

Developing a Virtual Chemistry Practicum Platform for University Students: Validity, Practicality, and Implementation Insights

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ABSTRACT

This study aimed to develop and evaluate a virtual chemistry practicum tool that meets criteria of validity, effectiveness, and practicality in higher education. R&D approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) was employed. The prototype was tested with 8 laboratory assistants and 22 Physics Education students at UIN Alauddin Makassar enrolled in basic chemistry, and validated by two experts. Instruments included expert validation sheets, observation sheets, student response questionnaires, and a concept-understanding test. Content validity was analyzed using the Gregory index (Aiken's V), while effectiveness and practicality were assessed through descriptive statistics. The virtual practicum platform demonstrated high validity (Aiken's V = 0.74), indicating it is feasible for use. Effectiveness was supported by learning outcomes, with 78% of students achieving scores ≥ 70 . Practicality was rated "very good" based on student responses. The platform integrates attendance management, assignment submission, assessment features, and video- and animation-based practicum guides that enhance procedural understanding. The developed tool facilitates practicum management and improves student engagement and task completion. Its strong validity, effectiveness, and practicality suggest it is a viable alternative to traditional laboratory instruction. This study contributes to the advancement of technology-enhanced chemistry education and supports broader adoption of virtual laboratory environments in higher education.

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1. INTRODUCTION

Technological and information advances have opened the veil of education globally. Higher education, especially practicum activities in the laboratory, provides a unique learning context, where students can actively participate in exploration and investigation, similar to activities carried out by

professional scientists (Domin, 2007). To support effective learning in such environments, adequate laboratory facilities are essential. The National Education Standards Agency (BSNP) has set standards for laboratory facilities and infrastructure in universities to ensure the implementation of quality learning (Anggereni et al., 2021; Muchlisa et al., 2021)

Chemistry, as a branch of basic science, relies heavily on experimental methodologies, in which the development and application of chemical knowledge is based on high standards in laboratory practice. Chemistry practicums, therefore, play an important role in developing students' technical skills, including equipment and materials management, observation, data collection, analysis, problem-solving, teamwork, and communication (Bennett, 1998). However, over time, traditional laboratory settings have been increasingly limited by factors such as limited resources and access, which require innovative alternatives.

In this context, virtual laboratories are present as a promising solution to overcome these limitations. Synthesis from previous research (Winkelmann et al., 2017) has demonstrated the effectiveness of immersive environments such as Second Life for conducting chemical experiments, which makes it easier for students to access and understand complex chemical concepts. Further research (Bazie et al., 2024) also shows that virtual labs can improve the academic achievement of chemistry students, proving the potential of this approach to improve learning outcomes compared to traditional lecture methods.

Despite these technological advances, the application of technology in chemistry education still faces several challenges, especially related to limited access to resources and the need for more advanced pedagogical methods. Augmented reality (AR) technology is emerging as a potential solution, offering an interactive and dynamic learning experience that deepens students' understanding of chemical concepts (Nazar et al., 2024). However, to utilize this technology effectively, proper training for educators and support from the online learning community is needed (Price et al., 2021; Xue & Keat, 2024)

In addition, laboratory administration also plays an important role in ensuring the success of virtual laboratories. Research highlights the importance of technology in managing virtual labs to ensure operational efficiency and provide effective support for students and educators (Chamorro-Atalaya et al., 2023; Yuliastrin et al., 2023). Additionally, the implementation of a hybrid approach that combines face-to-face and digital learning offers significant flexibility, allowing for the accommodation of a wide range of student learning styles (Masril et al., 2024). The use of gamification strategies (Wahyudi et al., 2023) can also increase students' cognitive engagement and motivation in studying chemistry.

Despite these technological innovations, many students have difficulties in using the equipment and practicum procedures. Laboratory assistants and lecturers have difficulty in providing comprehensive guidance due to time constraints, making it difficult to conduct effective assessments of student performance. In addition, traditional practicum guides are still limited, often simply explaining theories without demonstrating the practical steps required in the experiment. These challenges hinder students' understanding of key concepts and experimental procedures, particularly in complex chemistry practicum assignments.

To overcome this shortcoming, an innovation in the form of a digital solution is needed. This study proposes the development of a Virtual Chemistry Practicum Platform that integrates visual guidance and interactive multimedia tools to improve students' understanding and engagement in practicum work. The platform will be equipped with visual animation guides that allow students to mimic experimental procedures, as well as provide direct input for assignments and attendance, simplifying the practicum process for both students and assistants.

This study highlights the exploration of the development, validity, and practicality of this virtual chemistry practicum platform designed specifically for Physics Education students. By evaluating its effectiveness, this research is expected to contribute to the development of technology-based chemistry education and open up opportunities for the implementation of virtual laboratories on a wider scale in higher education.

2. METHODS

This research uses a Research and Development (R&D) approach, which aims to develop and evaluate an online-based chemistry laboratory device. The development model used in this study is the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, which is known for its logical and systematic steps, allowing flexibility in revising and evaluating products throughout the development process. The ADDIE model was chosen for its ability to support the development of valid and practical educational tools, which in turn can be used to enhance students' learning experience in the basic chemistry practicum. This approach allows researchers to focus research on needs analysis, design, development, implementation, and evaluation of the final product, with each step providing a basis for continuous improvement based on feedback from validators and trial participants.

ADDIE Research Design (Analysis, Design, Development, Implementation, and Evaluation) is a development model used for this research. One of the reasons researchers used the ADDIE model in this study is that the ADDIE model has logical steps and is easy to learn. In addition, the development model used in this study involves the assessment of experts or validators in its development. (Cahyadi, 2019) (Cahyadi, 2019)



Figure 1. ADDIE Model Development Steps

At each stage, the model can be revised and evaluated many times to ensure a reliable and useful final product. ADDIE's development model is considered suitable for product development on this basis. ADDIE's development model has only reached the evaluation stage, where evaluation is sourced from criticism and input by experts to help improve the product being developed.

The sample of this study involved two main subject groups. First, two validators consisting of experts in the field of chemistry education and learning technology. These validators are responsible for assessing the validity of the content and design of the developed online-based chemistry laboratory devices. Second, 8 assistants in the limited trial, and 22 students from the Physics Education Study Program, who are participants in the trial of the developed device, where they will provide feedback on the practicality and affordability of the device during the implementation of basic chemistry practicum. The selection of trial participants is based on their involvement in basic chemistry practicum activities during the 2024/2025 school year, so that the developed devices can be directly applied and tested in relevant learning contexts.

The instruments used in this study include several tools to collect the data needed to evaluate the validity and practicality of the developed device. These instruments include: 1) Expert Validation Sheet, which is used to assess the extent to which the developed device meets the validity criteria in terms of content, design, and functionality. Validators are asked to provide assessments based on predetermined indicators, as well as provide input related to further development. 2) Chemistry concept understanding test after using a virtual-based chemistry practicum device. 3) Response Questionnaire to Virtual-based Chemistry practicum Toolkit filled out by assistants and students. Practical response data was obtained using questionnaires. The purpose of this questionnaire is to get feedback on the media products that have been developed and to evaluate the level of practicality of

the product as a learning medium. The data obtained from this questionnaire will be used as a basis to improve and improve the quality of the learning media that has been developed. A practical response questionnaire is a type of closed questionnaire consisting of a series of statements filled in by students using the Likert scale.

Data collection is a variety of methods used to collect data, collect, retrieve, or capture research data. We know the methods of interviews, observations, test questionnaires, archives, and documents. Good data is data that is in accordance with the actual reality and the data is constant, fixed or trustworthy.

The validation sheet used is a device validation sheet that has been adapted and modified according to development needs. The response questionnaire to the basic Chemistry device is filled out by lecturers or heads of laboratories, assistants, and practitioners. Practical response data was obtained using questionnaires. The purpose of this questionnaire is to get feedback on the media products that have been developed and to evaluate the level of practicality of the product as a learning medium. The data obtained from this questionnaire will be used as a basis to improve and improve the quality of the learning media that has been developed.

The data that has been collected through validation questionnaire instruments, observation sheets, and response questionnaires is then analyzed quantitatively to evaluate the validity and practicality of the developed media. The data obtained from the results of validation by experts will be analyzed to determine the validity and feasibility of using the learning media that has been created

The validity of a product can refer to two things, namely whether the product is developed according to the theory and whether there is internal consistency in each component. The data from the experts' validation results were analyzed using Gregory analysis with the help of table D contingency to calculate the Gregory index. Expert-validated indicators are display, language and content. The criteria used to decide that the device has an adequate degree of validity are the value of the content validity coefficient for the entire aspect is at least in the sufficiently valid category and the validity value for each aspect is at least in the valid category. If this is not the case, then it is necessary to revise based on the suggestions of the validator or by reviewing the aspects that are considered deficient. Next, it was re-validated and then reanalyzed. The data of the research results were processed with several approaches, the validity test of Aiken V, and descriptive percentage. The results of the instrument validation were processed using the Aiken V Retnawati test (Heri Retnawati, 2016) as follows:

$$V = \frac{\sum s}{c(n-1)} \quad (1)$$

With V = the rater (validator) agreement index regarding the validation of the items, s = the score set by each rater (validator) minus the lowest score used, n = the number of raters, and c = the number of categories that raters (validators) can choose. Category validity follows category index; if $V < 0.4$, then the validity is weak, if it is $0.4 \leq V < 0.8$, then the validity is moderate, and if it is $V \geq 0.8$, then the validity is high (Retnawati, 2016).

The research data obtained from the observation sheet will be analyzed descriptively (Nuridin, 2007) as follows:

$$P = f/n \times 100\% \quad (2)$$

With P = percentage number, f = the frequency that the percentage is looking for, and n = the number of individuals. The categories of observation results are adjusted to the following category range:

Table 1. Category of Practicality of Learning Media

No.	Score Range	Remarks
1	$X > 54$	Very Practical
2	$45 < x \leq 54$	Practical
3	$35 < x \leq 45$	Enough
4	$26 < x \leq 35$	Less Practical
5	$X \leq 26$	Impractical

Sources: (E. Widyoko, 2014)

The criteria set to state that students have a positive response to the media is that more than 50% of them give a positive response to at least 70% of the aspects stated, so from the data obtained the product can be said to be practical to use (Arsyad, 2007).

To test the effectiveness of the virtual-based Chemistry practicum tool on learning outcomes, the criteria for completeness of learning outcomes are used with assessment standards set by the school, where if the score obtained is ≥ 70 , it is declared complete, and if it is < 70 , it is declared incomplete. According to Arikunto, learning media can be said to be effective if the percentage of classical learning completeness is at least 75% (Arikunto, 2009).

The criteria set to state that students have a positive response to the media is that more than 50% of them respond positively to at least 70% of the number of aspects stated, so from the data obtained the product can be said to be practical to use (Nurdin, 2007).

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3. FINDINGS AND DISCUSSION

3.1 Findings

The Procedure for the Development and Validation of the Virtual Chemistry Practicum Platform for Students Assessing the Validity, Practicality, and Educational Impact carried out in this study can be described as follows:

3.1.1 Analysis

At this stage, data is collected through observation, interviews, and questionnaires. Preliminary analysis showed constraints on the manual attendance system, preliminary assignments given directly by the assistant, and paper-based practicum guides with no visual explanation. This makes it difficult for students to understand procedures and manage time. In addition, the use of manual control cards for assessments often leads to card loss, hampering practicum. The needs analysis identifies the need for an online system to manage attendance, practicum guidance, assignments, and assessments. With an online-based platform, practitioners can access materials, collect assignments, and conduct assessments efficiently, as well as prevent data loss and control cards.

3.1.2 Design


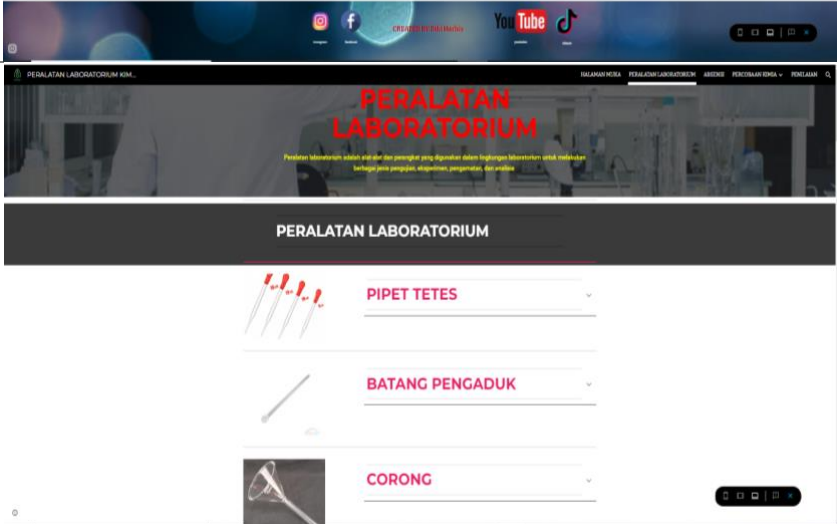
This stage includes media design through visual design of products in the form of story boards to simple displays. The design stage includes three main steps: media selection, format selection, and initial device design. After the needs analysis is completed, the website-based chemical laboratory device is compiled by following the design stage. The selection of media aims to match the needs of practitioners, by using the website as the main media, which makes it easier for practitioners to carry out practicums. The website format was adjusted to the results of the analysis, including the selection of font types such as Times New Roman for readability and professional design, as well as the use of

images in JPG format for clear visuals. In addition, PDF and Excel files are used to present experimental materials and data.

This website uses Google applications such as Google Sites, Google Sheets, Google Forms, and YouTube to improve functionality. Google Sites provides a website-building platform that integrates with other Google services, making it easy to deliver information. Google Sheets is used to manage experiment and assessment data in real-time, while YouTube is used for experimental learning videos that support interactive visualization. Practicum guides, attendance, preliminary assignments, and assessments are also integrated into the website to facilitate administration and access for practitioners and assistants. The website has several pages, including equipment pages, attendance, practicum materials, and assessments, all of which can be easily accessed through the navigation menu.

3.1.3 Development

This development stage includes the expert evaluation stage. Product development and expert assessment are carried out to check the content of the website, layout, format, language and images carried out by two teams of validators to check the content and media of instruments and websites.

No	Components	Image	Yes	Components
1.	Home Page			
2.	Laboratory Equipment			

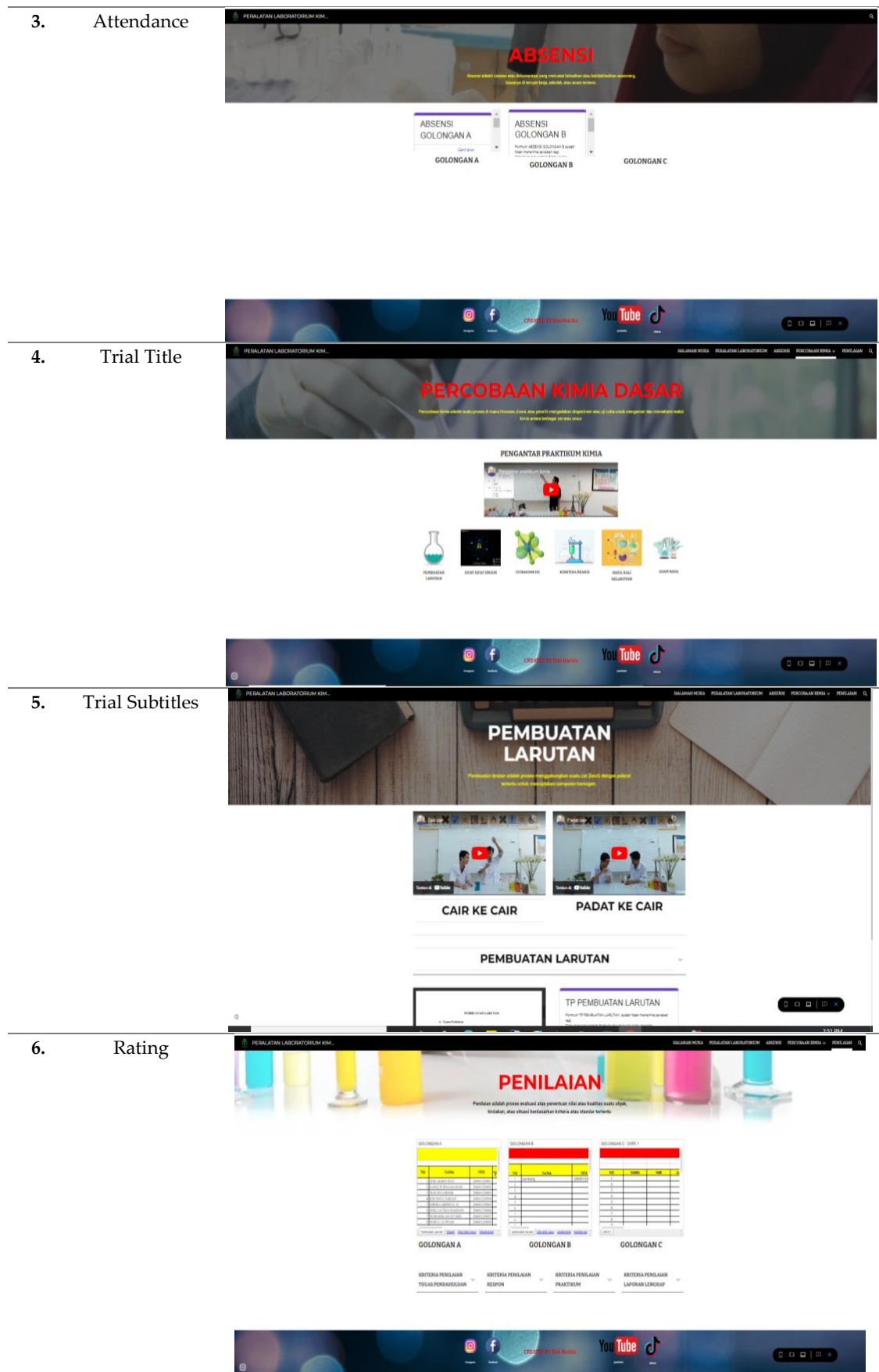


Figure 2. Revised set prototype

The development phase is focused on refining the initial prototype through validation and revision by experts. Validation is carried out by two expert validators, who evaluate the modules based on four aspects: content validity, presentation components, graphic components, and linguistic validity. The results of the validation process are presented in Figure 2.

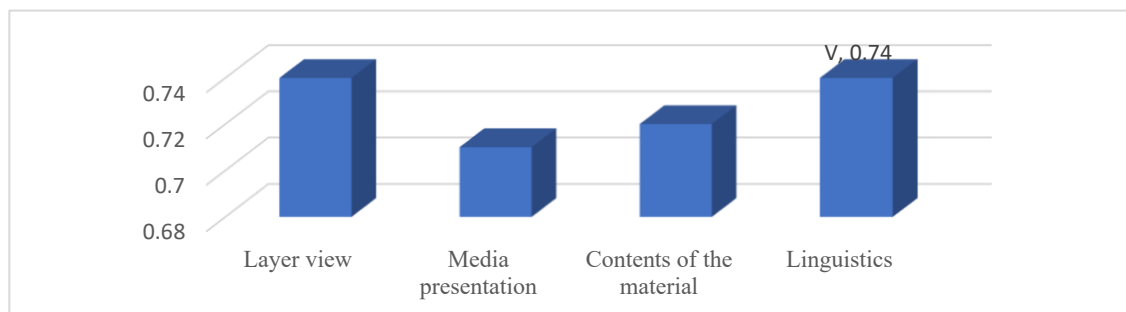


Figure 3. A graph of the validation results for each aspect of the component.

Analysis of the validation results showed that the online-based virtual chemistry practicum device obtained an average Aiken's V score of 0.74, which is included in the high validity category. This shows that the developed virtual chemistry platform meets the validity criteria in all aspects assessed. After the validation process, revisions are carried out according to the validator's suggestions, resulting in Prototype II, as illustrated in Figure 2. After reaching the required level of validity, Prototype II is implemented in the practicum learning activities in the classroom. The limited trial was carried out with the next 8 assistants based on the revised input. Furthermore, a large-scale trial was conducted on 22 Physics Education Students of UIN Alauddin Makassar who programmed the Basic Chemistry course. The results of the trial were used to assess the practicality and effectiveness of the developed online-based virtual chemistry practicum tool.

Table 2. Summary of observation data

No.	Range	Frequency	%	Remarks
1	$x > 54$	15	68	Very Practical
2	$45 < x \leq 54$	7	32	Practical
3	$35 < x \leq 45$	0	0	Enough
4	$26 < x \leq 35$	0	0	Less Practical
5	$X \leq 26$	0	0	Impractical

The practicality of the module was evaluated based on the observation data and student responses, as summarized in Table 2. The results showed that 15 students (68%) categorized the virtual chemistry platform as very practical, while 7 students (32%) categorized it as practical. No student rated the virtual chemistry platform as sufficiently practical, less practical, or impractical. These findings indicate that the development and validation of the Virtual Chemistry Practicum Platform for College Students for use in the laboratory, as most of them fall into the categories of "very practical" and "practical".

3.1.4 Implementation

At the implementation stage, after revision, all developed media designs are implemented at this stage, using online-based chemistry laboratory devices in the laboratory setting. The researcher tested the product in a small group, namely 22 students in the Physics Education Study Program of UIN Alauddin Makassar. The trial aims to evaluate the benefits of the teaching materials and media developed. The online-based device allows laboratories to access and manage experimental data in real-time, facilitates collaboration, and provides dynamic data analysis and visualization. The system integrates with apps like Google Sheets, Drive, and YouTube to improve efficiency. After the trial, an

observation sheet containing a questionnaire was given to find out the responses of the assistants and students to the teaching materials. Although the trial went smoothly, the implementation of real practicum is expected to increase active learning and enrich the practicum experience.

At the implementation stage, the revised product is applied in learning activities in a real classroom. During this stage, observations are made to assess student engagement and response to the use of newly developed learning materials.

The effectiveness of online-based chemistry laboratory devices was evaluated by providing learning outcome tests after students completed learning activities using the media. The test results after learning chemistry are presented in Figure 4. The analysis showed that 22 students, representing 78% of the total participants, achieved scores equal to or greater than 70. According to the standards of the Ministry of Education and Culture, learning mastery is achieved when students achieve an individual mastery level of at least 65%, and classical mastery is achieved when at least 75% of students meet the mastery criteria.

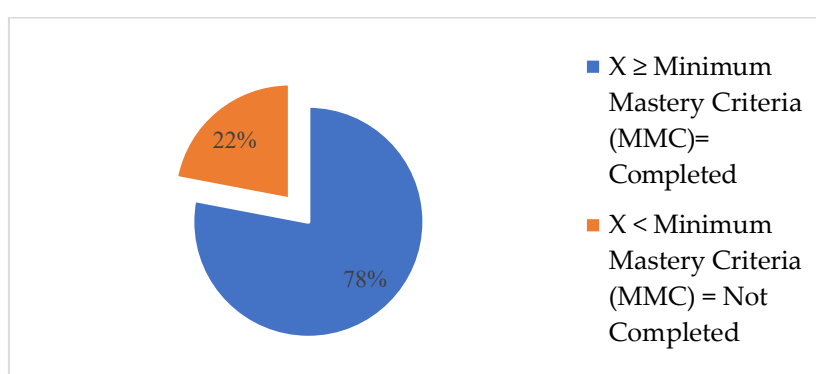


Figure 4. Analysis of mastery of learning outcomes

Based on these results, virtual-based chemistry learning tools can be categorized as effective in improving student learning outcomes. These findings are consistent with previous research that shows that chemistry teaching materials that integrate online media or websites can improve students' conceptual understanding.

3.1.5 Evaluation

The final stage of the ADDIE model is evaluation. The researcher conducted an assessment with interviews and tests of chemistry learning outcomes for students who had used online-based chemistry laboratory equipment. The final test of chemistry learning and interviews aims to gain an in-depth view of the user experience, perception of the content, and suggestions for improvement. The questions asked are related to website navigation, clarity of information, interactivity, and overall satisfaction. The interviewed users were college students who used the device frequently. Another evaluation is the final test of learning chemistry for 7 weeks by providing a learning outcome test to measure student understanding after using the online-based chemistry laboratory device. This evaluation provides feedback on the strengths and limitations of the developed device and confirms its effectiveness as a learning medium. The results of the evaluation showed that online-based chemistry tools made a positive contribution to students' understanding of chemistry concepts and supported the achievement of learning objectives.

3.2 Discussion

The findings of this study show that the development of an online-based chemistry learning tool or virtual chemistry platform developed shows high validity results, with an Aiken's V score of 0.74, which falls into the high validity category. This validation is carried out by two experts who assess the content, presentation, graphics, and language used in the platform or website. The results of this

validation show that the virtual chemistry platform meets the necessary criteria in terms of the quality of the content and media used, and is suitable for use as a learning tool in the laboratory.

These results also align with previous research showing that expert validation is an important step in developing digital learning materials, especially in ensuring the accuracy and relevance of the information presented (Astawan et al., 2023; Topsakal et al., 2022). The high validation of this medium reflects the maturity of the design and implementation of technology in accordance with the needs of students, which will have an impact on the sustainability of the platform's use in the long term.

One of the main findings in this study is the high level of practicality assessed by students on the developed virtual chemistry platform. Based on observation data and questionnaires given to 22 students, 68% of students found this platform very practical, while 32% considered it practical. No student categorizes this platform as either quite practical or less practical. These findings show that the use of a website-based platform for chemistry practicum can greatly facilitate students in accessing materials, collecting assignments, and conducting assessments, as well as preventing data loss that often occurs in manual systems.

This practicality supports the findings of previous research showing that the use of web-based technology in practicum learning can improve efficiency and reduce logistical constraints (Caspi et al., 2023; Cook et al., 2025). In addition, the platform allows for better collaboration between students and laboratory assistants, which is in line with a study by (Chu et al., 2024) that revealed that the use of digital platforms in STEM education encourages more effective interactions in project-based learning.

An analysis of the learning test results conducted after the use of the virtual chemistry platform showed that 78% of students achieved a score of ≥ 70 , which indicates that more than half of the participants gained a good understanding of the chemistry material after using the platform. This indicates that the platform is effective in improving student learning outcomes, and makes a positive contribution to conceptual understanding in chemistry courses.

These findings are relevant to research by (Bonnet de León et al., 2019; Fombona et al., 2020) which found that the use of web-based learning media can improve students' conceptual understanding and practicum skills in science courses. This study also confirms the results of research by (Anggereni et al., 2019; Rahmayani & Atmazaki, 2025) which show that interactive and technology-based learning media increase student engagement in learning and support the achievement of better academic outcomes. However, these results also show that although many students achieve good scores, there are some who are still below the threshold (score < 70). This may be influenced by several external factors, such as the technological readiness at the students' homes or their limited learning experience in the use of digital platforms. Further research can be done to dig deeper into these factors and optimize the platform to be more inclusive and accessible to various circles.

The main contribution of this research is the development and validation of a virtual chemistry platform that can be used for practicum learning in the laboratory. The platform not only improves efficiency in practicum management but also provides a more interactive and engaging learning experience for students. Using applications such as Google Sites, Google Sheets, and YouTube, this media integrates technology that is familiar to students, making it easier to transition to digital-based learning.

The implications of this research are particularly important in the context of higher education, especially in the disciplines of science and technology, where practicum learning is often hampered by logistical and resource constraints. The use of this online-based platform can be a solution to overcome these challenges, and can be applied to a variety of other disciplines that require laboratory practicums. This research also provides insight into the importance of valid and practical design in the development of digital learning tools.

Although these media have proven to be effective and practical, unexpected results have emerged in the form of differences in learning outcome scores between students who are more familiar with technology and those who are less familiar. This shows that there is a digital divide that needs to be considered in the implementation of technology-based platforms. In addition, there are still difficulties

in accessing online media website links that are not familiar with its features, and the ease of access is still a challenge because the network around the laboratory is still relatively low, especially the Wi-Fi network or certain providers. Therefore, more research is needed to identify and address these challenges by providing additional training or more comprehensive tutorials for students who are less familiar with the use of digital media.

Overall, these findings provide a clear picture of the effectiveness and benefits of using online-based virtual chemistry practicum tools and provide a foundation for further development in the context of technology-based higher education. This research is expected to pave the way for further research on the use of technology in education, practicum, and interactive learning.

4. CONCLUSION

The conclusion of this study is to develop and validate an online-based virtual chemistry practicum that shows a high validity score of Aiken's $V = 0.74$. The platform has proven to be effective and practical, with 68% of students categorizing chemistry practicum devices as very practical and 32% as practical. The results of the chemistry study test showed that 78% of students achieved a score of ≥ 70 , which indicates an increase in conceptual understanding after using the platform. With this score, this platform successfully met the research objectives of improving chemistry learning outcomes and the efficiency of chemistry practicums. The implications of this study show that the use of online-based chemistry practicum tools or technology in practicum education can overcome logistical constraints and improve the efficiency of practicum management. The platform can be adopted by a variety of other disciplines that require experiment-based learning. Further research can explore the integration of additional features and more media integration such as gamification to increase student engagement, as well as address the digital divide by providing further training to students who are less familiar with technology.

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