# Project-based Laboratory Rotation Blended Learning Model to Train Students' Critical Thinking and Collaboration in Physics Course

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**Abstract.** Critical thinking and collaboration skills are part of the 21st century skills that need to be trained in learning at the university level. This research focused on developing a project-based laboratory rotation blended learning (PjLRBL) model to train students' critical thinking and collaboration. Development was carried out using the ADDIE model. The resulting model products were lesson plans, digital module, critical thinking, and collaboration skills assessment tools. Experts' validation result of the entire product obtained valid criteria. The products were implemented in the course on Basic Physics 1, Science Education Study Program especially on projectile motion topic. At the implementation stage, the critical thinking skills of student obtained results of 12.00% low, 40.00% moderate, and 48.00% high. Then, the collaboration skills of student obtained results of 6.00% low, 36.00% moderate, and 56.00% high. Based on these results, the PjLRBL can be an offer to be applied to the higher education to train students' critical thinking and collaboration skills.

## 1 Introduction

In the 21st century, there are essential skills known as "The 4Cs" which comprise communication, collaboration, critical thinking, and creativity [1]. These competencies are crucial and should be integrated into core subjects such as science during education. The purpose of education is to equip students with a range of skills necessary for success in their lives [2]. To ensure the acquisition of these 21st century skills, it is important to enhance the quality of learning through the implementation of appropriate and relevant instructional models.

The 21st century skills that need to be trained in learning at the tertiary level are critical thinking and collaboration skills. The study conducted by Trilling and Fadel [3] shows that diploma and higher education graduates can think critically and work in teams (collaborate) which are still lacking. These abilities still need to be trained and improved during the learning process [3]. To practice critical thinking skills and collaborate, an appropriate learning model is needed.

The 21st century learning model should combine offline and online learning, known as blended learning [4]. Blended learning is an alternative learning strategy that can be used by teachers in the current era of globalization [5]. Blended learning can encourage students to utilize digital information, so they are expected to have critical thinking skills.

The blended learning model that is suitable for science learning is laboratory rotation. Laboratory rotation is a blended learning that applies a rotation model where students not only do offline and online theoretical learning, but also practical learning by utilizing computer-based laboratories (virtual laboratories) [6].

The laboratory rotation model is rarely used in physics learning even though this model allows students to practice examining, analyzing, interpreting, and evaluating evidence during virtual laboratory activities which are indicators of critical thinking skills.

In contrast, the project-based learning approach (PjBL) is highly appropriate for developing collaborative abilities [7]. PjBL allows students to work together in teams to create projects [8], PjBL can be applied to lectures because it has great potential in practicing good communication and collaboration skills for students [9].

Lab-rotation blended learning is suitable for use in physics courses and has the potential to improve critical thinking skills and PjBL has great potential in practicing good communication and collaboration skills for students. Therefore, this study combined both learning models into a new learning model, namely Project-based Laboratory Rotation Blended Learning (PjBLRBL). The PjBLRBL model combined the syntax of the two previous models so that it was possible to practice critical thinking and collaboration skills.

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## 2 Method

The study employed a Research and Development (R&D) approach with a five-stage model known as ADDIE (analysis, design, development, implementation, and evaluation) [10]. Figure 1 illustrates the stages involved. The outcome of the research is the PjBLRBL model, which encompasses various instructional resources such as lesson plans, digital modules, tools for evaluating critical thinking, and assessment tools for collaboration.

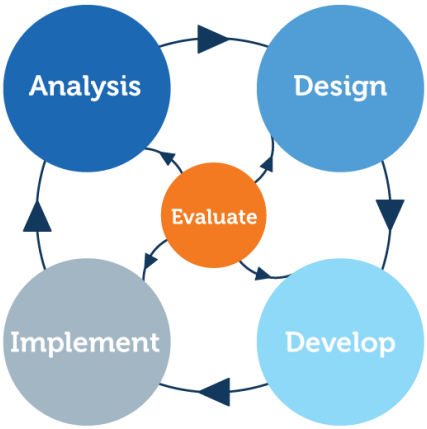



**Fig 1.** ADDIE model

### Analysis

In this phase, various aspects were examined, such as evaluating suitable physics classes, assessing critical thinking abilities and student teamwork, considering the accessibility of necessary hardware and software for students, evaluating the availability of internet connectivity, analyzing the frequency of meetings, and assessing the physics content to be taught using the PjBL model.

### Design

The Design Stage is the design of the PjBLRBL model whose output is a complete physics lecture kit in the form of lesson plans, digital modules, critical thinking skills assessment tools, and collaboration skills assessment tools.

### Development

Five experts reviewed the research product to assess its quality and assign a product quality score. Each expert rated the product's quality indicators on a scale of 1 to 4 and also offered suggestions for revisions if necessary. The product's quality was evaluated using Aiken's V formula (equation 1) and the criteria outlined in table 1 [11].

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (1)$$

$V$ = validation score, s = $r-lo$, $r$ = score form expert, $lo$ = minimum score, n = amount of expert, c = maximum score. Validation criteria is shown in Table 1

**Table 1**. Criteria of validation by expert validation

| V score | Criteria |
|---|---|
| < 0.87 | Not valid |
| > 0.87 | Valid |

### Implementation

The PjBLRBL model product, which underwent validation, was subsequently examined for its practicality. The practical test took place in the Basics Physics course on projectile motion material 1, specifically involving 50 students from the Science Education Study Program at Universitas Negeri Semarang. Following the utilization of the PjBLRBL Model, we evaluated the students' critical thinking and collaboration abilities. The assessment of these skills was divided into three categories: low, medium, and high, as outlined in Table 2.

**Table 2.** Critical thinking and collaboration skills categorizes.

| Categorize | Formula |
|---|---|
| Low | S < M – SD |
| Medium | M – SD < S < M + SD |
| High | M + SD ≤ S |

S is score of test, M is mean score, and SD is standard deviation.

### Evaluation

Throughout every stage, an assessment was conducted to acquire recommendations for enhancing the developed products.

## 3 Results and Discussion

### Product

The product of the PjBLRBL model was in the form of lesson plan in Basic Physics 1 course. The results of the developed learning model syntax are shown in Figure 2. The PjBLRBL syntax is an integration of the modified Lab-Rotation Blended Learning [12] and Project-Based Learning (PjBL) models [13]. Element of the Lab-Rotation Blended Learning model is found in virtual practicum activities and elements of the PjBL model are found in project activities (basic questions to evaluation of learning experiences).

In addition to lesson plan, a Digital Module for Basic Physics Course 1 for Projectile Motion Material was also developed which included material, practice questions, virtual lab practicum activities, and project activities. Practicum activities using virtual labs and project activities to accommodate PjBLRBL. The digital module was developed using a web-based application, namely flipbook maker. The appearance of the module cover is shown in Figure 3.

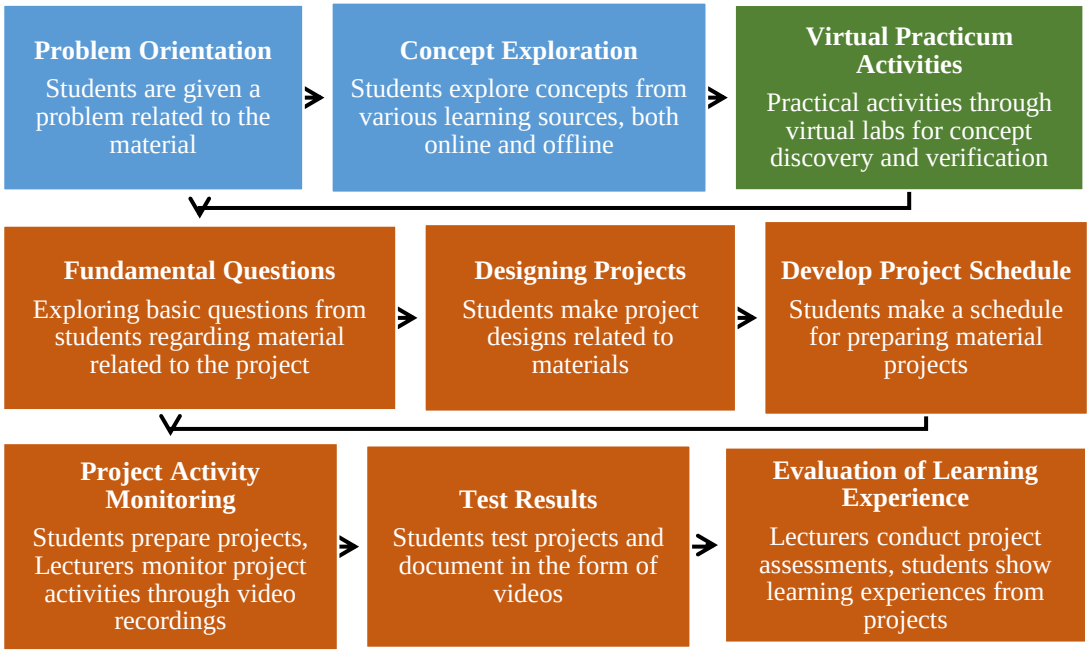



**Fig 2.** Syntax of PjBLRBL Model

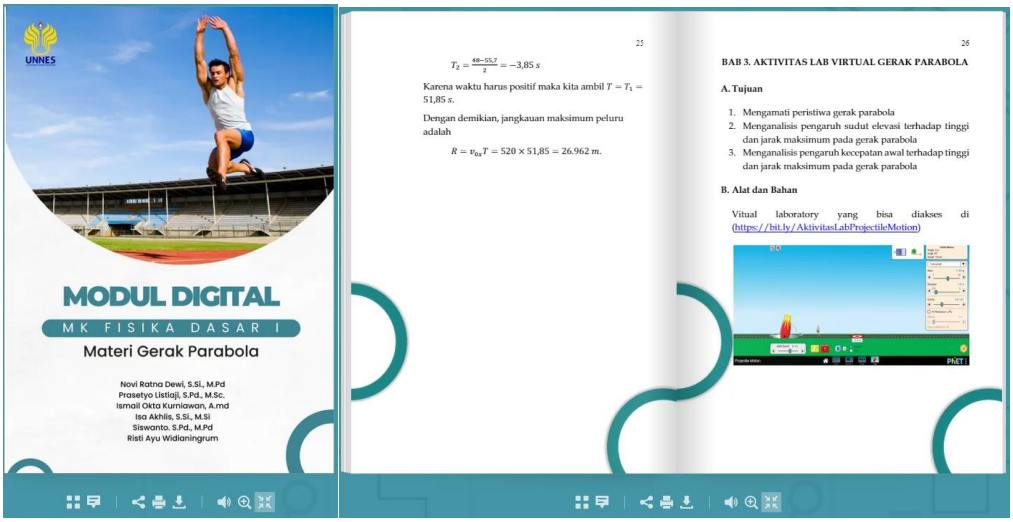
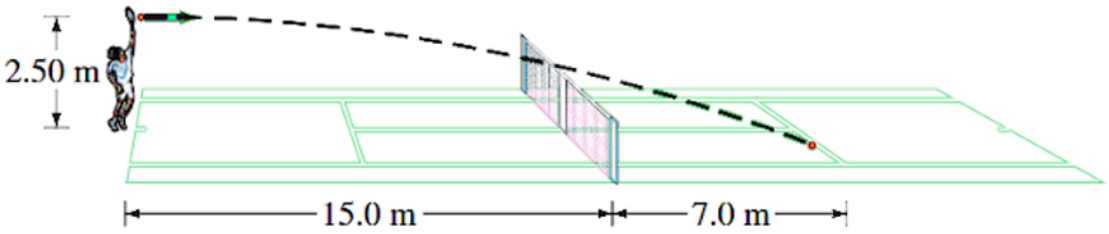



**Fig 3.** Interface of Digital Modul

Assessment instruments designed to measure critical thinking abilities were created based on specific markers of critical thinking skills. These markers include offering straightforward explanations (basic clarification), developing fundamental skills (basic clarification), drawing conclusions (inference), providing more detailed explanations (advanced clarification), and employing strategies and tactics (strategy and tactics). An example of a thinking skill evaluation tool that has been developed for parabolic motion material is shown in Figure 4.

The collaboration skills evaluation tool was developed in the form of an observation sheet that corresponds to the indicators of collaboration skills, namely commitment, respect for others, deliberation, and participation. Students are assessed with a score of 1 to 4 based on the assessment rubric for each indicator of collaboration skills.

position of the player who is serving. The ball is bounced vertically up to a height of 2.5 m by the players before being hit with a racket.




a. During the first service attempt, the ball is unable to cross the net. What actions did the players take to get the ball to cross the net? (The position of the player in relation to the net and the height of the ball before being hit cannot change)
b. Based on the information contained in the question. What is the minimum speed of the ball hit so that it passes through the thin net above it?
c. If the service stroke boundary line is declared to enter the opponent's court is 7 m from the net (more than 7 m the ball is considered not entered), for the second service attempt, what strategic steps do players need to take? What is the speed of the ball so that it falls exactly 7 m from the net?

**Fig 4.** Example of Critical Thinking Assessment Tools

## Product Validation

The results of the validation of PjBLRBL models in the form of RPS products, digital modules, critical thinking skills evaluation tools, and collaboration skills evaluation tools are shown in Figure 5. All products have an Aiken's V score of more than 0.87 so that they can be said to be valid according to experts. The Aiken index obtained can be used as a basis for measuring the content validity of a product.
We establish reliable standards. Using the outcomes of this verification, all products included in the PjBLRBL framework are deemed suitable for utilization during the implementation phase. Nevertheless, experts have suggested various enhancements, including refining the text across all products, incorporating references, enhancing image dimensions in instructional modules, and fine-tuning sentences in evaluation tools.

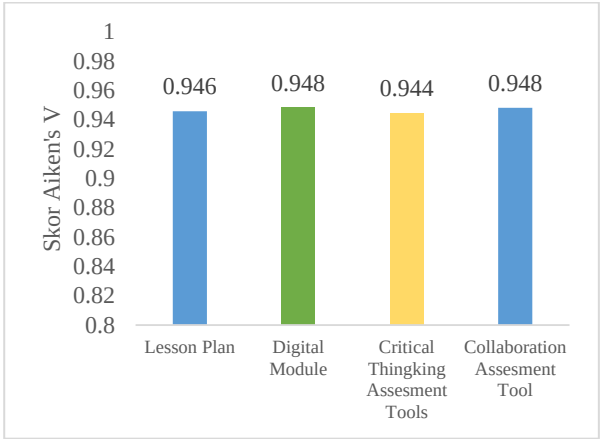



**Fig 5.** Validation score of research products

## Critical Thinking Skills Result

After the PjLBL model was declared valid by experts, then all products were implemented in lectures. Furthermore, students' critical thinking skills were measured using the assessment tools that have been developed. The results of students' critical thinking skills after receiving lectures with the PjBLRBL model are shown in Figure 6.

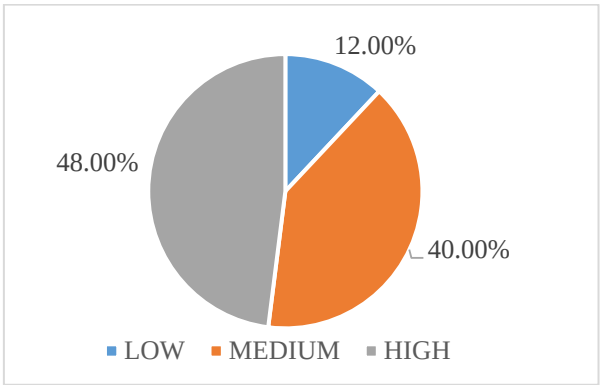



**Fig 6.** Students' critical thinking skills

The PjBLRBL model can train students' critical thinking skills. This is supported by data that only 12% of the student sample scored in the low category. The problem orientation stage in PjBLRBL trains students to analyze a physics problem related to everyday life [14]. Students are also trained to explore concepts from various learning sources both online and offline [15]. In virtual experiments train students to examine, analyze, interpret, and evaluate [16].

### Collaboration Skills Result

Furthermore, the results of student collaboration skills after receiving lectures with the PjBLRBL model are shown in Figure 7.

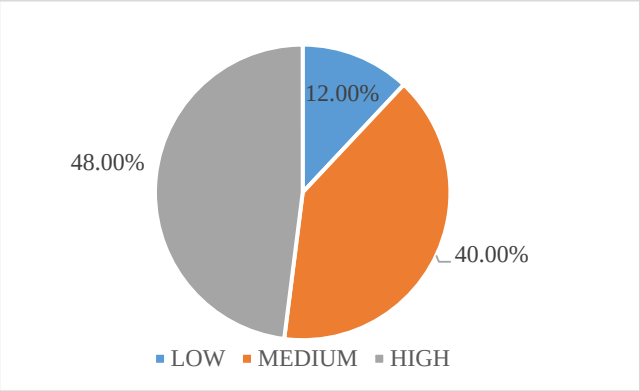



**Fig 7.** Students' collaboration skills

PjBLRBL allows students to work together in teams to create projects. Creating project can be applied to lectures because it has great potential in practicing good communication and collaboration skills for students. In implementing the PjBLRBL model, students were asked to make a water rocket project as an example of an object that uses projectile motion. Collaboration in project creation begins with designing, scheduling, manufacturing, monitoring, and testing project results.

## 4 Conclusion

The PjBLRBL model has been developed to train students' critical thinking and collaboration skills. The model products produced are RPS, digital modules, evaluation tools for critical thinking and collaboration skills. The valid criteria were obtained through expert validation of the entire product. This product was implemented in the Basic Physics I course. During implementation, the critical thinking skills of students were assessed, resulting in 12% falling into the low category, 40% in the medium category, and 48% in the high category. In terms of collaboration skills, 8% were categorized as low, 36% as medium, and 56% as high. Further research is required to test the reliability, difficulty level, and discriminating power of evaluation tools for critical thinking and collaboration skills. Additionally, the effectiveness of the PjBLRBL model in enhancing students' critical thinking and collaboration skills needs to be examined. Based on the findings of this study, the PjBLRBL model can be recommended as a suitable learning approach for tertiary institutions.

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