stage is to start the treatment process by selecting the learning material menu, which contains several materials and quizzes that the user will read and complete. If the quiz answer given is correct, the learning material will continue to the next page. The project-based student worksheet process is provided in learning media. After learning is complete, students can choose the evaluation menu to hone the material that has been presented in the learning process. The next stage is the posttest menu, where students hone their creative thinking skills again after the treatment process is carried out, whether there is an increase or decrease. Finally, students can see the researcher's profile related to the research carried out when students select the menu.

Develop Result

In the development stage, researchers developed learning media with Articulate Storyline 3, which includes the application of the project-based learning model. Figure 3 is a menu display of the media that has been developed.

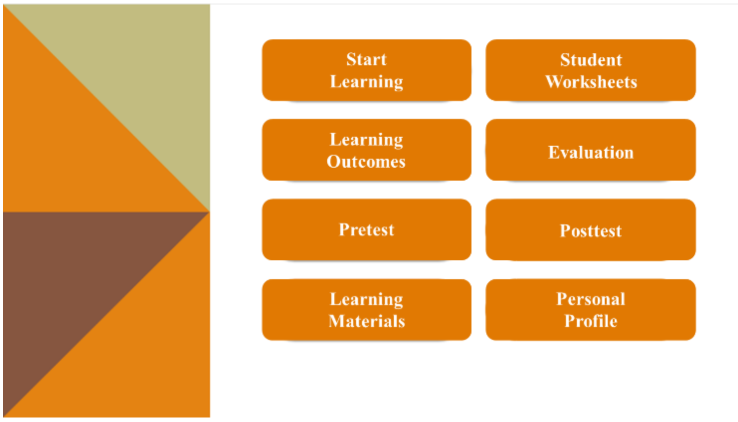

Figure 3. Learning Media Menu

Based on Figure 3, when students open the media, there will be a start button to go to the next page. Users will be presented with various menu options such as learning outcomes, pretest, learning materials, student worksheets, evaluations, posttests, and personal profiles. Each button will go to the page according to the button selected by the user.

Next, the media developed will be validated by media and material experts who refer to the Learning Object Review Instrument assessment. The instruments given to experts contain several aspects, such as content quality, learning goal alignment, feedback and adaptation, and motivation. Meanwhile, for media validation, there are several aspects, such as presentation design, interaction usability, accessibility, reusability, and standard compliance. The following is a calculation of the results of material and media validation in Table 2 and Table 3.

Table 2. Material Validation by Experts

No.	Aspect	Criteria	Ideal Score	Score	Percentage
1	Content Quality	4	20	18	90%
2	Learning Goal Alignment	11	55	47	85%
3	Feedback and Adaptation	1	5	5	100%
4	Motivation	1	5	4	80%
Total Average					88.75%
Category					Very Good

From the results of Table 3, the feasibility of the design aspect of material quality with an average of 88.75% and the category "Very Good". The division of aspects includes the content quality aspect at 90%, the learning goal alignment aspect at 85%, the feedback and adaptation aspect at 100%, and the motivation aspect at 80%.

Furthermore, media testing was carried out by an expert in the field of study, namely one of the Computer Science Education lecturers from Indonesia University of Education. Table 3 shows the results of the validation by media experts and the following results were obtained.

Table 3. Media Validation by Experts

No.	Aspect	Criteria	Ideal Score	Score	Percentage
1	Presentation Design	1	5	4	80%
2	Interaction Usability	3	15	14	93%
3	Accessibility	2	10	9	90%
4	Reusability	1	5	4	80%
5	Standard Compliance	1	5	4	80%
	Total Average				81%
	Category				Very Good

Based on the results of Table 3, the media feasibility has an average of 81% in the "Very Good" category. The division of aspects includes presentation design at 80%, interaction usability at 93%, accessibility at 90%, reusability at 80%, and standard compliance at 80%.

Implementation Result

In the implementation stage, the media that has been developed has gone through an expert validation process and is declared suitable for use, will be tested on a predetermined sample, which is class XI students at the BPI Vocational High School in Bandung in the Computer Network and Telecommunications Engineering department. The research was conducted in 3 meetings. At the first meeting, the researcher provided the students with the objectives of the research being conducted as well as the process of learning activities that would be carried out. Next, the research was carried out by giving a pretest and creative thinking questionnaire to students to get an initial score before the treatment process was carried out.

Figure 4. Pretest at First Meeting

At the second meeting, researchers studied Internet of Things material using the media that had been developed. Then, students use the media using the link that has been shared. Learning is carried out in the Computer Network and Telecommunications Engineering laboratory so that students can use computers. Learning is carried out with the constraint of only being given 2 hours of lessons by the teacher concerned. At the end of the lesson, students are asked to work on student worksheets and learning evaluations provided in the learning materials.

Figure 5. Providing Material on Learning Media at the Second Meeting

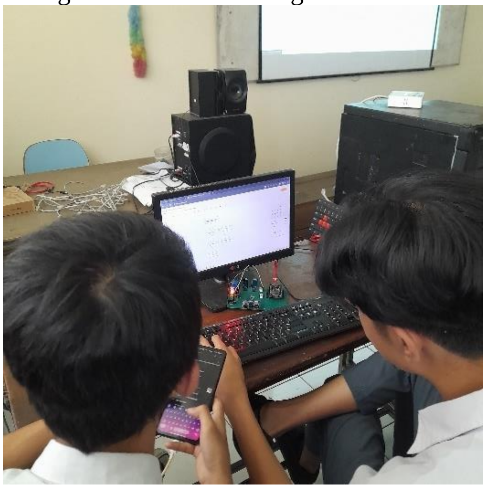

Figure 6. Implementation of the PBL Model Based on Student Worksheets at Third Meetings

At the third meeting, learning continued by applying the project-based learning model to students according to the student worksheet provided. Next, students are directed to form a group with their peers and start working on the task given, namely creating an Internet of Things-based project using Arduino. There are six stages in project-based learning. First, students are given case studies of problems on the LKPD provided. Second, students are asked to create a project design from the problem given and develop it into a complex project. Third, students begin to carry out the scheduling process of the project to be created. Fourth, students start working and the final results will be collected into a documentation report. Fifth, students present their final results in groups in front of friends. Sixth, each group provides evaluations and suggestions to the group that appears. At the end of the lesson, students are asked to do a posttest, creative thinking questionnaire, and responses to the learning media used to get final data from the research carried out. Each project-based learning flow is associated with each indicator of creative thinking ability, namely fluency, flexibility, elaboration, and originality.

Evaluate Result

After the implementation process is carried out, the next stage is evaluation, where this stage contains the results of the pretest and posttest as well as students' responses to the learning media used. Based on the results of the experimental research, the pretest and posttest data were obtained from 17 students, as shown in Figure 7.

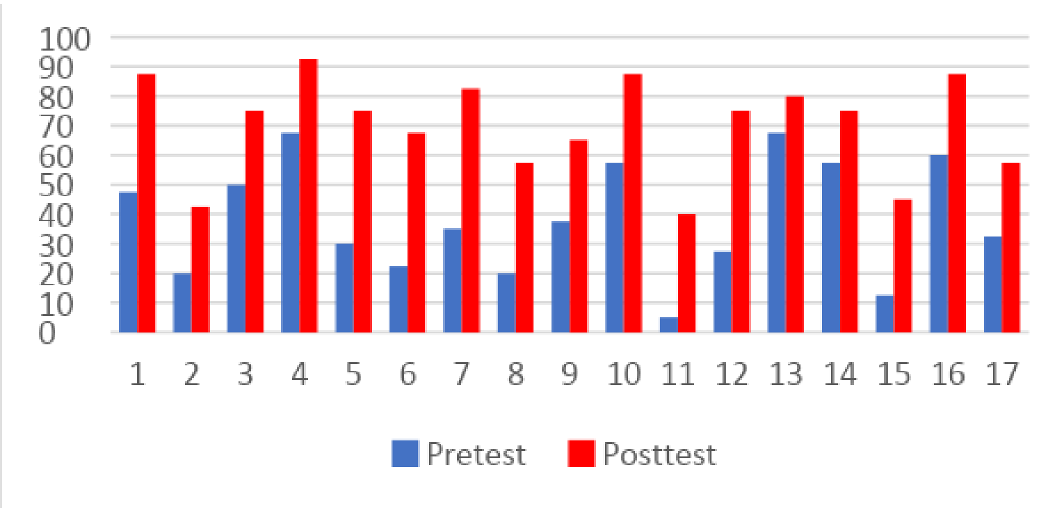

Figure 7. Pretest and Posttest Results

Figure 7 shows an increase in student learning outcomes, as seen by the average scores, where the average pretest score is 38.24, and the average posttest score is 70.15; the difference between the pretest and posttest scores is 31.91. This statement stated that there was quite a significant difference after treatment. However, to strengthen this statement, further data analysis is needed, namely the n-gain test. The n-gain test is carried out based on the total number of students in upper, middle, and lower groups, as well as based on indicators of creative thinking abilities based on the student's initial scores. Table 4 shows the results of the n-gain test based on the entire class.

Table 4. N-Gain Test Results Based on All Classes

Pretest	Posttest	Difference	Pretest Maximum Score	Gain	Gain (%)
38.24	70.15	31.91	61.76	0.517	51.7

Based on Table 4, the normalized gain results for all XI Computer Engineering and Technology students got an average of 0.517 in the "Medium" category.

Next, the final stage is a student response questionnaire which is given after the learning takes place in the form of a Google Form. Aspects that must be assessed by students refer to the Technology Acceptance Model (TAM). The assessment was carried out by 17 students who interacted directly with the learning media. Table 5 shows the results of students' responses to learning media as follows.

Table 5. Results of Student Responses to the Media

No	Aspect	Items	Ideal Score	Score	Percentage
1	Perceived Usefulness	3	255	221	86.67%
2	Perceived Ease of Use	3	255	216	84.71%
3	Attitude	3	255	213	83.53%
4	Intention of Use	3	255	220	86.27%
					85.29%

From Table 5, the results obtained from assessing student responses to learning media include aspects of perception of use towards usefulness with a percentage of 86.67% and the "Very Good" category, user perceptions of ease of use with a percentage of 84.71% and the category "Very Good", the attitude towards using with a percentage of 83.53% and the "Very Good" category and the aspect of attention to using with a percentage of 86.27% and the "Very Good" category. So, the average result in these four aspects is 85.29% in the "Very Good" category.

Next, after analyzing the results of students' responses to media from each aspect of TAM, the next stage is to determine the correlation between aspects of TAM. Figure 8 explains the correlation between TAM aspects and the SmartPLS 4 application.

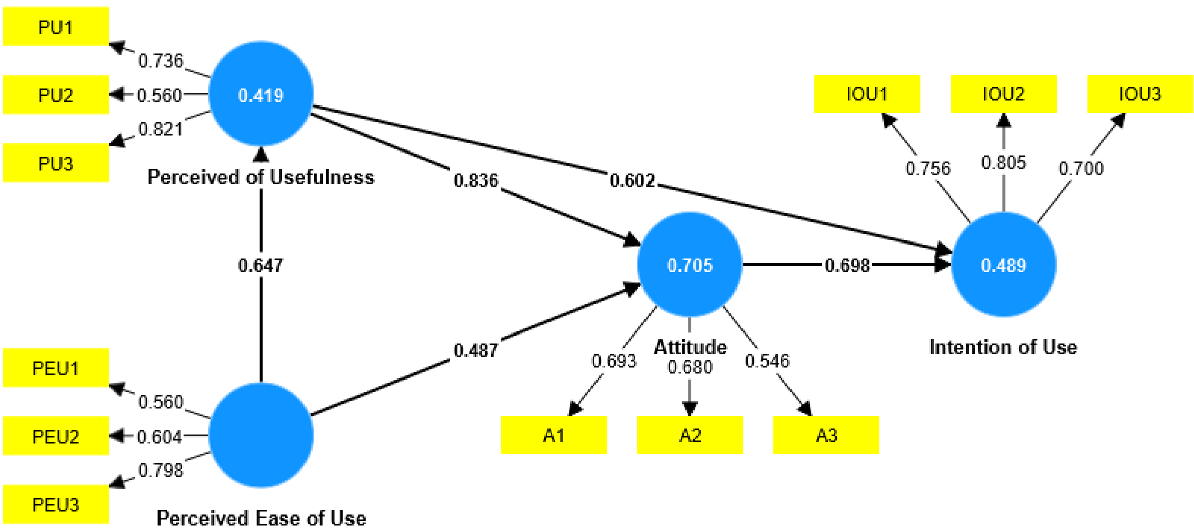

Figure 8. Correlation Between Each Aspect of TAM

From the results of Figure 8, we get a correlation between TAM aspects which are generally related to each other. The perceived ease of use aspect has a "Strong" correlation with the perceived usefulness aspect of 0.647 or 64.7%. The perceived usefulness aspect has a "Very Strong" correlation with the attitude aspect of 0.836 or 83.6%. The perceived ease of use aspect has a "Quite Strong" correlation with the attitude aspect of 0.487 or 48.7%. The attitude aspect has a "Strong" correlation with the intention of use aspect of 0.698 or 69.8%. Finally, the perceived usefulness aspect has a "Strong" correlation with the intention of use aspect of 0.602 or 60.2%.

CONCLUSION

Based on the stages and results of the research conducted, it can be concluded that the project-based learning model applied to the learning media for the Creative Products and Entrepreneurship subjects was developed using the Analyze, Design, Development, Implementation, Evaluation (ADDIE) model. The validation results showed that the learning media received an average score of 81% in the "Very Good" category, while the teaching materials received an average score of 91% in the "Very Good" category. In addition, there was a significant increase in students' creative thinking skills after using the project-based learning model, with an average pretest score of 38.24, increasing to 70.15 in the posttest. The n-gain test showed an average of 0.517 which was included in the "Moderate" criteria, indicating a significant difference in students' creative thinking skills after the learning process. Students' responses to the learning media were also positive, with the results of the TAM questionnaire showing that the learning media used in terms of perceived usefulness, ease of use, attitude towards use, and intention to use were in the "Very Good" category.

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