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Analyzing the Motivation and Self-Regulated Learning of Prospective Physics Teachers in Virtual Laboratory-Based Fundamental Physics Experiments

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Abstract: Virtual laboratories have emerged as innovative solutions in education, particularly in overcoming the limitations of physical laboratory infrastructure. In prospective physics teacher education, understanding how virtual laboratories influence motivation and self-regulated learning is crucial. This study aims to describe the motivation and self-regulated learning among prospective physics teachers participating in virtual laboratory-based fundamental physics experiments. A descriptive quantitative approach was employed, involving 27 prospective physics teachers at the Universitas Sulawesi Barat. Data were collected using a questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ). Results show that all items scored within the high category, with mean values ranging from 3.65 to 4.34 on a 5-point Likert scale, indicating generally high levels of motivation and self-regulated learning. However, one item (A5) indicated a relatively lower mean score, suggesting that some participants may be more extrinsically than intrinsically motivated. Additionally, most respondents perceived the virtual laboratory as moderately to highly helpful in understanding physics concepts. This study contributes to the development of technology-based learning strategies and emphasizes the importance of designing learning experiences that strengthen prospective teachers' self-belief. Further research should employ qualitative methods to explore the deeper learning experience of prospective physics teachers in virtual laboratories.

Keywords: Fundamental physics experiments; Motivation; Prospective physics teachers; Self-regulated learning; Virtual laboratory

Introduction

Physics plays a vital role in technological advancement and sustainable development by providing a foundation for scientific thinking and problem-solving (Mitrevski, 2019). Understanding physics means understanding nature and its principles, which form the foundation for many other scientific disciplines (Prihatiningtyas et al., 2024).

However, the implementation of physics learning faces several challenges. Laboratory equipment can be expensive and not available to some educational institutions. Purchasing equipment, maintenance, training, support, and cost of use can be prohibitively

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expensive or not available in regions of the world, such as many developing countries (Grout, 2017).

One of the key challenges in physics education is the low quality of instruction across different educational levels. The quality of both the learning process and outcomes in physics is influenced by several factors, including the availability of laboratory facilities. Laboratory activities are essential components of physics learning, as they enhance product, process, and attitudinal aspects—critical for solving real-world problems (Harjono et al., 2017; Supurwoko et al., 2017).

To overcome these limitations, teachers, as the primary facilitators of practical learning, must adopt current instructional technologies, such as virtual laboratories, to improve learning effectiveness (Achuthan et al., 2023). In the digital era, many educational institutions have transformed their physical laboratories into remotely accessible environments, known as remote labs (Nesenbergs et al., 2021; Reginald, 2023).

The advancement of virtual laboratory technologies has significantly impacted science education, offering innovative solutions to traditional challenges in laboratory-based learning (Ghergulescu et al., 2019; Zhang et al., 2024). Virtual laboratories have emerged as effective tools in science education, offering accessible and cost-efficient alternatives to traditional laboratory experiences (El Kharki et al., 2021). Given these widespread advantages, it is unsurprising that interest in virtual laboratories has grown steadily in education research. A bibliometric review of virtual laboratories in science education from 2013 to 2023 highlights their crucial role in transforming science education through innovative technological integration. The findings reveal a significant expansion in the use of virtual labs across multiple disciplines, demonstrating their versatility in enhancing learning experiences and outcomes (Zhang et al., 2024). Virtual laboratories excel in accessibility, convenience, and cost-effectiveness, making them highly valuable tools in remote learning environments (Ching-Pong Poo et al., 2023).

Research on virtual laboratories has grown rapidly since 2010, with a peak in publications occurring between 2019 and 2021, driven by the COVID-19 pandemic (Raman et al., 2022). A study by Eliza et al. (2024) demonstrated that a Proteus-based virtual laboratory fosters constructivist thinking in electrical measurement practices (Eliza et al., 2024). Diwakar et al. (2023) found that learning concepts using graphic animations in virtual laboratories had a greater impact on students' intrinsic motivation compared to e-book-based materials (Diwakar et al., 2023). A systematic review by Sapriati et al. (2023) showed that virtual laboratories can serve as effective tools for delivering learning experiences, as they help bridge the gap between students' prior knowledge and real-world experiences, while also promoting more active social engagement (Sapriati et al., 2023).

Studies have consistently shown the effectiveness of virtual laboratories in enhancing students' conceptual understanding, practical skills, and learning motivation. For example, (Byukusenge et al., 2022) reported significant improvements in comprehension, practical abilities, and motivation among biology students. Similarly, (Sasmito & Sekarsari, 2022) found increased motivation when students engaged with virtual labs on exothermic and endothermic reactions. Several studies also emphasize the role of motivational constructs in virtual lab learning: (Estoque Loñez & Errabo, 2022) highlighted the interplay between motivation, self-efficacy, and self-regulateion, while (Alnaser & Forawi, 2024) identified positive effects on intrinsic motivation, effort, and attitudes toward science. The use of specialized platforms, such as the Heat Transfer Experiment Virtual Lab (HTEVL), has been linked to higher student achievement (Bose & Humphreys, 2024). Other research also confirms the impact of virtual labs on student participation and performance (Asiksoy, 2023; Triejunita et al., 2021).

Although numerous studies have highlighted the benefits of virtual laboratories in science education, there is limited empirical evidence focusing on how such tools influence motivational and self-regulatory aspects in prospective physics teachers, a group that plays a critical role in shaping future science education. This study fills that gap by specifically analyzing motivation and self-regulated learning using the MSLQ instrument in the context of virtual fundamental physics experiments, offering insights that can inform teacher training programs and curriculum development.

The Motivated Strategies for Learning Questionnaire (MSLQ) is one of the most widely used instruments to assess students' motivation and self-regulated learning (Barkat Ali et al., 2021; Choo et al., 2023; Dohn et al., 2016; Khosim & Awang, 2020; Meijs et al., 2019; Morais et al., 2025; Wang et al., 2023). Developed by Pintrich et al. (1990) and Pintrich et al. (1993), the MSLQ contains 44 items divided into two main dimensions: motivation and self-regulated learning. The motivation dimension includes three constructs: self-efficacy, intrinsic value, and test anxiety. Self-regulated learning comprises two constructs: cognitive strategies and self-regulation. The instrument can be used either in full or partially, depending on the research need (Khosim & Isha Awang, 2020).

Building upon the aforementioned points, this study aims to analyze the motivation and self-regulated learning of prospective physics teachers in virtual laboratory-based fundamental physics experiments using the MSLQ. In addition, it evaluates their learning experiences with the use of virtual laboratories. The findings of this study are expected to contribute to the development of more effective and innovative instructional methods and strategies, particularly in physics education at the higher education level.

Method

This study employed a descriptive quantitative survey design with a cross-sectional approach (Gay et al., 2012). In addition to measuring motivation and self-regulated learning, the questionnaire included items exploring prospective physics teachers' learning experiences with virtual laboratories, such as usage frequency, perceived effectiveness, and instructional preferences. The participants were selected through purposive sampling, consisting of 27 prospective physics teachers enrolled in the fundamental physics laboratory course at the Universitas Sulawesi Barat during the even semester of the 2024/2025 academic year.

The research instrument used in this study was a questionnaire adapted from the Motivated Strategies for Learning (MSLQ) (P. R. Pintrich & De Groot, 1990; Wang et al., 2023), modified to suit the context of virtual laboratory-based experiments. The questionnaire consisted of 48 items measuring two main dimensions: motivation and self-regulation, each comprising five sub-aspects. A five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) was used to rate each item (Gay et al., 2012).

The specific indicators of students' motivation and self-regulated learning in virtual laboratory-based fundamental physics experiments used in this study are presented in Table 1.

Table 1. Indicators of Motivation and Self-Regulated Learning in Virtual Laboratory-Based Fundamental Physics Experiments

Aspect and Item	Item Number
A. Learning Motivation	
1. Intrinsic Goal Orientation	A1
I feel happy when I succeed in understanding the physics concept through a virtual laboratory.	A11
I feel satisfied when I can complete an experiment in a virtual laboratory.	A12
I am motivated to understand physics concepts more deeply through virtual experiments.	A13
I want to complete this experiment because I enjoy the learning process from virtual experiments.	A14
I am interested in finding out more about physics phenomena observed in the virtual lab.	A15
2. Extrinsic Goal Orientation	A2
I tried to complete the virtual experiment to get a high grade.	A21
I feel compelled to take this experiment because it will affect my GPA.	A22
I completed the experiment because I wanted to fulfill the expectations of my lectures and friends.	A23
I took this virtual lab because I want to understand the content of this virtual lab, not just complete a requirement.	A24
I feel my motivation to study increases if there is a reward from the lecturer or institution.	A25
3. Assignment Value/Benefits of Virtual Lab	A3
I feel that the virtual laboratory helps my understanding of the Fundamental Physics concept.	A31
I am confident that the skills I learned in this internship will be useful in the future.	A32
I consider virtual lab experiments to be as important as physical lab experiments.	A33
I believe that using virtual laboratories is an effective method for learning physics.	A34
I consider this virtual experiment to be a valuable learning experience for me.	A35
4. Beliefs in Control of Learning	A4
I believe that my efforts in conducting virtual experiments will improve my understanding.	A41
I am confident that I can understand the concept if I try harder in the virtual experiments.	A42
If I have difficulty in a virtual lab, I try to solve it myself.	A43
I feel like I have a complete handicap in my success in understanding the concept of this lab.	A44
I believe that understanding the physics concept in the virtual laboratory is my responsibility.	A45
5. Self-Efficacy for Learning and Performance	A5
I am confident that I can understand the physics concepts taught through virtual laboratories.	A51
I believe that I can complete every task in the virtual experiment well.	A52
I feel confident in using virtual labs to understand physics concepts.	A53
I was able to complete the experiments in the virtual lab without much difficulty.	A54
I can explain to friends the physics concepts that I learned from the virtual laboratory.	A55
B. Self-Regulated Learning (SRL)	
1. Metacognitive Self-Regulation in Learning	B1
I plan a strategy before conducting experiments in the virtual laboratory.	B11
I try to understand the purpose of the experiment before starting the virtual lab.	B12
I monitor my understanding as I go through the virtual experiment.	B13
If I don't understand something, I look for alternative ways to learn.	B14

Aspect and Item	Item Number
I often evaluate my understanding after completing virtual labs.	B15
2. Effort Regulation	B2
I still tried to understand the concept even though the virtual lab experiments felt difficult.	B21
I don't give up easily when facing difficulties in virtual practicums.	B22
I still complete virtual experiments in earnest, not just fill out reports.	B23
If I fail in one virtual experiment, I try again until I succeed.	B24
3. Time and Study Environment Management	B3
I set my schedule to do experiments in the virtual lab	B31
I am looking for a comfortable and conducive place to do virtual experiments.	B32
I make sure I have enough time to understand the concepts being practiced.	B33
I avoid distractions when conducting virtual lab experiments.	B34
I divide my time well between virtual experiments and other tasks.	B35
4. Peer Learning	B4
I discussed with my friends to understand the virtual laboratory practical concept.	B41
I find it easier to understand the concept when studying with friends than when studying alone.	B42
I often exchange ideas and opinions with friends about the results of virtual experiments.	B43
I am used to collaborating with friends to complete virtual labs.	B44
5. Help-Seeking	B5
I do not hesitate to ask the lecturer if I experience difficulties in virtual experiments.	B51
I seek help from friends if I have difficulty understanding the results of the experiment.	B52
I look for additional sources (books, journals, or videos) if I feel the concept is not clear enough.	B53
I feel comfortable seeking guidance from lecturers or friends/seniors if needed.	B54
I prefer to try it myself before asking for help from others.	B55

To facilitate the interpretation of participants' responses, this study employed a categorical scale adapted from (Lindner & Lindner, 2024), classifying average scores into five levels: Very High (4.51-5.00), High (3.51-4.50), Moderate (2.51-3.50), Low (1.51-2.50), and Very Low (1.00-1.50). This framework aids in explaining the distribution of motivation and self-regulated learning levels among participants.

The questionnaire instrument in this study underwent a content validity test conducted by three experts in physics education and instructional technology. Each item was evaluated based on its relevance to the construct, clarity of wording, and appropriateness within the context of virtual laboratory-based experiments. The Content Validity Index (CVI) was calculated to confirm the adequacy of expert agreement. The expert evaluations indicated that all items met the criteria for substantive validity, with minor revisions made to the wording of several items to improve clarity. The internal consistency of the questionnaire was assessed post hoc using Cronbach's Alpha. While ideally conducted during a pilot phase, the reliability testing in this study was performed after full data collection due to sample size constraints. Despite this limitation, all subscales achieved acceptable reliability levels ($\alpha \geq 0.70$).

The flowchart in Figure 1 illustrates the steps involved in the content validation and reliability testing process of the questionnaire instrument used in this study.

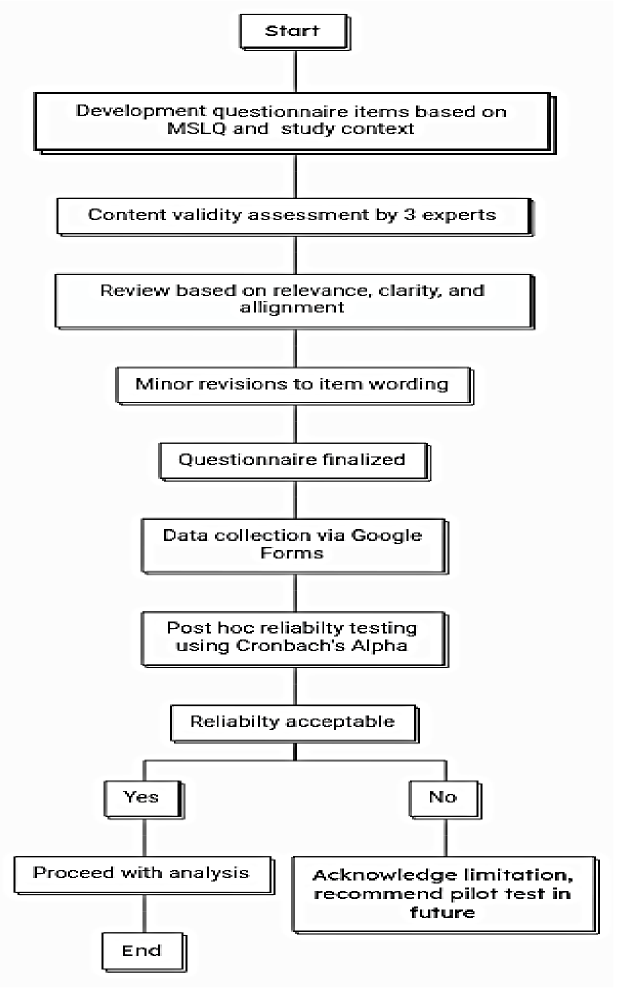

Figure 1. Flowchart of the content validity and reliability testing process of the questionnaire instrument

Following the confirmation of content validity, the researcher proceeded to contact prospective physics teachers and provided comprehensive information regarding the study's objectives and procedures. Data were collected online via Google Forms. The collected responses were analyzed using descriptive statistics, including mean, standard deviation, and frequency distribution. All analyses were performed using RStudio. Ethical considerations were upheld throughout the study—respondents' identities remained confidential.

The virtual laboratory activities included experiments on wave motion on a string, heat and temperature, Coulomb's law, and capacitors, utilizing PhET Interactive Simulations and The Physics Aviary. These simulations were selected based on their alignment with learning objectives and their online availability. An illustration of the virtual physics laboratory activities is presented in Figure 2.

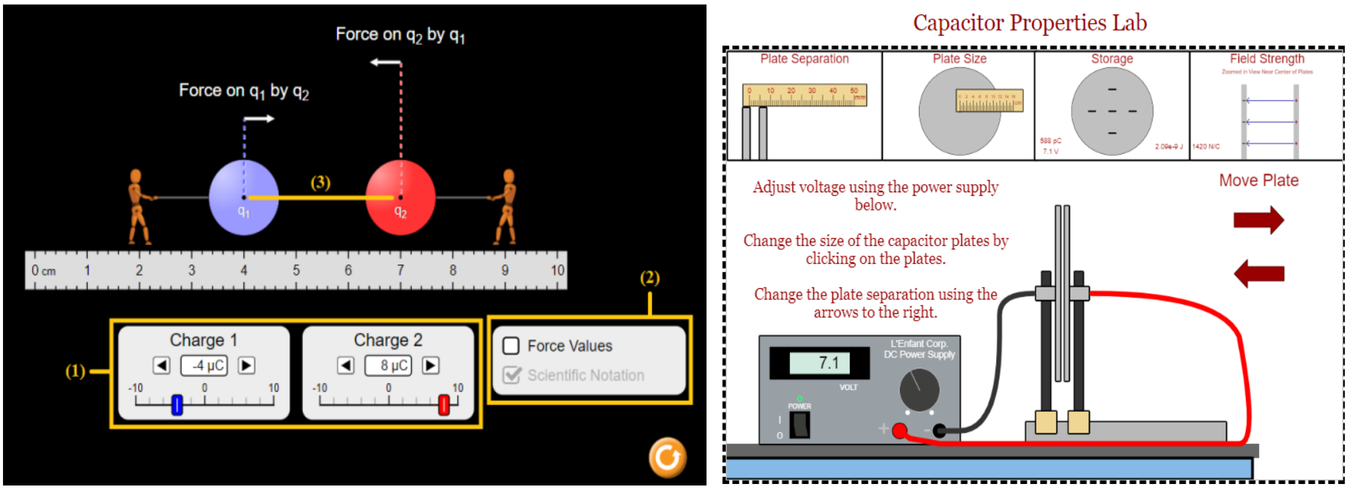

Figure 2. Screenshot of virtual laboratory-based fundamental physics experiments using PhET and the physics aviary

Result and Discussion

Descriptive Statistics of Motivation and Self-Regulated Learning of Prospective Physics Teachers

This study aimed to analyze the motivation and self-regulated learning of prospective physics teachers through virtual laboratory-based fundamental physics experiments. Data were collected from 27 prospective physics teachers (18 females and 9 males) enrolled in the physics education program at Universitas Sulawesi Barat during the even semester of the 2024/2025 academic year. The questionnaire used in this study was adapted from the MSLQ and modified to include specific aspects relevant to virtual laboratory practices.

Table 2 presents the descriptive statistics for motivation and self-regulated learning items (A1 to B5). The mean scores ranged from 3.65 to 4.34 on a 5-point Likert scale, with most participants choosing "agree" to "strongly agree." Based on the interpretation scale used in this study, all measured aspects fell into the High category. The highest average score was found in item B2 (M = 4.34), indicating a strong level of agreement related to a specific self-regulated learning behavior. Meanwhile, the lowest average score was recorded in item A5 (M = 3.65), which, although relatively lower than other items, still falls into the High category. This overall distribution indicates a generally high level of motivation and self-regulated learning among the participants.

This indicates a generally high level of motivation and self-regulated learning among the participants. The internal consistency of the questionnaire was high, as indicated by Cronbach's alpha values ranging from 0.87 to 0.90 for all constructs, confirming the reliability of the instrument.

Table 2. Descriptive Statistics of Motivation and Self-Regulated Learning of Prospective Physics Teachers in A Virtual Laboratory-Based Fundamental Physics Experiment

Aspect	Mean	SD	Med	Min.	Max.	R	α
A1	4.16	0.52	4.00	3.20	5	1.8	0.90
A2	4.08	0.45	4.20	3.40	5	1.6	0.90
A3	4.15	0.75	4.20	2.20	5	2.8	0.88
A4	3.88	0.63	4.00	2.20	5	2.8	0.88
A5	3.65	0.78	3.60	1.40	5	3.6	0.88
B1	3.97	0.59	4.00	3.00	5	2.0	0.87
B2	4.34	0.61	4.25	3.00	5	2.0	0.88
B3	4.16	0.64	4.00	3.00	5	2.0	0.87
B4	4.25	0.69	4.25	3.00	5	2.0	0.90
B5	4.16	0.59	4.00	3.00	5	2.0	0.88

Figures 3 to 5 illustrate the descriptive visualization of the data. Figure 3 illustrates the mean scores for each item under the motivation (A11 to A55) and self-regulated learning (B11- to B55) dimensions. The figure shows that the mean scores for both motivation and self-regulated learning items are relatively high, with most items scoring around 4 on the Likert scale (agree). Similarly, Figure 4 displays the mean total scores for each aspect of motivation and self-regulated learning (A1 to B5). This graph also indicates that the majority of prospective physics teachers agreed.

However, a few aspects received scores below 3, one of which is A5. This suggests a tendency among some participants to engage in virtual laboratory activities primarily due to extrinsic motivation—such as fulfilling academic requirements—rather than intrinsic motivation to deeply understand the concept.

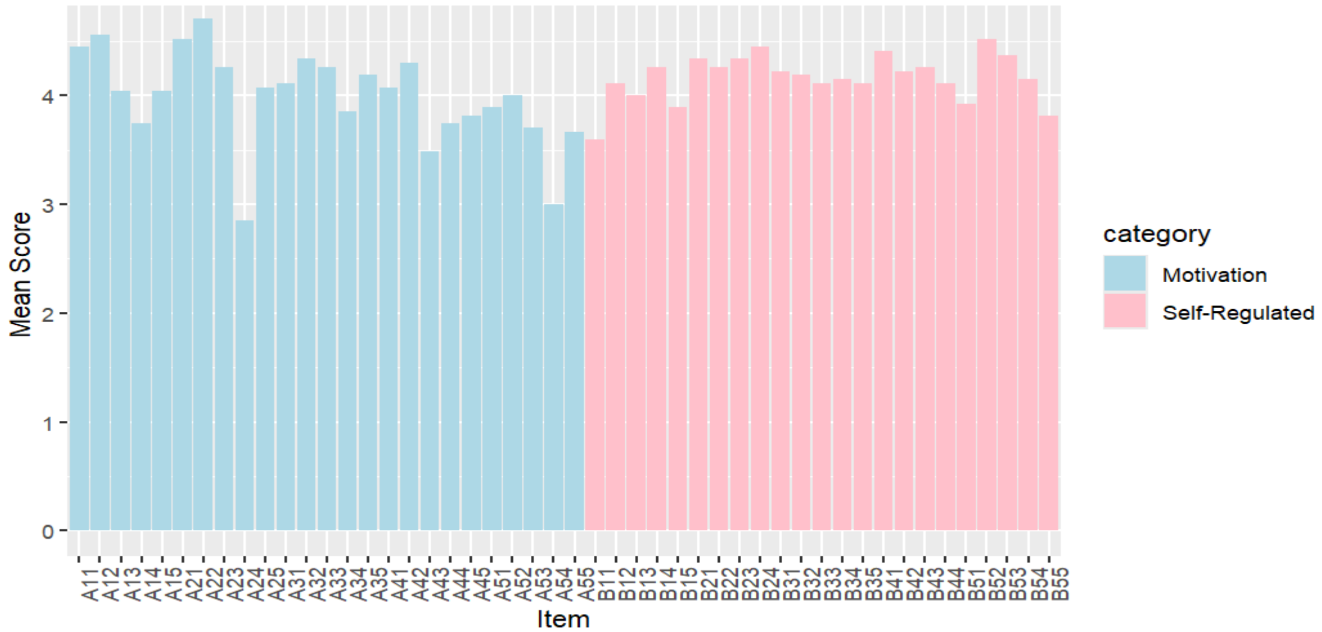

Figure 3. Mean scores for each item in the motivation and self-regulated learning aspects

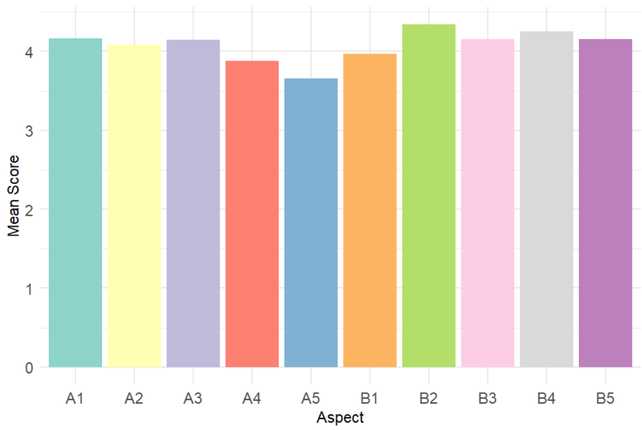

Figure 4. Mean scores for each aspect of motivation and self-regulated learning

Figure 5 presents a boxplot of the score distributions for the motivation and self-regulated learning aspects. Overall, the self-efficacy for learning and performance aspects displays the lowest media score (similar to Figure 4). This may serve as an important indication of the need to enhance instructional strategies or implement motivational interventions. In general, the self-regulated learning aspects (B1-B5) exhibit higher medians compared to some of the motivational aspects. This suggests that the students tend to demonstrate relatively stronger abilities in organizing, managing, and monitoring their learning than in their motivational drive.

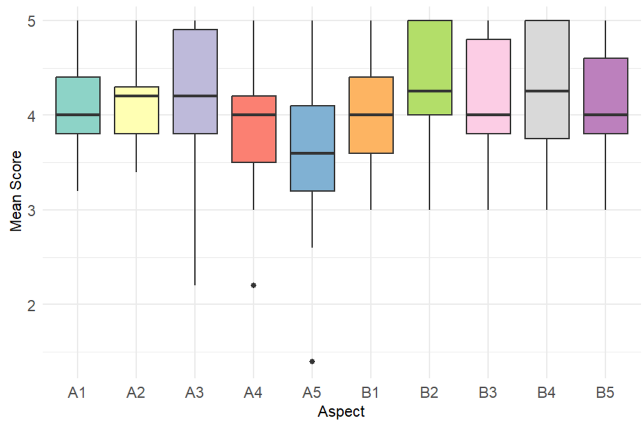

Figure 5. Boxplot of mean scores for each aspect of motivation and self-regulated learning

Experience with Virtual Laboratory Usage

The frequency and perceived effectiveness of virtual laboratory usage were also assessed. Figure 6 indicates that most participants used the virtual laboratory 1-2 times per week, suggesting regular engagement with the tool. However, only a few used it more than four times per week, possibly constraints or limited access.

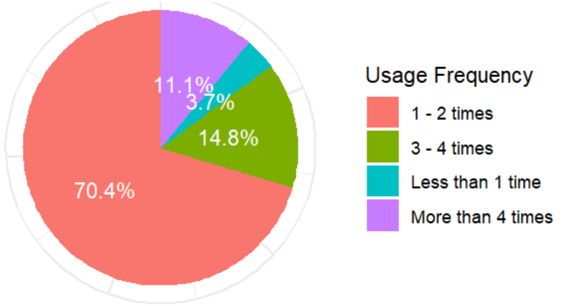

Figure 6. Frequency of using virtual laboratory per week

Figure 7 shows that 55.6% of participants found the virtual laboratory very helpful for understanding physics concepts, while 29.6% found it somewhat helpful. This indicates that the virtual laboratory has significant potential as a learning medium, although a small proportion of them did not experience its benefits to the fullest.

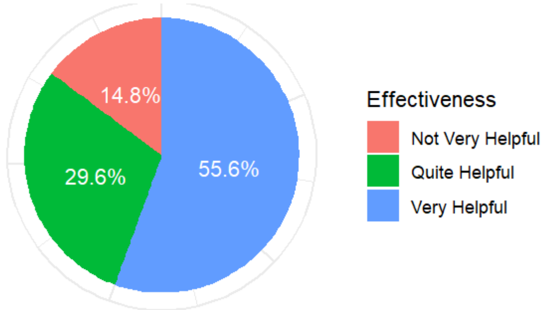

Figure 7. Effectiveness of virtual laboratory in understanding physics concepts

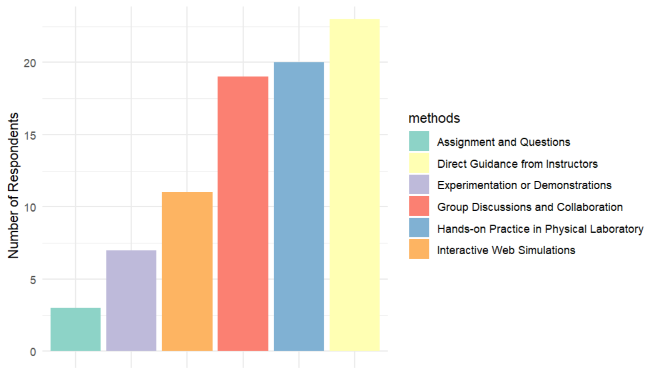

Figure 8. Effective methods for understanding physics concepts according to the responses of prospective physics teachers

Figure 8 presents preferred learning methods for understanding physics concepts, with "direct guidance from instructors" rated highest, followed by "hands-on practice in physical laboratories" and "group discussion and collaboration." Interactive web simulations were moderately preferred, indicating a growing acceptance of digital tools, while assignments and demonstrations were less favored.

Discussion

The findings of this study indicate that overall, prospective physics teachers exhibit a high level of motivation and self-regulated learning in engaging with virtual laboratory-based fundamental physics experiments. This is reflected in the mean scores across nearly all subscales of the MSLQ being above 4.0, suggesting that most participants agreed or strongly agreed with the statements assessing their motivation and self-regulated learning behaviors. These results imply that virtual laboratories can effectively support active engagement and intrinsic motivation among prospective physics teachers in their understanding of physics concepts.

However, the mean score for Aspect A5, which refers to self-efficacy, and students' confidence in their ability to learn or perform well academically, was lower compared to other aspects. This indicates that many prospective physics teachers still harbor doubts about their academic competence, despite showing high motivation and the use of self-regulated learning strategies. Low self-efficacy in educational settings is often associated with academic anxiety, a lack of effective learning strategies, or negative past learning experiences.

These findings are consistent with previous research. For instance, Byukusenge et al. (2022) found that virtual laboratories were effective in enhancing both students' conceptual understanding and learning motivation. Similarly, Al-Duhani et al. (2024) reported that virtual laboratories significantly improved metacognitive regulation and overall self-regulated learning. Similar outcomes have also been noted in several other studies (Diwakar et al., 2023; Ghergulescu et al., 2019; May et al., 2022; Peechapol, 2021; Sharifov, 2022; Suyanta et al., 2022; Tatenov et al., 2023; Triejunita et al., 2021; Viitaharju et al., 2023). Regarding the relatively lower self-efficacy compared to other aspects, this finding aligns with the observation that most prospective physics teachers identified direct guidance from instructors as the most effective learning method. This is in line with the research by Affuso et al. (2023), which emphasized the importance of implementing teacher-led interventions and support to improve academic performance (Affuso et al., 2023).

In terms of usage patterns and attitudes, participants reported positive perceptions toward virtual laboratories. Most reported using virtual laboratories 1-2 times per week, and over half stated that these tools significantly enhance their understanding of physics concepts. Although interactive simulations were not ranked as the top preferred method, they occupied a middle position among various learning options. This points to a gradual shift toward acceptance of digital learning technologies, even if they have not yet fully displaced traditional methods.

Despite these promising findings, the study has several limitations. First, the sample was drawn from a single institution and involved a relatively small number of participants, which limits the generalizability of the results. Second, the use of self-reported questionnaires may introduce biases, as participants might overestimate or underestimate their motivation and self-regulation due to social desirability or misunderstanding of questionnaire items. Third, reliability testing of the instrument (the MSLQ) was conducted after data collection rather than through a prior pilot test, which may limit the accuracy of item interpretation in the study context. Lastly, the study used only a descriptive quantitative approach, without qualitative insights. Future research should include pilot testing, qualitative or mixed methods, and broader samples to strengthen results.

The implications of these findings are significant for physics education. Virtual laboratories can serve as powerful complementary tools in enhancing motivation and promoting self-regulated learning. However, their implementation should be paired with strong pedagogical support to address gaps in students' confidence and guide effective use. Future studies should also explore how specific design elements of virtual laboratories (e.g., feedback, scaffolding, interactivity) influence conceptual understanding and learner engagement. Researching a larger, more diverse population will provide a broader understanding of best practices for integrating virtual laboratories in teacher education and beyond.

Conclusion

This study concluded that prospective physics teachers demonstrated high levels of motivation and self-regulated learning in conducting virtual laboratory-based fundamental physics experiments, as indicated by consistently high mean scores across measured aspects. Despite this, the self-efficacy component revealed comparatively lower ratings, highlighting a degree of uncertainty regarding their academic capabilities. Most participants perceived the virtual laboratory as highly beneficial for conceptual understanding, although direct instructor guidance remained the most preferred instructional method. These findings underscore the potential of virtual laboratories as effective tools to foster student engagement and independent learning in physics education.

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Author Contributions

Conceptualization, N.N. and A.R.; methodology, N.N. and A. R.; software, N.N.; validation, I.R., A.R., and A.A.A.; formal analysis, N.N. and I.R.; investigation, N.N.; resources, N.N., I.R., A.R., A.A.A., and U.K.; data curation, N.N.; writing—original draft preparation, N.N.; writing—review and editing, N.N.; visualization, N.N.; project administration, I.R. and U.K.; funding acquisition, N.N., I.R., A.R., A.A.A. and U.K. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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