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Physics laboratory management: Implementing project-based learning to support learning at UHAMKA

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Abstract

This study aims to analyze the effect of the implementation of the Project-Based Learning model on improving the quality of physics laboratory management, Faculty of Teacher Training and Education UHAMKA. The study focused on five main aspects of laboratory management, namely planning practical activities, organizing tools and materials, implementing activities, evaluating practical results, and documentation and reporting. This type of research uses a quantitative approach with a pretest-posttest one group design. The methods used to collect data are observation, documentation, and questionnaires conducted on 22 students who are currently taking physics practical courses in the odd semester of 2024-2025. The research instruments are in the form of observation sheets and laboratory management assessment questionnaires that have been validated by experts. Data were analyzed using descriptive-comparative statistics by calculating the average score before and after the implementation of project based learning, as well as the percentage increase in each aspect. The results showed that all aspects of laboratory management improved after the implementation of the project based learning model. The highest increase occurred in the documentation and reporting aspect at 19%, followed by planning practical activities at 18%, evaluating practical results at 17%, implementing activities at 15%, and organizing tools and materials at 14%. The conclusion of this study is that project-based learning can improve students' abilities to plan, implement, and evaluate laboratory activities systematically, collaboratively, and reflectively.

Keywords: Laboratory management, Learning, Physics, Project based learning.

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1. Introduction

For Indonesia, education has a very important role for survival, because along with the development of the times, education has become a very basic need, as well as technological advances, which have become one of the benchmarks for the progress of the Indonesian nation. Education also plays an important role in creating globally competitive human resources. One of the supports for the implementation of education is the availability of adequate facilities and infrastructure such as laboratories [1]. Practical lecture activities will be very useful for student skills in using tools, using practical materials, and being scientific in facing scientific problems [2] which are shown by an open view, critical thinking, free from deviation, respecting the opinions of others, maintaining honesty, patience, accuracy, precision, and discipline which are shown by an open view, critical thinking, free from deviation, respecting the opinions of others, maintaining honesty, patience, accuracy, precision, and discipline [3].

An educational laboratory is an academic support unit in an educational institution that is systematically managed for testing, calibration, and production activities on a limited scale, using equipment and materials based on certain scientific methods, to support the activities of the Tridharma of Higher Education. The role of the laboratory is considered strategic at the university level because it can support the quality of education. The laboratory is an integral part of the academic field (not part of the household or administration), so laboratory management must be planned in accordance with the academic plan (program and budget). Effective and efficient use of resources related to laboratory management is needed to improve laboratory quality [4]. According to Hofstein and Lunetta [5], laboratory activities are a means to connect theory with practice, strengthen conceptual understanding, and develop critical thinking and problem-solving skills [5]. Therefore, the laboratory must be managed well so that it can function optimally in supporting the learning process.

According to Tone, a laboratory is a room, either closed or open, designed according to the needs to carry out activities related to educational functions, research, and community service [6]. In order for a laboratory to function properly, it must be managed well, and good laboratory management must be supported by good laboratory management as well. A laboratory will support the educational process if it is managed well. In addition, the goal of laboratory management is to create a comfortable and safe atmosphere for its users [7]. No matter how small the laboratory is, there must be rules and regulations, because these rules and regulations will greatly contribute to the safety of oneself, others, and the environment, as well as the smooth operation of the laboratory itself. Every student or other person working in a laboratory must know the regulations that apply in that laboratory [8].

According to G.R. Terry, management is a process consisting of planning, organizing, actuating, implementing, and supervising, utilizing both science and art in order to accomplish predetermined objectives (Management is a distinct process consisting of planning, organizing, actuating, and controlling, utilizing both science and art and followed in order to accomplish predetermined objectives) [9]. Management is a process in which a person can organize everything done by an individual or group. Therefore, laboratory management is a process that includes planning, organizing, actuating, and controlling equipment and supplies used, both directly and indirectly, to support the educational process in the form of teaching, research, observation, training, and scientific testing Arif and Nuri [10]. Arikunto [11] explains that management includes four main functions, namely planning, organizing, implementing, and controlling [11].

Laboratory management is the effort to manage a laboratory. The success of a laboratory is determined by several interrelated factors. Laboratory management is an inseparable part of daily laboratory activities [9]. The success of a laboratory is determined by several interrelated factors. Good laboratory management includes a sound organizational system, clear job descriptions, effective and efficient facility utilization, discipline, and good laboratory administration [12]. In the context of physics laboratory management, the implementation of project-based learning offers the opportunity to improve not only learning effectiveness but also operational sustainability. Thus, the success of physics laboratory management depends not only on the availability of facilities, but also on the ability of lecturers and technicians to manage a meaningful learning process.

Project-Based Learning (PBL) has emerged as a significant instructional approach in physics education, particularly in laboratory settings. This method emphasizes student engagement through real-world problem-solving and interdisciplinary collaboration, fostering deeper understanding and skill development [11]. In the context of physics laboratory management, the implementation of project-based learning offers opportunities to improve not only learning effectiveness but also operational sustainability. Physics laboratories play a crucial role in science education, providing an environment where theory meets practice.

Project-Based Learning (PBL) has emerged as a significant instructional approach in physics education, particularly in laboratory settings. This method emphasizes student engagement through real-world problem solving and interdisciplinary collaboration, fostering deeper understanding and skill development [13]. According to Thomas, Project-Based Learning is a student-centered learning approach that organizes learning through complex, real-world problem-based projects and produces concrete products [14]. Meanwhile, Krajcik and Blumenfeld [15] added that Project-Based Learning increases student motivation and engagement because it provides space for creativity, collaboration, and independent decision-making [15]. Project-Based Learning encourages students to design, research, analyze, and present the results of the projects they design.

The project-based learning model used uses steps, namely determining fundamental questions based on the problems presented, designing project planning based on the results of problem solving from fundamental questions, preparing a project schedule, monitoring and evaluating students and the progress of the project being carried out by the lecturer in charge of the physics practicum course, testing results and evaluating experiences through discussions with lecturers and colleagues [16]. In addition, Bell explained that project-based learning not only improves conceptual understanding, but also develops 21st-century skills such as critical thinking, communication, collaboration, and creativity (4C) [17]. This is in line with the demands of the Independent Learning Independent Campus Curriculum (MBKM) developed by the Ministry of Education and Culture, namely creating students who are independent, innovative, and ready to face global challenges [18]. Thus, the implementation of project-based learning in the Physics laboratory is expected to develop students' ability to think scientifically while increasing their professional competence.

Previous research by Rahmawati, et al. [19] showed that the implementation of Project-Based Learning in the Physics laboratory increased students' critical thinking skills by 25% and increased their learning motivation [19]. Meanwhile, Wahyuningtyas [13] study confirmed that the integration of project-based learning with good laboratory management can increase the efficiency of equipment use and the effectiveness of practicum implementation time [20]. In line with the vision of Muhammadiyah University Prof. Dr. HAMKA (UHAMKA) which is oriented towards developing superior, character-based, and globally competitive graduates, the implementation of project-based learning in the Physics laboratory is a strategic step to form students who are not only academically competent, but also have reflective thinking skills and an Islamic scientific attitude. Thus, the laboratory is not only a place for mechanistic practice, but an arena for character formation and scientific creativity.

The novelty of this research lies in the integration of Physics laboratory management and the Project-Based Learning approach in the context of Islamic higher education at UHAMKA. This research not only highlights the administrative aspects of laboratory management but also examines how project-based learning can be a pedagogical and managerial strategy to realize a more active, collaborative, and holistic character-oriented Physics learning.

2. Methodology

2.1. Research Design

This study uses a descriptive qualitative approach, with the aim of in-depth describing the physics laboratory management process through the application of Project-Based Learning (PjBL) to support learning at UHAMKA. This approach was chosen because it allows researchers to understand laboratory management phenomena contextually and naturally, as Creswell [21] suggests that qualitative research focuses on the meaning, process, and understanding of real-world situations.

2.2. Subjects And Object

The research subjects consisted of:

- Lecturer teaching the Basic Physics course
- Laboratory assistant
- 22 second-semester student practicum participants in the Physics Education study program.

The research object was physics laboratory management integrated with the implementation of Project-Based Learning (PjBL) as a practicum learning model.

2.3. Research Timeline and Setting

Data collection took place during 1 odd semester 2024-2025 (August–December 2024), with each student subject designing and implementing a simple physics project. The lecturer acted as a facilitator and the laboratory assistant provided the necessary equipment. This includes the preparation stage, implementation of the project-based learning model, observation, and evaluation of activity results.

2.4. Data Collection Techniques

This research was conducted through three main stages:

2.4.1. Preparation Stage

- Analysis of laboratory needs (availability of equipment, materials, and practicum schedule).
- Formulation of a project-based laboratory activity design.
- Development of research instruments (observation guidelines, interviews, and student questionnaires).

2.4.2. Implementation Stage

- Implementation of practicum activities using the Project-Based Learning model, which consists of six main steps [14]:
- Determining the basic project question.
- Planning project activities.
- Developing an implementation schedule.
- Monitoring project implementation in the laboratory.
- Testing project results and reporting.
- Evaluating the learning experience.
- The lecturer acts as a facilitator, while students act as designers and implementers of simple physics projects.

2.4.3. Evaluation and Reflection Stage

- Evaluation is conducted on aspects of laboratory management, student participation, and learning effectiveness.
- Reflection was carried out with lecturers and laboratory technicians to find the advantages and obstacles of implementing project-based learning.

2.5. Data Analysis Techniques

2.5.1. Data Qualitatively

Data analysis was conducted descriptively and qualitatively using the following steps according to Miles and Huberman [22]:

- Data reduction
- selecting and simplifying data from observations
- interviews,
- questionnaires.
- Data presentation
- presenting data in tables, graphs, and narratives.
- Conclusion drawing
- analyzing relationships between findings to generate meaning related to the effectiveness of PjBL-based laboratory management.

2.5.2. Data Quantitative

Quantitative data (e.g., questionnaire scores), percentage analysis was used to illustrate general trends in student perceptions and the effectiveness of model implementation.

Data were collected using the following techniques:

- Direct observation, to observe the implementation of PjBL in the laboratory.
- In-depth interviews, with lecturers and laboratory technicians.
- Questionnaires, to obtain students' perceptions of the implementation of project-based learning.
- Documentation, in the form of project reports, activity photos, and notes on lab evaluations

2.6. Data Validity

To enhance validity, the study employed:

- Direct observation to observe the implementation of project-based learning in the laboratory.
- In-depth interviews with lecturers and laboratory technicians.
- Questionnaires to obtain students' perceptions of the implementation of project-based learning.
- Documentation in the form of project reports, activity photos, and notes on lab evaluations.

3. Result

This research was conducted at the UHAMKA Physics Laboratory, focusing on the application of Project-Based Learning (PjBL) in student practicum activities. Data were obtained through observations of laboratory activities, interviews with lecturers and laboratory assistants, and questionnaires to student practicum participants.

3.1. Improving Laboratory Management

In research, laboratory management is a vital aspect in supporting the success of science learning, particularly in Natural Sciences (IPA), specifically Physics. The purpose of this study was to determine the extent to which the implementation of Project-Based Learning can improve the effectiveness of physics laboratory management at UHAMKA.

To this end, a comparison was made between conditions before and after the implementation of the PjBL model in five key aspects of laboratory management: (1) planning practical activities, (2) organizing tools and materials, (3) implementing activities, (4) evaluating practical results, and (5) documentation and reporting.

The results of the study indicate that the implementation of Project-Based Learning in physics laboratory activities at UHAMKA has a positive impact on increasing the effectiveness of laboratory management and the quality of student learning. Before the implementation of the project-based learning model, laboratory activities were still procedural and oriented towards implementing job sheets determined by lecturers. Students carried out experimental steps without much room for creativity or linking theory to practice. After the implementation of project-based learning, laboratory activities changed to be more collaborative, innovative, and project-based, where students played an active role as designers and implementers of activities. Data from observations and questionnaires showed a significant improvement in aspects of laboratory management after the implementation of the project-based learning model. The activity planning process became more systematic because it involved coordination between lecturers, technicians, and students in determining project themes, equipment needs, and implementation schedules. The organization of tools and materials also ran more efficiently because each student group had responsibility for the equipment used. In addition, the process of implementing laboratory activities became more lively because students not only followed experimental procedures but also created simple project designs relevant to the course material, such as making a mathematical pendulum based on Arduino, more details can be seen in Table 1 and Figure 1 graph.

Table 1.
Laboratory Management Aspects Before and After project-based learning.

Laboratory Management Aspects	Project Based Learning		Improvement (%)
	Before	After	
Planning practical activities	70	88	+18
Organizing tools and materials	72	86	+14
Implementing activities	75	90	+15
Evaluating practical results	68	85	+17
Documentation and reporting	65	84	+19

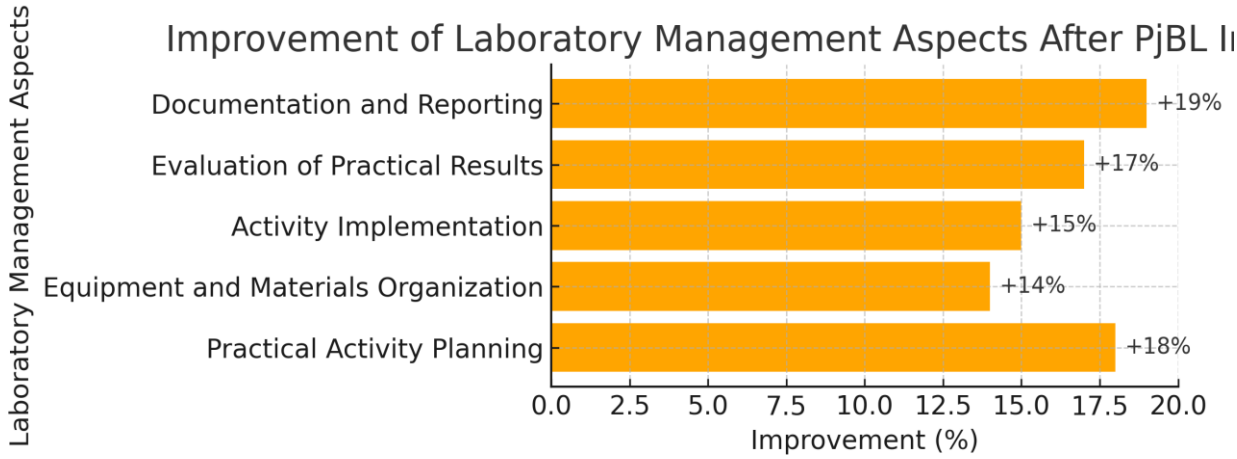

Figure 1.
Laboratory Management Graph after using project based learning.

Based on Table 1 and Figure 1 above, it can be seen that all aspects of laboratory management have improved after the implementation of the Project-Based Learning model. The highest increase occurred in the documentation and reporting aspect at 19%, which indicates that the implementation of project-based learning is able to raise awareness of the importance of recording, documenting, and reporting activities systematically. This is in accordance with Wena [23] opinion that Project-based learning encourages students to produce or create reports that are reflective, communicative, and accountable as part of academic responsibility [23].

3.2. Student Engagement

Students demonstrated increased active participation during laboratory activities. In the project-based learning model, students not only conducted experiments based on instructions but also designed physics mini-projects relevant to the lecture topic. More details can be seen in Table 2 below.

Table 2.
Student Responses to the Implementation of Project-Based Learning.

No	Statement	Average
1	The practicum is a project that involves solving real-life problems	75.66
2	I was involved in designing and implementing the practicum project	84.28
3	Project-based learning helped me better understand physics concepts	80.86
4	Project-based learning improves my creativity and teamwork	85.34
5	I feel more engaged in learning physics through Project-based learning	82.65

Based on the table above, the statement of Practical work in the form of a real project got an average of 75.66, which shows that some students agree, some still feel less related to the implementation of real problem-based projects. For the Statement of Involvement in designing the project got a score of 84.28, indicating that most students feel actively involved in designing and implementing the practical project. The statement of Understanding Physics Concepts got an average of 80.86, indicating that the majority of students feel they understand the concept of physics better through PjBL. And the Statement of Increasing Creativity and Teamwork got a score of 85.34, indicating that project-based learning succeeded in increasing students' creativity and teamwork skills. Meanwhile, the Statement of Interest in Learning Physics through Project-Based Learning had an average of 82.65, indicating that project-based learning succeeded in attracting students' interest in learning physics.

4. Discussion

Based on the data in the table above, it can be seen that the implementation of the Project-Based Learning model provides a significant improvement in all aspects of physics laboratory management. The aspect of planning practical activities also shows a significant increase, namely 18%. This shows that project-based learning helps students and lecturers in designing directed and contextual learning activities. Thomas said that planning is a key component in project-based learning because the project-based learning process requires students to organize ideas, goals, and activity steps independently and systematically [14]. in line with research by Sari [12] who said that the implementation of project-based learning in chemistry laboratory activities increased students' documentation skills by 21% due to the demand for project reports based on empirical data and fostered academic responsibility through authentic and communicative project reporting activities [23, 24].

A 17% increase in the evaluation aspect of practicum results indicates that the implementation of project-based learning strengthens students' analytical skills in assessing the results of their individual and group work. The evaluation carried out is not only oriented towards the final product, but also on the work process and collaboration, as stated by Moursund [25]. Meanwhile, the results of research by Yuliana and Puspitasari [26] found that project-based learning increased the evaluative skills of physics students by 16%, especially in assessing the effectiveness of experimental methods and the accuracy of data analysis [26].

Meanwhile, the implementation aspect of activities experienced a 15% increase, which indicates that the practical activities were running more effectively and collaboratively. Project-based learning encourages students to learn through direct experience (experiential learning), in accordance with Kolb [27] which states that effective learning occurs through the active involvement of participants in the process of exploration and reflection on real experiences [27].

The final aspect, namely the organization of tools and materials, increased by 14%, indicating that the implementation of project-based learning helps students become more skilled in preparing and managing laboratory resources efficiently. Sutikno [28] emphasized that good learning management requires planned resource management to achieve effective learning activities [28].

Overall, all aspects of laboratory management reinforce previous research that project-based learning has a positive impact on laboratory management. Project-based learning not only contributes to improving students' cognitive abilities and practical skills, but also to managerial aspects such as planning, implementation, evaluation, and reporting of activities. Therefore, the project-based learning model can be recommended as an innovative approach to improving the quality of physics laboratory management in a professional and sustainable manner.

5. Conclusion

Based on the research results and discussion, it can be concluded that the implementation of Project-Based Learning (PjBL) has a significant positive impact on increasing the effectiveness of physics laboratory management at UHAMKA. Improvements occurred in all aspects of management, including planning, organization, implementation, evaluation, documentation, and reporting.

The project-based learning model encourages students to be more active, creative, and collaborative in laboratory activities. Through a project-based approach, students are directly involved in the planning process through to reporting results, making learning more meaningful and oriented towards real-world experiences.

Overall, the implementation of Project-Based Learning not only improves the quality of laboratory management but also develops students' scientific character, responsibility, and critical thinking skills. Therefore, Project-Based Learning is a suitable innovative learning model to support more effective, productive, and sustainable physics laboratory management.

6. Implications of Research Findings

The results of this study indicate that the implementation of project-based learning not only improves students' scientific skills but also strengthens the overall physics laboratory management system. This model can serve as a reference for higher education laboratory managers in developing more innovative, efficient, and relevant learning strategies to meet the needs of the 21st century.

7. Obstacles and Solutions

Several obstacles were encountered during the implementation of project-based learning, including limited laboratory equipment and relatively long project implementation times. To overcome these obstacles, lecturers employed a group rotation strategy, alternated project themes, and utilized digital simulation tools (PhET) and simple Arduino devices. This approach proved effective in maintaining the continuity of activities and the quality of learning without increasing the burden on laboratory facilities.

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