Active and Authentic Learning in Remote Laboratory: Means of Improving Prospective Physics Teachers' Multiple Representation Ability

Siska Desy Fatmaryanti [1], Dwi Sulisworo [2], Nooraffandi Yahaya [3], Ishafit Ishafit [2], Muji Setiyo [4], Yusro Al Hakim [1], Eko Setyadi Kurniawan [1]

[1] *Universitas Muhammadiyah Purworejo, Purworejo, Indonesia*
[2] *Universitas Ahmad Dahlan, Yogyakarta, Indonesia*
[3] *Universitas Teknologi Malaysia, Johor, Malaysia*
[4] *Universitas Muhammadiyah Magelang, Magelang, Indonesia*

Abstract **– Remote laboratories are a new domain that allows students and teachers to conduct experiments in hands-on exploration remotely. We studied how constructing an active and authentic learning in a remote laboratory affects prospective physics teachers' multiple representation ability. The research method used is based on the development procedures of the ADDIE research and development model. We have designed and validated a learning design with a remote laboratory environment with 2 physics experiment apparatuses, active and authentic learning stages, multi-representation ability assessment, and remote laboratory application evaluation tools. This study implemented design-based research with a one-group pre-test and post-test design. The research was conducted on 28 prospective physics teacher students. In terms of effectiveness, this learning design was able to improve significantly [t (28) = 7.480, p.05] in verbal, visual, and mathematics representation ability. Therefore, it can be used by lecturers and those in other science fields to improve the quality of learning and developing prospective physics teachers' multiple representation Skills.**

Keywords **– Active learning, authentic learning, remote laboratory, multiple representation ability, prospective physics teacher.**

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Corresponding author: Siska Desy Fatmaryanti,
Universitas Muhammadiyah Purworejo, Purworejo, Indonesia
Email: siskadesy@umpwr.ac.id

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1. Introduction

In the perspective of the challenges of science education towards technological progress, it is important to develop skills for prospective physics teachers. Among these skills is a basic proficiency in conveying complex physics concepts through a variety of representations. The ability to understand, interpret, and communicate scientific concepts effectively through various forms of representation is a characteristic of a skilled physics teacher. In an era characterized by technological advances and continuously evolving pedagogical paradigms, the role of prospective physics teachers is not limited to delivering traditional content. They need to involve the use of a variety of representations, including visual, mathematical, and experiential to engage students with different learning styles and preferences.

The use of technology in the classroom has been rapidly increasing in recent years due to the rapid development of new educational technologies. How teachers may integrate technology into their classrooms has become a key issue in recent years. Several researchers [1], [2], [3] have discovered that a good balance of material and pedagogy with related lecturers to share and interchange their classrooms with technology is essential. Moreover, technology can be used to overcome pedagogical challenges in lesson planning [5].

In other words, technology can help teachers use content, pedagogy, and technology that are appropriate for each student [6], [7].

How to extend traditional hands-on laboratory settings across the Internet is a special problem for online education. Hands-on laboratories have been an integral feature of undergraduate science education programs since the beginning of science laboratories [8]; topics taught through lectures are frequently supplemented with laboratory experiments. Hands-on education exposes students to the foundation of the science laboratory by allowing them to perform experiments, observe dynamic events, test ideas, learn from their mistakes, and reach their conclusions. With the fast advancement of microprocessors and communication technology, an increasing number of instruments may be altered and operated remotely. These new features have enabled remote hands-on teaching through the Internet.

Remote laboratories are an emerging domain in science education. These virtual environments allow students and educators to conduct experiments, collect data, and engage in hands-on exploration remotely. This article investigates the field of active and authentic learning in the context of remote laboratories, exploring how this innovative approach serves as an effective means to improve the multiple representation skills of future physics educators.

2. Theoretical Framework

In this study, we examined how constructing an active and authentic learning design in a remote laboratory affected prospective physics teachers' multiple representation ability. We studied the effects of a remote laboratory learning design on prospective physics teachers' competence in integrating and using technology in the classroom. Learning design was also evaluated for three items: (i) phases of an active and authentic learning process (ii) suitable direction to operate apparatus and all equipment in containing a remote laboratory, and (iii) using multiple assessment techniques.

2.1. Active and Authentic Learning

Active learning is a broad concept that typically refers to student-centered and engaging instructional strategies and instructor-led activities [9], [10]. Constructivism is applied as a framework for developing pedagogical approaches that are designed to enhance deep knowledge [11], [12]. Active learning aims to help students plan their own learning processes with a focus on building internal knowledge [9], and responsibility [12] for students.

Authentic learning (AL) is a method of learning that brings information in real-life contexts and forces students to think about and solve problems as if they were occurring in real life [13]. The constructivist viewpoint is the theoretical basis for the approach that is used in AL. According to this approach, students create their understandings of new ideas and procedures by combining together previous experience, resources, their studies, and their current experiences [14]. As a result, participants can draw comparisons and construct mental bridges between the concepts they learn and their application to real-world situations [15].

Work assessment is one type of authentic assessment that is used to examine particular abilities that students are required to have. In a performance assessment, examinees demonstrate their knowledge and abilities by participating in a process or producing a product [16]. Students can use performance assessment to actualize their conceptual knowledge and abilities to acquire specified competencies. Students are directed to carry out instructions and work assignments in an organized way via performance assessment.

Laboratory work is vital to balance cognitive, emotional, and psychomotor factors [17]. It can provide students with opportunities to engage in authentic scientific practice [14], develop technical laboratory skills [17], and collaborate with others in designing and constructing experiments, collecting and interpreting data, and communicating scientific content [18].

The basis of instructional laboratory work in the undergraduate curriculum is that students can practice in a "hands-on or mind-on" manner [19], [20]. Work laboratory in this study is regarded as a learning technique that incorporates students in direct experience utilizing scientific procedures, laboratory abilities, and scientific attitudes, based on many definitions of laboratory work.

2.2. Remote Laboratory

In 1999, the idea of "remote laboratories," which use the Internet to connect to real plants, was first placed forward [21]. Experience has shown that engineering students are more motivated to learn hard theoretical ideas when they have the chance to test them out in real-world experiments where projects and teamwork are important. This is referred to as active learning [10], [22]. With an increasing number of students, providing learning experiments is a challenge with limited time and financial resources. This problem can be solved by implementing a remote laboratory for hands-on experiments. In the current era it is imperative to provide renewal of learning in education [23].

In recent years, studies have been conducted to assess the efficiency of remote laboratories in teaching. The effects of student learning experiences in remote laboratories have been reported [23], [24]. However, from the author's review of the literature, studies on the effect of remote laboratories on student group interactions in class have not been reported.

2.3. Multiple Representations

Learners' ability to represent concepts in different ways is an interesting topic in modern science and mathematics education. A specific idea or problem can be expressed in different representations [25], [26]. As a science that studies natural phenomena, physics must be able to present different representations to understand the same concept or topic. The ability to describe physical processes in multiple representations can help learners solve physically demanding problems. Maste ry of physics content can therefore appropriately derive from mastery of multiple representations of physics, namely verbal, mathematical, pictorial, an d graphical representations [27], [28].

Learning design must consider the complex relationship between the tasks given to students, cognitive processes, integrating technology and the way of perception of the various media used by teachers [29]. Apart from that, teachers must also be able to meet students' different learning needs by utilizing various methods that allow students to interact with the material they are studying [30].

There are some students who have difficulty interpreting and understanding verbal instructions but will easily respond to what they see. Other students may find it easier to read, and maybe they can also understand easily by being listeners [31].

3. Method

This research is development research carried out using the ADDIE research and development design model. This model is more generic and simple which helps researchers design products that will help students improve their abilities in the learning process [32]. This research is intended to be used as a guide in developing active and authentic learning in a remote laboratory environment that is effective and efficient in improving the multi-representation ability of prospective physics teacher students. The ADDIE development model consists of five stages, namely analysis, design, development, implementation, and evaluation. In summary, the research process in each stage of the ADDIE model is as presented in Figure 1.

This research was conducted on 28 prospective physics teachers (6 men and 22 women) who were enrolled in the school physics laboratory course. Participants have taken pedagogy courses, namely physics education planning and laboratory management before. All of these courses are taught in a hands-on laboratory environment. They have also taken technology-based courses that primarily focus on digital electronics and basic programming languages.

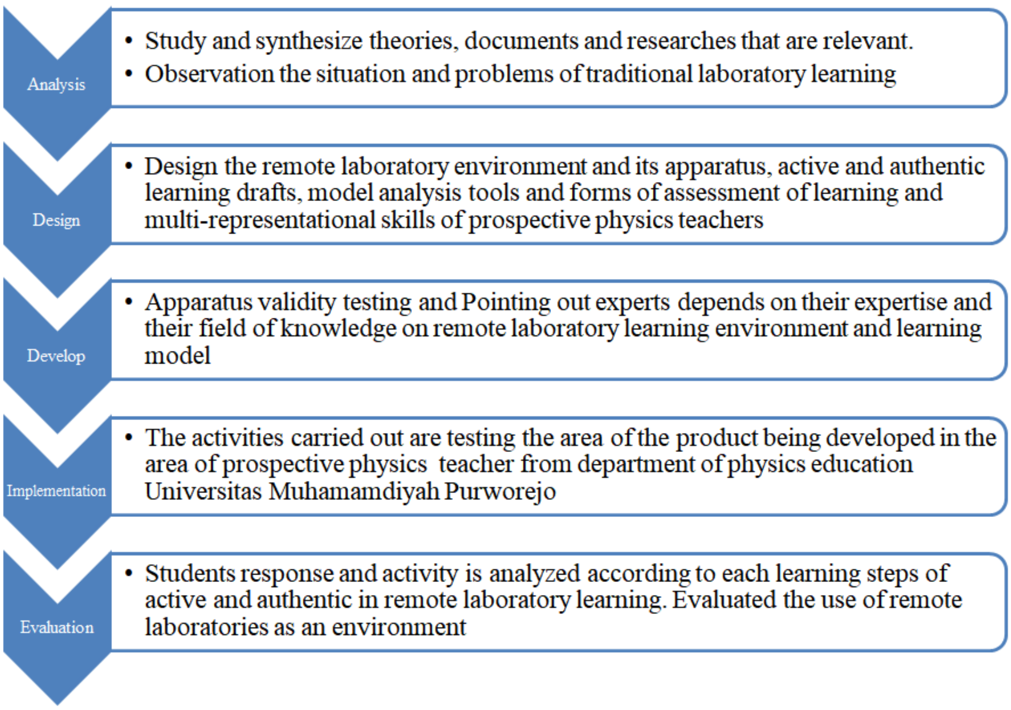

Figure 1. Research process with ADDIE model stage of development

The analysis phase is carried out in several ways including field studies and literature studies. We studied the situation and problems of traditional laboratory learning. During research observations, data was collected to evaluate active and authentic learning experiences involving remote laboratory learning environments for prospective physics teachers. After that, the data is analyzed together with theoretical studies, documents and relevant research to reconstruct a learning model that is more effective and suits students' needs. In addition, through relevant research and document, a study of multiple representation skills measurement instruments was carried out in remote laboratory environment.

The results obtained from the analysis phase become the basis for the second phase. In this phase we design the remote laboratory environment and its apparatus, active and authentic learning drafts, model analysis tools and forms of assessment of learning and multi-representational ability of prospective physics teachers.

In the development stage, tool validity testing and learning device validation were carried out. Validation of learning devices was carried out by two experts in the fields of educational technology and physics education to ensure the suitability of the devices to be used to achieve learning objectives. Reliability tests and agreement tests were also carried out between the two value results using the Cohen's Kappa coefficient with the help of the IBM SPSS Statistics 25 application. The Kappa coefficient is the Inter-Rater Agreement index that is most commonly used in measuring agreement on the assessment of categorical variables assessed by two raters [33].

At the implementation stage, pre-experimental design was chosen as the experimental research method. This method is used to find causal relationships involving only one group of subjects or no control group which can affect internal validity [34]. Descriptive statistics are used to analyze data collected from pre-test and post-test results from each form of representation using average scores and standard deviations. After that, as an inferential statistic, a paired sample t-test was carried out to compare the pre-test and post-test scores of the students to determine whether there were significant differences in their multiple representation abilities during the study.

At the evaluation stage, researchers evaluated the observation results of student responses and activities by analyzing suitability with active and authentic distance laboratory learning steps. Observation data was used to evaluate the remote laboratories as an environment. We used the assessment item from learning design development with analysis data using average scores and standard deviations.

4. Results

The results and analysis of research on how to construct active and authentic learning in a remote laboratory on the multi-representational abilities of prospective physics teachers are presented in detail in each stages of the ADDIE development model below.

4.1. Analysis

In physics learning, hands-on activities in the laboratory have a very important role. In reality, these activities are often difficult to implement due to financial and practical constraints. However, along with the latest technological advances, science learning laboratory activities can be carried out through interaction with computers. Remote laboratories can be a solution for schools that have limited laboratory equipment through access to experience and learning outcomes.

In this stage we also conducted a study regarding indicators of multiple representations ability needed by prospective physics teachers. In general, multi-representation ability can be divided into 3, namely verbal representation (VeR), visual representation (ViR), and mathematical representation (MR). Study of assessment indicators for each type of representation adapted to the learning environment, remote laboratory, and active and authentic learning. The assessment indicators for each representation skill are presented in Table 1.

Table 1. Multiple representations ability for prospective physics teacher

Representation	Indicator
Verbal representation (VeR)	Finding concepts verbally through the presentation of physical phenomena, data, and information presented. Interpret the meaning of a concept in written form (verbal).
Mathematics Representation (MR)	Conclude conditions with mathematical equation operations to get results.
Visual Representation (ViR)	Connect the variables contained in a problem in the form of images, tables, diagrams, and graphs to solve problems.

4.2. Design

The distance learning environment is not intended to replace the conventional classroom, but it is designed to enhance learning outside the classroom. In simple terms, we design a learning environment with remote laboratory as in Figure 2.

The remote laboratory server can be an experiment connected to a computer via a standard interface and with a host computer connected to the Internet. The client can be any computer connected to the Internet running a simple browser. In this research we use data acquisition (DAQ) sensor with LabView Interface and remote desktop application for browser. Once connected, teachers and students will see the same front panel as the local host and also have the same program functions.

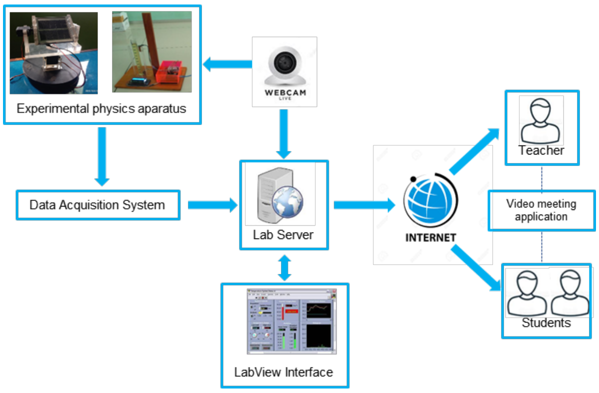

Figure 2. Learning design with remote laboratory environment

Guidance is used in the remote laboratory environment to promote students' self-regulated learning. In our previous research [35] there were two essential parts in learning with virtual or remote environment to support self-regulated learning by students. First part is about student interaction with environment (remote laboratory). Second part is about how students communicate their experiment. After conducting a literature review, researchers modified the five phases of active and authentic learning. These modifications consider important aspects in the context of a remote laboratory environment, such as the need to consider pedagogical implications, the link between student interactions and laboratory learning, and engaging students in a reflective process. The modification process refers to findings and recommendations in the literature to improve the overall student learning experience.

In this lesson, lecturers have to create real experiments in real life. Therefore, in these learning phases, apart from observing and collecting data, students are also required to be able to provide good explanations of the content of physics material, mathematical equations and benefits for everyday life. This can be seen in phases 2, 3, and 5 in Table 2.

Table 2. Students' activities in each phase of active and authentic learning

Phase	Students' activities
Phase 1: Observational experiment	Observing from simple observational experiment
Phase 2: Pattern identification	Identifying patterns using appropriate presentation
Phase 3: Making hypothesis, explanation, and models	Developing explanation or mathematical model
Phase 4: Testing experiment	- Designing experiment - Making the prediction based on the explanation of relation under test
Phase 5: Reflection and revision	Comparing the outcome to the prediction

4.3. Development

The application of the remote laboratory concept for physics learning in schools and universities is based on physics experimental apparatus and computerized data acquisition systems. For this reason, we also developed 2 apparatuses, namely apparatus for experiments on light energy on the solar panel and viscosity in fluids.

Solar tracking systems play an important role in solar energy applications. The first apparatus used an automatic tracking mechanism using a light sensor (Figure 3). The control system uses LabVIEW which is programmed to determine the direction of movement of the solar panels so that sunlight can fall perpendicularly on the panels.

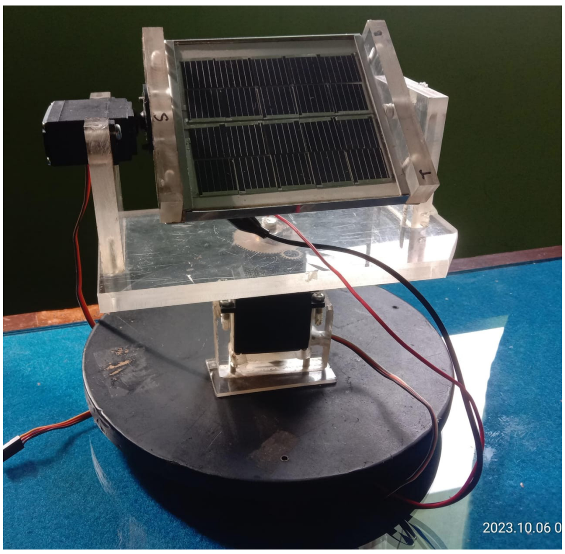

Figure 3. Apparatus for experiments on light energy with two axis solar tracker

An example of the second apparatus that we developed is a fluid viscosity meter (Figure 4). In this experiment, students measured the viscosity of vehicle oil and cooking oil. The automation system uses a mini reed switch magnetic sensor to detect the fall of a magnetic ball dropped into the fluid.

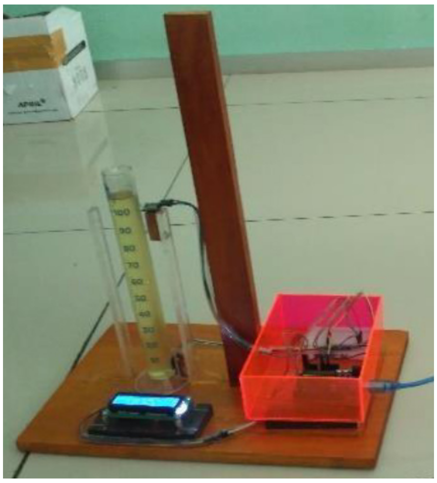

Figure 4. Apparatus for experiments on viscosity in fluids

A data acquisition system using a computer/laptop requires a conversion process from analog signals to digital signals. So software is needed for processing and controlling the process. One of the softwares that can be used as a data acquisition system is Laboratory Virtual Instrument Engineering Workbench (LabVIEW). LabVIEW is graphical programming so that users can create instrumentation which is called a virtual instrument and can be used for remote data acquisition, analysis design, and distributed control. The LabVIEW used in this research is used as users interface (Figure 5) to make it easier for users to run the system, retrieve, collect, and prepare data.

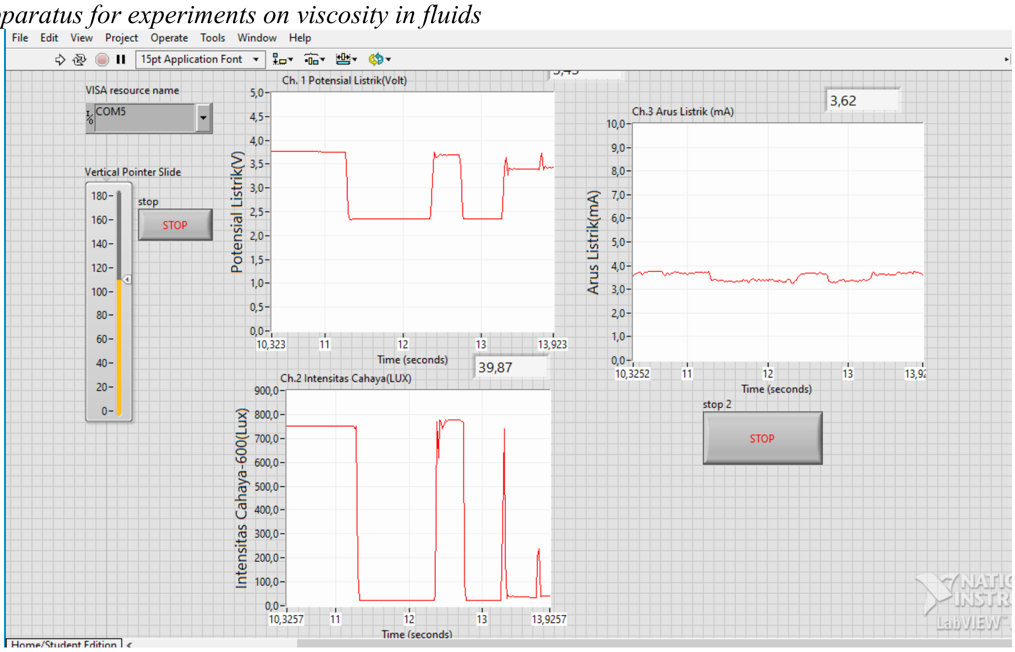

Figure 5. LabView front panel

These two apparatuses have been validated in laboratories with results that are suitable for use. For the assessment of multiple representation ability we found Cohen's kappa coefficient (κ) as 0.78 for verbal representation (VeR), 0.86 for mathematics representation (MR) and 0.87 visual representations (ViR). Meanwhile assessment for evaluation of implementation for remote laboratory environment we found Cohen's kappa coefficient (κ) as 0.88 for active and authentic learning process, 0.93 for sufficient guidance, and 0.84 various assessment tools.

4.4. Implementation

A description of the data from the pre- and post-test results of each aspect of representation is shown in Table 3. It was found at the end of the study that on average the prospective physics teacher students had developed multiple representation ability at a sufficient level (69.04/100). Even though their multi-representation ability in the MR aspect score was the lowest, their ability in the VeR aspect was at the highest score.

Table 3. Pre-test and post-test results of the scale concerning each representation

	VeR Mean (SD)	ViR Mean (SD)	MR Mean (SD)
Pre-test	65.34	67.50	65.83
Post-test	78.60	72.86	69.04
Mean different	13.26	5.36	3.21

After determining the normality of the data using the Kolmogorov-Smirnov test (pre-test=0.076; post-test=0.126), data analysis was carried out using the paired sample t-test. In Table 4, the results of the paired sample t-test findings are presented for each aspect and the overall scale. The results showed that students were able to improve their multiple representation ability significantly [t (28) = 7.480, p.05] after implementing active and authentic learning using remote laboratory environment.

Table 4. Paired samples t-test results concerning each representation

Representation	t	Sig. (2-tailed)	d
VeR	6.673	0.010	1.65
ViR	3.264	0.045	1.57
MR	1.029	0.060	-
Total	7.480	0.000	1.86

Except for the MR aspect, the students have been able to develop their ability in other aspects (Table 4). In fact, their ability in the MR aspect have increased, but it is not statistically significant. The overall findings suggest that incorporating a guided learning environment, as well as integrating remote labs and other assessment tools, has a major impact on multiple representation ability.

4.5. Evaluation

At the evaluation stage, the implementation of active and authentic learning is analyzed according to each learning phase. Table 5 presents the findings from observations from two meetings regarding the learning activities of prospective physics teacher students. All activities are grouped and reviewed based on active and authentic learning phases in a remote laboratory environment.

So far, the learning process for basic physics experiments is still traditional through direct observation and data collection in the laboratory carried out in groups. Students tend to be passive by filling in existing worksheets and based on existing theories without analysis. From the results of observing this activity (Table 5), it can be seen that the majority of students were active in learning, especially during the observation and reflection phases.

In this case, remote laboratories can help provide a learning environment so that students have the opportunity to participate by making real process calculations in real time. Apart from that, it can be used to experiment with their curiosity about equipment and how it works. This means that this remote laboratory activity allows the lecturer to introduce several ideas regarding how future teachers will work. In this solar tracker experiment, students can access a graphical interface where they can see changes in light intensity with changes in the angle of the light's position relative to the cross-section.

Table 5. The mean score of prospective physics teacher activities

Phase	Student activities	
	1	2
Observational experiment	3.00	3.38
Identify pattern	2.62	3.25
Making hypothesis, explanation and models	3.00	3.67
Testing experiment	2.86	3.00
Reflection and revision	3.33	3.67

Apart from evaluating the implementation of the learning phases, we have also evaluated the use of remote laboratories as an environment and the use of various assessment tools as seen in Table 6. From the overall implementation findings show that all evaluation criteria in learning were implemented at a moderate level (3.61/5.00). Meanwhile, the average score for the criteria for following the active and authentic learning stages in learning is 3.72, which is the highest score, while the average score for the criteria for using a distance laboratory with adequate guidance is 3.45, which is the lowest score.

Table 6. Evaluation criteria for implementation of the learning phases

Criteria	Mean	SD
The active and authentic learning process	3.72	0.72
Suitable direction to operate apparatus and all equipment in containing a remote laboratory	3.45	0.94
Using multiple assessment techniques	3.66	0.97

Achieving the highest score on the evaluation criteria for active and authentic learning may be because students are already familiar with authentic learning from previous courses.

During observations of the implementation of learning at the involvement and investigation stages, there were still several findings, for example, students were still just memorizing basic physics concepts rather than analyzing facts obtained from the research and information gathering process.

5. Discussion

In this research we have investigated the effectiveness of creating active and authentic learning designs on the multiple representation ability of prospective physics teacher students. It is important to measure teachers' multiple representation ability with the aim of providing insight into teachers' use of technology [29], [36]. The long-term goal is to provide provisions so that when they become teachers they can use their multiple representation abilities to integrate technology in lesson plans.

From the results of the data analysis above (Table 3 and Table 4), it shows that the multiple representation ability of prospective physics teacher students increased rapidly at the end of the lesson. Students' multiple representation ability was found to be significantly influenced by lesson planning. Several other studies have found that learning planning that involves active students, as well as authentic learning, can influence students' perceptions and self-confidence regarding technology integration [37], [38]. Students who take part in this learning are senior students in the physics education department, and most of them have taken content and pedagogy courses, so implementing a learning model that requires the integration of technology, pedagogy, and content is easier. We came to specific conclusions. Specifically, it can be concluded that the representation in the VeR and ViR categories of prospective teacher students increased significantly. But in the MR category, there was no significant increase. Students read more about the application of case studies and present in graphic form experimental data.

In designing a remote learning strategy, this laboratory uses a lab interface and visualization to make the learning experience more realistic. Several studies show that when learning uses distance or virtual laboratories, students tend not to always believe the data obtained [35], [39], [40]. The use of interfaces and visualization with a web camera is intended to make students feel like they are in a realistic work space by carrying out actual experimental steps. As in the fourth phase, testing experiment, students are asked to write research questions to encourage curiosity, design experiments, make predictions, and analyze their own results.

Remote laboratories with the addition of visualization and interface are able to create an authentic, contextual, and enriching learning environment. Even though the lab location is far away, the simulation looks the same on the screen. Remote lab connections to real devices are an integral part of the system in creating a realistic laboratory experience. These findings are very useful considering that current learning demands are to place more emphasis on scientific learning [41], and more authentic lab experiences [42], [43], [44].

In other research on science students, it was also reported that the learning experiences gained in laboratory experiments influenced student motivation in other science courses [8], [17], [4]. The implementation of authentic remote laboratories, which actively engage students and are easily accessible to students, can have a positive impact on their experience as future physics teachers. This is very important when in future work they are placed in schools with limited resources and equipment. They can consider this remote laboratory as a solution to these limitations because the online learning trend will continue to develop and this will be a solution to access laboratory equipment in other possible places such as universities or industry.

6. Conclusion

We have succeeded in developing learning designs in remote laboratory environments with active and authentic learning. This learning has 5 phases, namely observational experiment, pattern identification, making hypothesis, explanation and models, testing experiment, and reflection evaluation. This research found that prospective physics teachers' multiple representation skills were developed significantly when using active and authentic learning with remote laboratory environment. This means that when students are given the opportunity to practice technology in laboratory learning, their multiple representation abilities also increase. It can be concluded that active and authentic learning can be adapted to each other efficiently.

Based on the results of our research and its limitations, there are several recommendations for future research. First, we used various measurement tools to assess active and authentic learning lesson plan, yet we were not able to observe students' misconception in material physics. Second, developing active and authentic learning lesson plan cannot be done instantly and quickly, it takes quite a long time. For this reason, it is also necessary to carry out longitudinal studies, for example observing teachers based on their capability in operating remote laboratory and students' attentions for remote laboratory activities.

It is primarily suggested that physics teachers should be exposed to technological tools in their laboratory and should be using their multiple representations' ability to develop learning.

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