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Virtual Multiple Skill Laboratory: An Integrated Web-Based Experiment for Science Students

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Abstract. The 21st-century skills are essential for students to adapt to global changes in economics, ecosystems, and politics by developing critical thinking, communication, collaboration, adaptability, and creativity. This article discusses the development of a practicum learning website using the virtual multiple skill laboratory model (VMSLM), an innovation made in response to the obstacles faced in implementing the VMSLM during the covid-19 pandemic. Although focused on solutions during the pandemic, the results of this development have broader potential in supporting online-based practicum learning and distance learning in the future. This research is developmental research that prioritizes qualitative testing as the primary data source. However, quantitative analysis is also required to provide support for the qualitative findings. The results showed that the website developed was considered good and feasible to use based on the results of group discussions with experts. A positive response was also given by the experienced group, who stated that the VMSLM website provided a comprehensive learning experience. These results indicate that practicum using the VMSLM website has the potential to be a valuable tool in the development of physics learning in the future. In addition to providing practical solutions during the pandemic, the use of VMSLM can also support changes towards more interactive, effective, and inclusive learning. Thus, the development of VMSLM websites not only provides a short-term solution but also offers a sustainable contribution to the overall transformation of physics learning.
Keywords: digital learning; higher-order thinking skills; multiple skills; web-based learning

Introduction

21st-century skills can help students learn and adapt to all forms of changes that occur over time (Binkley et al., 2012; Kivunja, 2019; Tan et al., 2017). These changes are related to global economic, ecosystem, and political networks. This condition requires students to learn how to communicate, work together, and solve problems with people all over the world. Students need seven survival skills including critical thinking and problem-solving, leadership and cooperation, agility and adaptability, a spirit of initiative and entrepreneurship, the ability to communicate effectively both orally and in writing, easy access to information and analysis of information, imagination and curiosity (Alismail & McGuire, 2015; Qian & Clark, 2016).

A 21st-century learning framework that requires students to have skills, knowledge, and skills in technology, media, and information, learning and innovation skills, as well as life and career skills (Kivunja, 2015, 2019; Jariah et al., 2025; Subagja et al., 2025). This framework also explains the skills, knowledge, and expertise that must be mastered so that students can be successful in life and work. In line with that, the 21st-century learning paradigm emphasizes students' ability to find out from various sources, formulate problems, and carry out analytical thinking, cooperation, and collaboration in solving problems. (Ikmah, 2018; Wulandari et al., 2018). 21st-century skills that need to be practiced and developed by Educational and teaching staff institution (LPTK) in preparing prospective teachers to face the opportunities and challenges in the industrial revolution 4.0 era include critical thinking skills (CTS), creative thinking (CrTS), communication (CMS) and collaboration (CLS) (Häkkinen et al., 2017; Kingsley & Grabner-Hagen, 2015; Scott, 2015). These 21st-century skills must be trained and developed by teachers for students according to the demands of the 2013 curriculum. Therefore, prospective teacher students should be trained and developed 4C skills before they can implement them in madrasas/schools to educate and guide their students.

21st-century skills can be trained and developed in classroom learning and laboratory practicums. Practicum in the laboratory is an integral part of physics teaching and learning activities, which can generate motivation and achievement in learning physics, develop basic experimenting skills, become a vehicle for learning to apply scientific methods, develop higher-order thinking skills (HOTS), provide practical skills, and a vehicle for confronting students' preconceptions (Liana et al., 2020; Nuryantini et al., 2020; Zakwandi & Istiyono, 2022)

Physics practical activities can be carried out through real laboratories and virtual laboratories. Virtual laboratories are very important to support practical activities for students in educational institutions (Abdjul & Ntobuo, 2019; Maulidah & Prima, 2018; Sapriadil et al., 2019; Wahyuni et al., 2021). Virtual laboratories have several advantages compared to real laboratories, including saving learning time, developing independent learning, increasing flexibility and interactiveness in learning, making it easier to understand various abstract concepts, have the ability to demonstrate theory, results in satisfaction in acquiring theoretical knowledge (Arista & Kuswanto, 2018; Bogusevschi et al., 2020; Yusuf & Widyaningsih, 2020).

Previous research related to the implementation of science practicums during the covid-19 pandemic shows that practicum learning can be carried out online (Burns et al., 2020; Kidd & Murray, 2020; La Velle et al., 2020). Technology-based simulation environments can complement and support practicum experiences during the covid-19 pandemic (Mauliana et al., 2022; Sultan, 2021). Virtual practicum provides experience for prospective teachers adapting to new technology, developing skills, flexibility, and handling student interactions in an online setting (Averichev et al., 2019; Fitriya & Maiyanti, 2023). Virtual practicums were effectively and efficiently implemented during the covid-19 pandemic; virtual practicums increased students' understanding of concepts (Farhan et al., 2021; Kua et al., 2021; Nanto et al., 2022).

The results of the initial research study through distributing questionnaires showed that teachers still had difficulty in making practical instructions; the physics practicum tools available are less standardized; lack of physics practical instructions; lack of teacher understanding of virtual laboratories; teachers only real practicum 1-4 times per semester and agreeing that virtual practicums can make it easier to understand abstract and microscopic concepts (Malik & Ubaidillah, 2020; Malik et al., 2020).

The results of laboratory observations in several Physics Education Study programs at UIN and IAIN show that physics practicum equipment still experiences limitations in terms of quality and quantity. In terms of quality, the physics practicum equipment is still below the standard of physics practicum equipment. In terms of quantity, practical equipment is still limited, not proportional to the number of students. Judging from the quality and quantity of laboratory equipment owned, there is a need for a breakthrough in implementing practicums, namely virtual laboratories.

Government policies regarding the covid-19 pandemic education require educational institutions to optimize various facilities and infrastructure for learning. The use of various learning management systems (LMS) is used in learning, especially physics. Educators make breakthroughs to carry out physics practicums. Previous research on the use of virtual laboratory platforms in physics learning during the covid-19 pandemic included LiveWire in basic electronics learning (Kartikawati & Nita, 2019; Makhrus et al., 2021), PhET interactive simulations (Hasyim et al., 2020; Malik et al., 2019; Rahmawati et al., 2020), Wave Optics NEET physics test on google play (Erdoğan & Bozkurt, 2022; Gare et al., 2022). The virtual laboratory application used by previous researchers was not integrated with the assessment instruments and was not recorded in the system.

These findings provide an important basis for further research regarding the virtual multiple skill laboratory model in an effort to improve 21st-century skills for students. This research aims to bring innovation by offering a new approach compared to the previous virtual multiple skill laboratory model. It is hoped that this research can provide a more effective solution in training and developing vital skills such as CTS, CrTS, CMS, and CLS, which are really needed in facing the challenges of the Industrial Revolution 4.0 era.

The focus of this research is the development of integrated virtual media through a website. This media allows skills assessment and practicum activities to be recorded in an integrated manner in the system, making it easier for researchers to carry out monitoring and evaluation efficiently. Apart from that, this model is expected to be able to overcome several obstacles that are often faced in implementing physics practicum, such as the lack of practicum equipment, inadequate standards, and limited time for implementing practicum in the laboratory. Thus, this research not only contributes to the development of innovative learning models, but also provides concrete solutions to the challenges faced in 21st-century skills education.

Methods

This research is a development into a digital version of the multiple skills laboratory practicum model (Malik & Ubaidillah, 2020). VMSLM was designed by carrying out several stages, starting from needs analysis, design, prototype development, limited trials, and extensive trials (Lee et al., 2017; Ronen-Fuhrmann & Kali, 2008). The results of the needs analysis become the beginning or basis for the development of VMSLM. This is presented in the introductory section of this article. At the design stage, the researcher carried out a comprehensive study of the content aspects and learning stages using VMSLM.

The next stage is creating a website design. At this stage, various studies are carried out regarding the features that will be developed. The results of the next design stage will be developed at the develop prototype stage. At the develop prototype stage, the actualization process of the design that has been prepared is carried out. Actualization includes considering the UI/UX factors of the VMSLM website being developed (Zakwandi et al., 2024). At the final part of the prototype development stage, an focus group discussion (FGD) was also carried out regarding the development results. FGD was conducted to review the advantages and disadvantages of the website with experts. The final stage of the research series is conducting a website trial. Trials are divided into two, namely limited trials carried out on groups of experts, and extensive trials on groups of students who are taking lectures. However, reports regarding the results of wide-scale trials are presented separately from this development process.

This research places more emphasis on the qualitative aspects of the VMSLM website being developed. However, researchers also asked students for quantitative responses in order to provide feedback on the product development process. Qualitative analysis is based on the results of the FGD before data collection or at the time of data collection. The FGD was carried out with a group of experts, in this case the lecturers who taught the school physics laboratory course, the basic physics lecturers, and also the lecturers who taught the learning media courses. The collected data was then analyzed qualitatively using ATLAS.ti software free version. Next, data related to the responses of experienced group students. The physics learning response questionnaire was divided into four broad groups. First, the group of questions about interpretation and analysis skills, which includes questions 1 to 4, discusses increasing students' abilities in interpreting and analyzing ideas, arguments, or information, as well as the ability to relate information to the arguments put forward and evaluate claims and arguments. Second, the group of questions about synthesis and evaluation abilities, consisting of questions 5 to 10, illustrates the increase in students' ability to draw conclusions based on analysis, produce varied ideas and answers, as well as enrich and develop ideas or products. Third, the group of questions about creative thinking and problem-solving abilities (PSA), which includes questions 11 to 13, discusses students' abilities in representing images in schematic form, representing data in graph/diagram form, and representing graphs in verbal/mathematical form. Finally, the group of questions about perceptions of the VMSLM, from questions 14 to 29, covers various aspects such as the novelty of the learning method, assessment of the VMSLM product, as well as user impressions and experiences in using the platform. In more detail, Table 1 shows the questionnaire used to obtain student responses regarding the use of VMSLM. The questionnaire data were then analyzed using a quantitative statistical approach.

Table 1. Response questionnaire for using the VMSLM website

Aspects	Statements
Interpretation and analysis skills	1. Implementing VMSLM in physics learning can improve my ability to interpret the meaning of ideas, arguments, or information in other forms.
	2. Implementing VMSLM in physics learning can improve my ability to analyze ideas, information, arguments and claims.
	3. Implementing VMSLM in physics learning can improve my ability to connect the information provided with the arguments put forward.
	4. Implementing the VMSLM in learning can improve my ability to evaluate claims and arguments.
Synthesis and evaluation capabilities	5. Implementing VMSLM in physics learning can improve my ability to draw conclusions based on analysis.
	6. Implementing VMSLM in physics learning can improve my ability to ask lots of questions.
	7. Implementing VMSLM in physics learning can improve my ability to produce various ideas and varied answers.
	8. Implementing VMSLM in physics learning can improve my ability to enrich and develop an idea or product.
	9. Carrying out VMSLM in physics learning can improve my ability to generate new and unique ideas.
	10. Implementing VMSLM in physics learning can improve my ability to provide opinions to solve problems.
Creative thinking and PSA	11. Implementing VMSLM in physics learning can improve my ability to represent images in schematic form.

Aspects	Statements
Perception of virtual multiple skill laboratory	12. Implementing VMSLM in physics learning can improve my ability to represent data in the form of graphs/diagrams. 13. Implementing VMSLM in physics learning can improve my ability to represent graphs in verbal/mathematical form. 14. Implementing the VMSLM is new learning method. 15. Implementing VMSLM is a learning method that can be used for other physics materials. 16. The VMSLM products used are very interesting. 17. I have never encountered the VMSLM product used before. 18. Answer strongly agree to this statement. (control of questionaire) 19. The VMSLM product is suitable for use in further practicums. 20. I had no difficulty using the VMSLM. 21. The instructions in the VMSLM are easy to understand. 22. Answer disagree to this statement. (Control of Questionaire) 23. VMSLM saves more time in the practicum implementation process. 24. Giving tests using the VMSLM saves more time in practical reporting. 25. The activities contained in the VMSLM are in accordance with competencies. 26. I am interested in using the VMSLM for my next practicum. 27. I suggest that the next practicum use the VMSLM. 28. The use of the VMSLM in practicum implementation provides faster and more accurate response (feedback). 29. The use of the VMSLM reduces the level of cheating (cheating, cooperating, etc.).

Results and Discussion

Design

The design stage results in the conversion of the multiple skill laboratory model stages (Figure 1a) into a flowchart from VMSLM (Figure 1b).

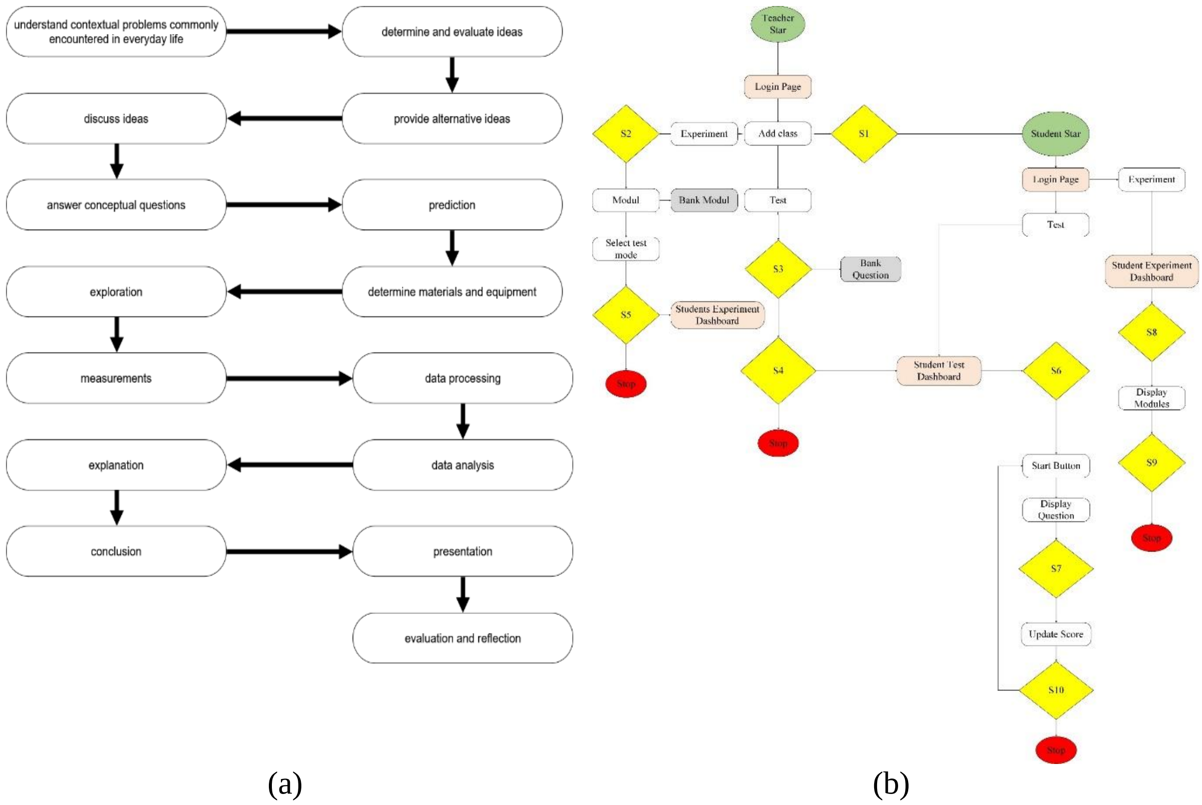

Figure 1. (a) Stages of the multiple skill laboratory model; (b) VMSLM flowchart

Referring to Figure 1b, the system flowchart being developed contains several posts according to the activities carried out. The first post is the login system according to each dashboard. The next post is the process of configuring students into classes (S2) which can be done in two ways, namely self-enrollment from the student side and manual enrollment from the teacher side. Students who have joined a class managed by a teacher will get an active dashboard to follow the learning. The next stage is for the teacher to prepare the class by organizing practical activities and activities. Preparation of experimental activities (S2) gives teachers access to activate and deactivate the practicum module. Practical modules can be taken from creating new modules or using modules contained in the module bank.

The module that is ready is then configured (S5). Active modules will be visible on the student's experimental dashboard, while inactive modules will be hidden. The next configuration is test preparation (S3). Test configuration includes preparing the test title, determining the test format, and preparing question items. Test items that are ready will be stored in the question bank. The test items that are ready are then configured (S4) to set the test implementation time and determine the class target. Active tests will be displayed on the student test dashboard. The initial stage of taking the test is for students to choose the test they will choose (S6). There are two forms of assessment carried out by students, namely cognitive assessment in the form of test instruments and non-cognitive assessment in the form of surveys. The test assessment consists of three forms of tests, namely tests of CTS, creative thinking and computational thinking, while non-test assessments take the form of observing collaboration skills and communication skills. Apart from that, there are 2 surveys, namely a learning style survey and learning responses using the VMSLM.

Students who open the exam scheme will be asked to choose the type of assessment they will take first. The number of exams depends on the type of exam prepared by the teacher. Every answer obtained will be administered (S7) so that it can be accessed by the teacher. At the end of the test (S10) students are required to continue the assessment process until all assessment processes have been completed. Apart from completing tests, students must also complete experimental activities via the experimental dashboard. The experiment dashboard will present the number of experimental activities that students can participate in (S8). Experimental activities are carried out based on the modules prepared and if the experimental activities have been completed (S9) then students will be directed to complete other modules.

Develop Prototype

The develop prototype stage is the actualization of the design that has been created. Development is carried out using the PHP programming language with the CodeIgniter 3 framework. At this stage, the initial implementation of the features being developed is also carried out while building a representative basic framework to enable the functional evaluation process and user interface. (Zakwandi et al., 2024). There are three user levels with varying access as in Figure 2.

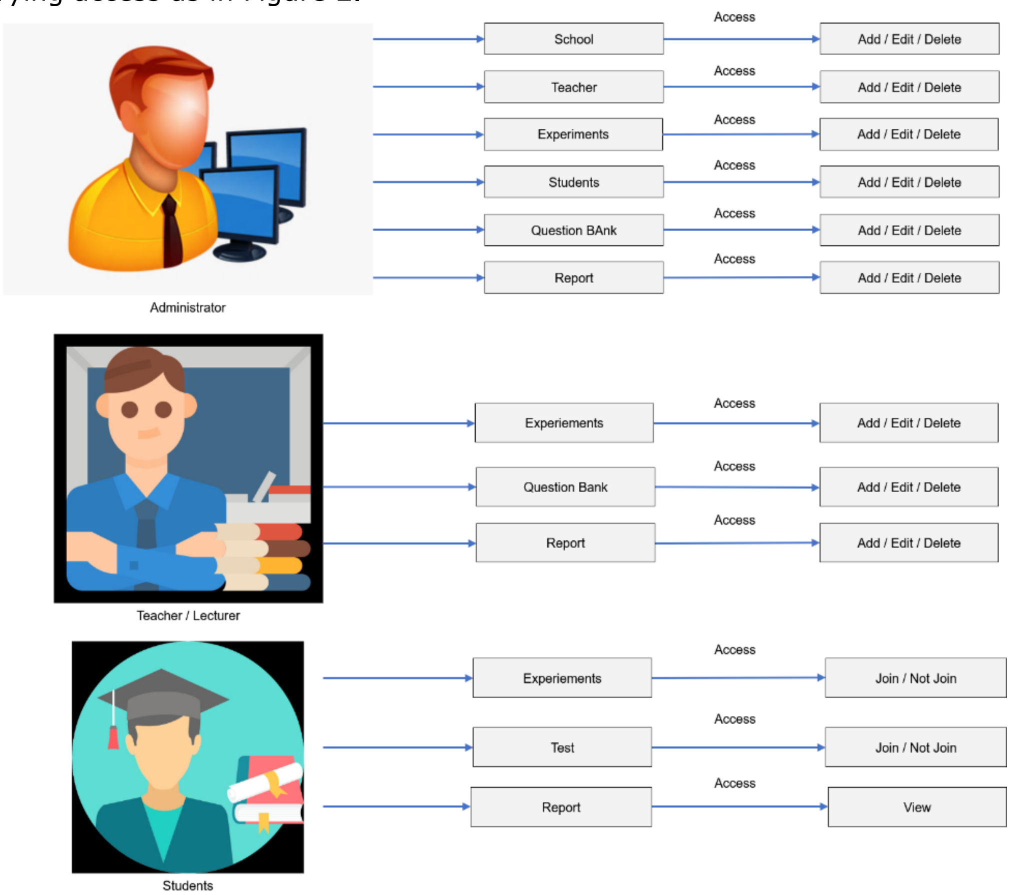

Figure 2. User level and user access of the VMSLM website

Figure 2 shows a complete, detailed picture of the development of VMSLM, which consists of the admin dashboard, teacher dashboard, and student dashboard. VMSLM was developed in the form of a website that can be accessed by every device connected to an internet connection. The admin or administrator dashboard has the highest authority in the system being developed. Admin has the authority to add schools, add classes, add practicum modules, add questions, and access reports. Teachers have a level 1 dashboard with the authority to manage learning in the classes they teach. The teacher rules in this system are that 1 class can only be taught by 1 teacher, but 1 teacher can teach in more than 1 class. The next user is a student who has authority as a participant. Students are only given access to attend classes, do assignments, discuss and take exams. The design of this website is available on the following page: https://github.com/rizkidz97/v-msl.

Limited Tested

A limited trial phase was carried out to review the performance of the VMSLM website being developed. At this stage, the researchers asked 22 physics education students to carry out practical activities using the VMSLM website. This group was declared as an experienced group because they had participated in learning using the multiple skills laboratory practicum model (Zakwandi et al., 2024).

The results of the questionnaire analysis showed a very positive response to the implementation of a virtual multiple skill laboratory model in physics learning. The majority of respondents agreed or strongly agreed that using this platform had succeeded in improving their ability to interpret, analyze, and relate information in a physics context (Questions 1-3). Overall, these positive responses reflect strong adoption of virtual learning approaches in developing academic skills.

Positive responses were also seen in the perception that the virtual multiple skill laboratory model is a new and interesting learning method (Question 14). Most respondents expressed interest in using this platform in future practicums and recommended its use to others (Questions 26 and 27). Support for time efficiency and reducing the level of cheating in the learning process was also a positive highlight, with the majority of respondents agreeing or strongly agreeing with this (Questions 23 and 28).

However, there were some areas where respondents' responses tended to vary. For example, a small proportion of respondents felt less confident in their ability to ask many questions in the virtual practicum context (Question 6). In addition, there were also several respondents who felt that the instructions on the virtual multiple skill laboratory model were not easy to understand, indicating the need to further clarify instructions and guidelines for using this platform.

In the context of physics learning, the results of this analysis highlight the great potential of using virtual technology in improving students' learning skills. The positive adoption of virtual multiple skill laboratory model suggests that this method may be a valuable addition to the physics education landscape, especially in distance or hybrid learning contexts.

To optimize the use of the virtual multiple skill laboratory model, it is important to continue to carry out continuous evaluation and improvement. Responses from respondents can be used as a valuable source of information to improve aspects that are still lacking in this platform, such as improving hints and instructions, as well as increasing the availability and diversity of learning materials (Rizaldi et al., 2022). By paying attention to the results of this questionnaire analysis, virtual learning approaches in physics can continue to be developed to provide a more meaningful and effective learning experience for students. The integration of technology in physics practicum not only enriches students' learning experiences but also opens up opportunities for further exploration and innovation in the science learning domain as a whole. Based on the outline/aspect questions, the results of the limited trial questionnaire are shown in Figure 3.

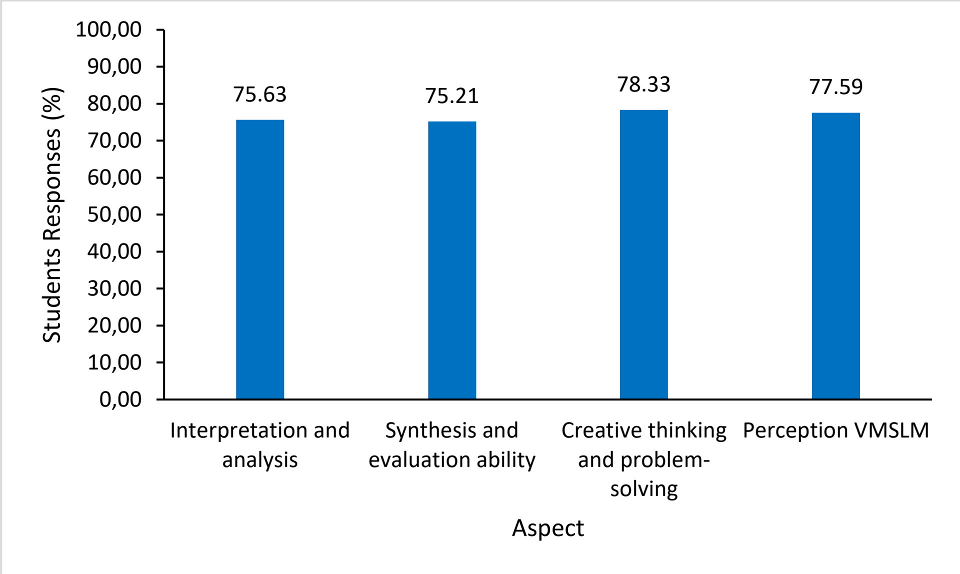

Figure 3. Experienced group student responses

Based on the results of the questionnaire analysis in Figure 3, it can be seen that the majority of respondents expressed positive perceptions of VMSLM. They consider that this platform helps them develop various abilities and provides new and interesting learning experiences. In detail, the graph shows that the majority of respondents agree that this platform is effective in helping them interpret and analyze physics data, with a percentage of 85.63%. In addition, as many as 95.00% of respondents also agreed that this platform helped them relate information in a physics context, confirming its benefits in developing analytical thinking skills (ATS).

Apart from that, the results of the analysis also reveal that the virtual multiple skill laboratory model supports the development of creative thinking and PSA. As many as 78.33% of respondents agreed that this platform helped them develop creative thinking abilities, while 77.59% of respondents agreed that this platform helped them develop PSA. This shows that the use of this platform not only improves understanding of physics concepts but also stimulates critical and innovative thinking in students.

Apart from its academic benefits, perceptions of VMSLM also show a positive impact. As many as 75.21% of respondents felt that this platform was a new and interesting learning method, reflecting enthusiasm for innovative learning approaches. This shows that the use of technology in physics learning can increase students' interest and motivation towards this subject.

In terms of time efficiency, 87.10% of respondents agreed that this platform helped them save time in completing practicums. This shows that the use of technology in physics learning not only increases learning effectiveness but also speeds up the overall learning process (Saleh et al., 2017). Finally, the analysis results also highlight the role of this platform in reducing cheating in the learning process. As many as 83.87% of respondents agreed that this platform helps reduce cheating, indicating that the use of technology in physics learning can create a fairer and more transparent learning environment (Sukamto & Wijayamti, 2017).

Overall, the results of this questionnaire analysis show that VMSLM has a positive impact on developing students' abilities in physics. This platform is not only effective in improving understanding of physics concepts but also stimulates critical thinking, accelerates the learning process, and creates a more equitable learning environment. Therefore, the use of technology in physics learning, such as VMSLM, can be considered as an effective way to improve the quality of learning in the future.

Conclusion

VMSLM in virtual physics learning received a positive response from the majority of respondents. This platform has proven effective in developing various student abilities and providing new and interesting learning experiences. Questionnaire analysis shows that most respondents agree that the platform helps them interpret, analyze, and relate information in a physics context. Apart from that, the virtual multiple skill laboratory model also supports the development of creative thinking and PSA, and has received positive responses as a new and interesting learning method. Using this platform is also time-efficient and helps reduce cheating in the learning process. Therefore, the results of the analysis show that the virtual multiple skill laboratory model can be a valuable tool in developing physics learning in the future.

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