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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 describe the planning, organization, implementation, supervision, and evaluation of the Physics Education Laboratory, Faculty of Teacher Training and Education, UHAMKA. The implementation of laboratory management is combined with a project-based learning model integrated into the physics practicum course. This type of research is a case study with a qualitative approach. The methods used to collect data are observation, documentation, and questionnaires conducted on 22 students taking the physics practicum course in the odd semester of 2024-2025. The results of the study indicate the following: (1) The physics laboratory is well managed, (2) The physics laboratory provides adequate tools and materials and has been implemented well, (3) The process of borrowing and using laboratory equipment is easy to do and is implemented quite well, (4) The head of the laboratory and technicians assist students during the practicum and have been implemented well, (5) The physics laboratory implements work safety standards well. Meanwhile, the implementation of project-based learning used in the physics practicum learning Laboratory is in the very good category. This means that this research provides valuable insights for laboratory management and physics educators in optimizing laboratory learning and operations through a project-based learning approach.

Keywords: Laboratory Management, Project Based Learning, Learning, Physics

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 Tridharma Perguruan Tinggi activities. 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 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 [5]. 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 [6]. 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 [7].

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) [8]. 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 [9].

Laboratory management is the effort to manage a laboratory. The success of a laboratory is determined by several interrelated factors. Laboratory management is an integral part of daily laboratory activities [8, 9]. Successful laboratory management 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 [9, 10]. 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.

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.

The project-based learning model used uses steps, namely determining basic questions based on the problems presented, designing project planning based on the results of problem solving from basic 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 [12]. By conducting lectures with the project-based learning model, all deficiencies in the laboratory management aspect can be completed. All administration and deficiencies in laboratory management evaluation can be assisted by students through the physics practicum course.

From the results of the observations, documentation, and interviews above, it will be used as a background to be able to describe (1) planning (2) organizing (3) implementation (4) supervision and evaluation in the Physics Education laboratory, Faculty of Teacher Training and Education, Muhammadiyah University Prof. Dr. HAMKA. This research will describe the results of the laboratory management case study obtained and will provide an evaluation of the results of the case study research obtained in the Physics Education laboratory of FKIP UHAMKA.

2. Methods

This research employed a case study with a qualitative approach. Data collection included observation, documentation, and a questionnaire conducted with 22 students taking physics practicum courses in the odd semester of 2024-2025. The interview and questionnaire data collection methods were also supported and strengthened by observations and photographic documentation in five physics education laboratories. Observations and documentation were conducted in the optics and modern physics laboratories, the electronics laboratory, the basic physics laboratory, and the physics learning workshop. Observations were conducted by observing the physical condition of the laboratory and the availability of laboratory documents. Documentation was conducted by taking photographs and documenting laboratory administration. The results of the questionnaire are presented descriptively in this study. Table 1 is a list of questions that students need to answer about laboratory management, and Table 2 is an instrument about the implementation of Project-Based Learning (PjBL).

Table 1
Laboratory management instruments

	Laboratory Management Statement Components
Laboratory Management	The physics laboratory is well-managed (well-planned)
	The physics laboratory provides adequate equipment and materials (organization)
	The process for borrowing and using laboratory equipment is easy (administration)
	The laboratory head and technicians assist students during lab work (supervision and maintenance)
	The physics laboratory implements good work safety standards (security)

Table 2
Project-Based Learning (PjBL) Instruments.

	Project-Based Learning Statement Components
Project-Based Learning (PjBL)	The physics practicum I undertook was a project involving solving real-life problems
	I was involved in designing and implementing the physics practicum project.
	The project-based learning model helped me better understand physics concepts.
	Project-Based Learning enhanced my creativity and teamwork.
	I felt more engaged in learning physics through the Project-Based Learning method.

This method was chosen because it allows researchers to obtain more in-depth and contextual information directly from students who have knowledge and experience related to laboratory management [13].

3. Results And Discussion

The first element in laboratory management is planning. Laboratory management without planning will proceed without a clear vision and mission. Laboratory management should also be implemented in conjunction with the elements of management [14]. Laboratory managers within the laboratory's organizational structure must determine plans to ensure smooth, effective, and efficient laboratory activities. Therefore, laboratory planning aims to address several issues, including organizing all laboratory activities, including research, trials (experiments), application of theory in the laboratory, testing of theory, and so on. It also determines success indicators for each stage of the planned activities.

Laboratory management is a vital aspect in supporting the success of science learning, especially in the subjects of Natural Sciences (IPA) and Physics. Laboratory management in the Physics Education study program FKIP UHAMKA will be discussed in 4 aspects: the first aspect is planning, the second aspect is arrangement, the third aspect is administration, the fourth aspect is security, maintenance, and supervision. In this study, data were obtained from the results of interviews and questionnaires filled out by students who had taken the physics practicum course totaling 22 students. The questionnaires were distributed when students had completed the physics practicum lecture and they had conducted observations in the Physics Education laboratory, so that the results of student assessments were accurate when filling out questionnaires related to laboratory management assessments. A summary of survey data using questionnaires filled out by students related to laboratory management in the Physics Education study program FKIP UHAMKA is presented in table 3 below.

Table 3.
Results of Laboratory Management Instruments in the Physics Education Study Program, FKIP UHAMKA

No	Laboratory Management Statement Components	Average	Criteria
1	The physics laboratory is well-managed (well-planned)	70,65 %	Good

No	Laboratory Management Statement Components	Average	Criteria
2	The physics laboratory provides adequate equipment and materials (organization)	67,74 %	Good
3	The process for borrowing and using laboratory equipment is easy (administration)	64,66 %	Pretty good
4	The laboratory head and technicians assist students during lab work (supervision and maintenance)	72,22 %	Good
5	Laboratorium fisika menerapkan standar keselamatan kerja dengan baik / Pengamanan	69,96 %	Good

The results of this researcher's survey were obtained by distributing questionnaires to students via Google Forms, then students assessed them using the questionnaires, resulting in the table presentation above. The distributed questionnaires covered all aspects of laboratory management: Planning, Arrangement, Administration, Security, Maintenance, and Supervision. Therefore, before providing these services, the laboratory must create a well-documented plan. The practicum service plan includes the practicum schedule, the lecturer in charge of the practicum, the practicum time plan, and the practicum activity plan.

Physics Laboratory Management / Planning in the Physics Education Laboratory , Planning is the primary aspect of laboratory management. Planning is a crucial foundation for successful laboratory operation. Performance indicators in the planning aspect that must be present in the management of the Physics Education Laboratory at the Faculty of Teacher Training and Education, Universitas Muhammadiyah Yogyakarta (UHAMKA), include planning for practical services, planning for equipment and materials procurement, and planning for activity funding [15]. Planning in laboratory management will be discussed in full below: 1) The physics laboratory is managed / planned, with mandatory practical services as the primary planning performance indicator. The purpose of the laboratory The purpose of a lab is to provide services for a practicum. This planning must be well-documented so that it can be read by lecturers and students. However, in this practicum service planning, the Physics Education study program has not documented it by printing or sharing it online, so the planning section still received a good score of 70.65%. The planning also requires an administrative tool format or book that includes an inventory book, stock card, request card, borrowed equipment and materials, notebook, label format, etc. [16]. This is necessary to facilitate laboratory assistants or lecturers when proposing items for the practicum. 2) Planning for equipment and materials procurement is a crucial indicator. If equipment and materials are incomplete, the practicum will not run smoothly. The planning for equipment and materials procurement in the Physics Education laboratory is well-documented in the form of a proposal for the procurement of non-consumable equipment and materials. 3) The activity budget planning is very detailed and controlled. Funding will always be facilitated by the university. 4) Subsequent planning is implemented through the laboratory work program document, but this has not yet been documented in a structured manner by the Physics Education study program. Planning documents are still being prepared separately and have not been combined into a laboratory work program document.

The physics laboratory provides adequate equipment and materials (Setup), Laboratory setup includes the arrangement of equipment and materials, the effectiveness and efficiency of

equipment use, scheduling, regulations, equipment usage procedures, lab instructions, and safety procedures. The roles of laboratory assistants and laboratory heads are crucial in setting up the laboratory. Laboratory assistants are responsible for organizing laboratory equipment and materials, ensuring proper equipment availability and repair, and assisting with the implementation of labs. The laboratory head is responsible for establishing regulations, developing standard operating procedures (SOPs) for equipment use, ensuring that each lecturer in charge of the lab submits lab instruction sheets, and developing safety procedures [17]. The arrangement of laboratory equipment in Physics Education must be easy to reach, neat, and easy to see. Therefore, the arrangement of material tools must be in a glass cabinet so that they are easy to find when they are to be used in a practicum. This means that if the tools are used according to their function in the practicum, so that the value of the arrangement section is in the good category, namely 67.74%. Laboratory arrangement, besides the physical form, time must also be arranged. In using the laboratory, time must be arranged, this avoids time conflicts if it is not arranged in the schedule. The laboratory is also used a maximum of 2 times a day for practicums. This is done so that there is time to organize the tools and clean the room after each practicum is completed [18]. Activities in the laboratory must be regulated by rules. Rules are in the form of order in the laboratory.

The process of borrowing and using laboratory equipment is easy (Administration) Administration is the process of recording or inventorying laboratory facilities and activities. According to Rumilah, a laboratory will be effective and efficient if it maintains a complete list, including inventory and equipment maintenance and repair lists.[19] This is also supported by survey results, which indicate that laboratory administration received an average score of 64.66%, which is considered quite good.

The laboratory head and technicians assist students during practicums (Supervision and Maintenance), Supervision in the Physics Education laboratory is carried out by the laboratory head, laboratory assistants, and cleaning service personnel. A persistent shortcoming in laboratory supervision is that not many laboratory assistants have training certificates related to laboratory management. This is inconsistent with the theory of the Ministry of National Education, Directorate General of PMPTK, Directorate of Education, that a lack of knowledge and experience among laboratory personnel often hinders laboratory management [20]. Supervision is also consistently conducted, especially regarding the suitability of equipment and materials for use and their availability. If equipment is no longer suitable, it must be replaced; if it is no longer available, a new one must be procured. Materials that have run out or expired must be replaced and new ones procured. According to Rokhim et al. (2020), monitoring the availability of equipment and materials must be carried out optimally to ensure the smooth implementation and management of practicums [21]. Laboratory supervision in the Physics Education Study Program is good, as evidenced by the questionnaire assessment, which obtained an average score of 72.22%, in the good category.

The physics laboratory implements occupational safety standards (Safety), Laboratory safety in the Physics Education Study Program is good, as evidenced by the questionnaire assessment, which scored 69.96%. Laboratory safety in the Physics Education Department, Faculty of Teacher Training and Education, Universitas Muhammadiyah Yogyakarta (UHAMKA), has become a culture within the laboratory. Safety in the laboratory is crucial. Laboratory safety is an effort to prevent adverse impacts in the laboratory, such as hazardous chemical leaks,

exposure to organisms, illness, and accidents involving laboratory equipment [22]. The method consistently used is to accustom all laboratory personnel to prioritize occupational safety, comply with regulations, and follow standard operating procedures (SOPs) when conducting lab experiments.

Implementing Project-Based Learning in Laboratory Management, In physics practicum courses, this model is frequently used by lecturers to assist with laboratory management. During the implementation phase of laboratory management, this project-based learning model is particularly helpful in inventory management and laboratory administration. Students taking physics practicum courses will actively participate in the various phases of laboratory management, particularly implementation, as shown in Table 4.

Table 4
Results of Student Instruments on the Implementation of Project-Based Learning

No	Project-Based Learning Statement Components	Average	Criteria
1	The physics practicum I undertook was a project involving solving real-life problems	75,66 %	Good
2	I was involved in designing and implementing the physics practicum project.	84,28 %	Very Good
3	The project-based learning model helped me better understand physics concepts.	80,86 %	Very Good
4	Project-Based Learning enhanced my creativity and teamwork.	85,34 %	Very Good
5	I felt more engaged in learning physics through the Project-Based Learning method.	82,65 %	Very Good

From table 4 above, Project Based Learning has a syntax of determining basic questions, designing projects, preparing project schedules, designing projects and monitoring the progress of project creation and testing project results. Project Based Learning is a learning that has a long period of time, focusing on student activities in understanding which are then implemented in project work, so that students get meaningful learning experiences from knowledge that is built independently [23]. and principles by conducting in-depth investigations related to a problem and finding solutions. Project Based Learning often utilizes laboratories as a tool to support learning. Laboratories are places to carry out experimental or practicum activities [24].

Practicum in the form of a project that involves solving real problems, In the first stage of implementing Project Based Learning, the steps taken by the lecturer are to provide an explanation regarding a project or problem and inform the benefits and objectives of the project that will later be carried out by students with a value of 75.66% in the good category. Meanwhile, in designing and implementing the practicum project that is carried out also depends on the learning achievements of the course and sub-indicators to be achieved, this is supported by the results of a score of 84.28% with a very good category. Students said that project-based learning makes them understand physics concepts better by 80.86% with a good category, and are more interested in learning physics through Project-based learning by 82.65% with a very good category. Students who take laboratory management courses will actively participate in the

phases of laboratory management, especially implementation [25]. Project-based learning can also improve high-level thinking skills in the cognitive learning domains of C4, C5, and C6.

4. Conclusion

Laboratory management encompasses four aspects: planning, organization, implementation, security, supervision, and maintenance. (1) Planning in laboratory management, including the effectiveness and efficiency of equipment use, scheduling, regulations, equipment usage procedures, laboratory instructions, and work safety procedures, has been implemented well; (2) the organization of laboratory equipment, materials, and administration has been implemented quite well; (3) the implementation of laboratory work programs has been carried out well; (4) Laboratory security is consistently maintained by accustoming all laboratory users to prioritize work safety in accordance with regulations and implementing SOPs when conducting laboratory work, and this has been implemented well. Overall, the management of the Physics Education Laboratory at the Faculty of Teacher Training and Education, Muhammadiyah University Prof. Dr. Hamka, can be categorized as good, with the caveat that administrative aspects still need to be a primary focus for improvement. In addition, strengthening planning documentation, laboratory staff competency, and work safety culture needs to be continuously developed so that the laboratory can function more optimally.

Transparency

The authors confirm that the manuscript is an honest, accurate, and transparent report of the research; that no important features of the research have been omitted; and that any deviations from the planned research have been explained. This research adhered to all ethical practices during the writing process.

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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 improvements in the quality of physics laboratory management after the implementation of the Project-Based Learning (PjBL) model. The research focused on five key aspects of laboratory management: planning practical activities, organizing tools and materials, implementing activities, evaluating practical results, and documenting and reporting. The research method used a quantitative approach with a one-group pretest–posttest design. The study subjects consisted of 22 students taking the Physics Practical course in the odd semester of the 2024–2025 academic year at Muhammadiyah University Prof. Dr. HAMKA (UHAMKA). Data were collected through observation, documentation, and questionnaires using expert-validated instruments. Data analysis was performed using descriptive-comparative statistics to compare average scores before and after the implementation of PjBL and to calculate the percentage improvement in each aspect. The results showed that all aspects of laboratory management improved after the implementation of the PjBL model. The highest improvement occurred in documentation and reporting (19%), followed by planning lab activities (18%), evaluating lab results (17%), implementing activities (15%), and organizing tools and materials (14%). These findings confirm that the PjBL model encourages students to be more independent, reflective, and collaborative in managing laboratory activities. Conclusion: The implementation of Project-Based Learning has proven effective in improving students' abilities to systematically and collaboratively plan, implement, evaluate, and document laboratory activities. This model also strengthens students' scientific character through contextual, project-based learning activities. Implications: The results of this study provide an empirical basis for educators and laboratory management to integrate the Project-Based Learning model into physics lab activities. The implementation of Project-Based Learning can be used as a strategy to improve the quality of laboratory management, strengthen students' managerial skills, and support the transformation of science learning toward a more participatory and reflective approach.

Keywords: Laboratory Management, Project Based Learning, Learning, Physics

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, 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 [10]. Arikunto 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 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. 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, Wahyuning's 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 (2018) 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:

- o Lecturer teaching the Basic Physics course
- o Laboratory assistant
- o 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

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

2.4.2. Implementation Stage

- o Implementation of practicum activities using the Project-Based Learning model, which consists of six main steps (Thomas, 2000):
  - ❖ 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 (1994):

- 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

Aspek Manajemen Laboratorium	**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

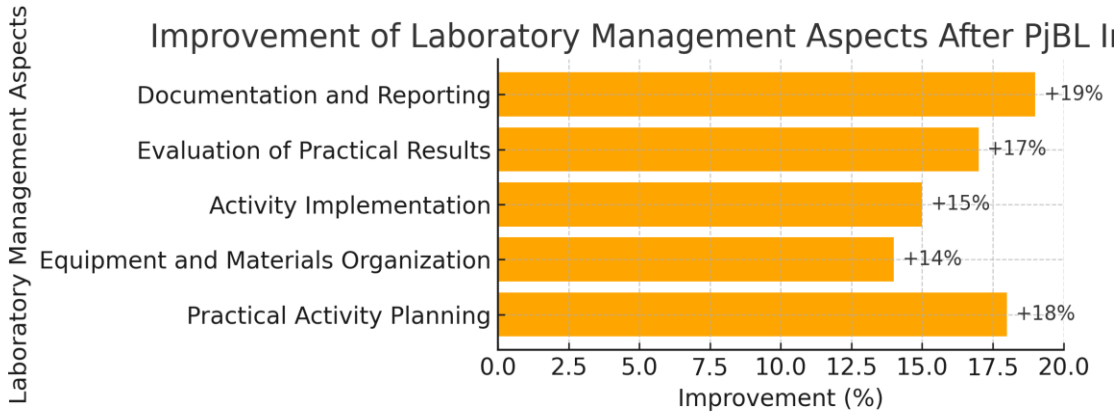

Figure 1
Laboratory Management Graph after using project based learning

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's opinion that Project-based learning encourages students to produce or create reports that are reflective, communicative, and accountable as part of academic responsibility [24].

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 & Wina 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 [24,25].

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 [26]. Meanwhile, the results of research by Yuliana 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 [27].

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's theory (1984) which states that effective learning occurs through the active involvement of participants in the process of exploration and reflection on real experiences [28].

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 emphasized that good learning management requires planned resource management to achieve effective learning activities [29].

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.

Transparency

The researcher/author confirms that the manuscript is an honest, accurate, and transparent research report; no important features of the research have been omitted; and any discrepancies from the planned research have been explained. This research adhered to all ethical practices throughout the writing process.

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Conflict of Interest Declaration

The author declares that there are no potential conflicts of interest, either financial or non-financial, that could have influenced the results, interpretation, or writing of this article. All authors worked independently based on the principles of scientific objectivity and academic integrity.

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Author Contribution

Imas Ratna Ermawati	Research conceptualization; methodology development; formal analysis; research implementation; data collection and processing; writing the initial draft of the manuscript.
Sugianto	Supervision; validation of research results; manuscript review and editing; project administration.
Tri Isti Hartini	Methodology development; instrument validation; manuscript review and editing.
Onny Fitriana Sitorus	Provision of data sources; field data collection; visualization of research results.
Dasmo	Research conceptualization and direction; academic supervision; funding acquisition; final review and editing.
Nuraini Nanda Sari	Data processing; statistical analysis; preparation of documentation and reporting of research results.

All authors have read and approved the final version of this manuscript and agree to be responsible for the entire contents of the article, both in terms of accuracy and scientific integrity of the research.

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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

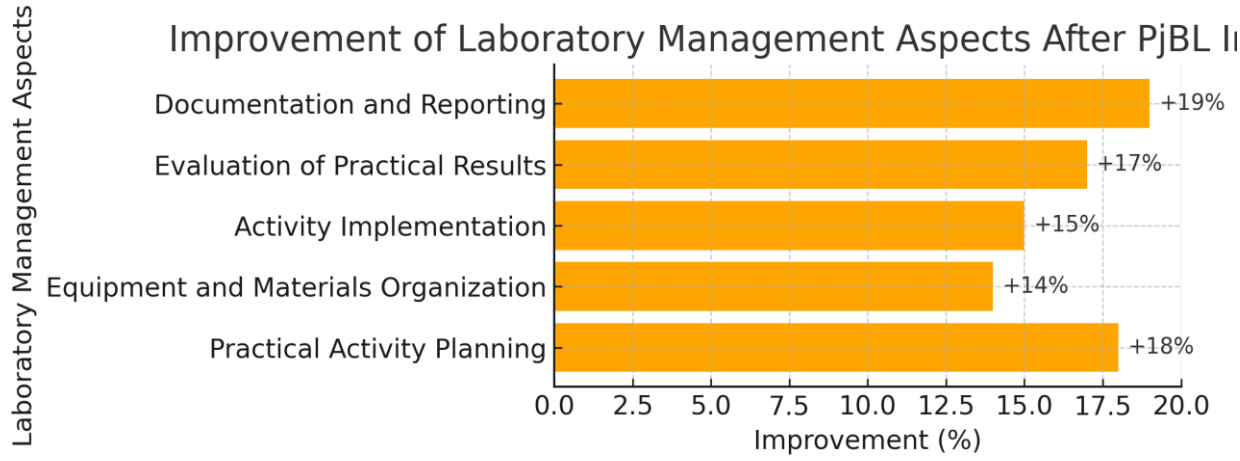

Figure 1.
Laboratory Management Graph after using project based learning.

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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