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Improving Students Learning Outcomes and Digital Literacy on Acid-Base Titration Using Titration Screen Experiment Media

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ABSTRACT

This study aims to enhance students' digital literacy and learning outcomes in acid-base titration through Titration Screen Experiment Media. The research used a quasi-experimental method with two class samples, including the experimental class utilizing Titration Screen Experiment Media and the control class without it. Data were collected through digital literacy questionnaires and post-test questions evaluating students' cognitive domain knowledge in acid-base titration. The Multivariate Analysis of Variance (MANOVA) test was used to analyze the data. The results demonstrated that the experimental class, which utilized the Titration Screen Experiment Media, exhibited higher digital literacy levels than the control class and improved learning outcomes in acid-base titration. The average digital literacy score in the experimental class was 56.50, whereas the control class scored 41.70. The experimental class indicated students with intermediate cognitive domain learning outcomes around 84.00, while the control class scored 76.67. These findings suggest that implementing the Titration Screen Experiment Media enhances digital literacy and positively impacts students' learning outcomes in acid-base titration. Educators can effectively improve students' digital literacy skills by integrating this innovative media into teaching and learning while encouraging their academic achievements in chemistry learning. The research emphasizes the significance of digital literacy in modern education. The practical implication lies in the roles of educators in preparing students' chemistry digital literacy.

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1. INTRODUCTION

Today, the rapid growth of Information and communication technology (ICT) significantly impacts human life and requires in various fields (Rizal et al., 2020), including changes in education (Li et al., 2019). Technological progress can synergize teaching and learning by changing conventional learning methods into modern teaching approaches. Digital media is demanding and has become mandatory integration in schools because of the potential to increase student knowledge and skill. Moreover, digital media's features offer a new and easy way to interact, communicate, and socialize with various supports (Lai & Tai, 2021).

The use of online media to improve learning practices has attracted many researchers' attention (Asraf et al., 2018; Mulyono et al., 2021; Zen et al., 2022; García-Ros & Alhama, 2023). Therefore, students' digital literacy skill is essential for students' learning process to use information and technology effectively. Digital literacy is knowledge and skills for using digital media, communication tools, or networks to browse, assess, use, create information, and use it in a healthy, wise, intelligent, careful, precise, and law-abiding manner to build communication and interaction in everyday life (Kementrian Pendidikan dan Kebudayaan, 2017). In this case, skills in understanding and utilizing various information from digital resources are also defined as literacy, which is essential to improvement in education reform (Bulger et al., 2014). However, sufficient digital literacy was not achieved when the high demand for internet use increased in education. Data from the Indonesian Internet Service Providers Association showed 73.7% or 196.71 million internet users in Indonesia from 2019-2020. However, Indonesian digital literacy had not yet achieved a good result, but It was only a bit better than the parameter of good digital literacy (Kemkominfo, 2020). Therefore, Amhag et al. (2019) recommended using technology in learning activities to promote digital literacy. Previous research showed that digital learning media effectively improves learning outcomes and interest (Sidiq & Najuah, 2020) and helps students accelerate their learning (Sibaweihi et al., 2021).

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In chemistry lessons, the chemistry theories were taught by verifying the experiments. Chemistry experiments were more than just the practical application of theoretical knowledge; they also fostered students' practical skills, developed a scientific mindset, and established a solid groundwork for future scientific exploration (Zhao, 2019). Therefore, chemical experiments were crucial in promoting comprehensive knowledge of chemistry to students. However, according to SEAMEO QITEP in Science (SEAQIS), teachers indicated that their practical or experimental chemistry activities were limited in classroom implementation. The reasons were the absence of a laboratory, the lack of equipment, the absence of Laboratory practical manuals, and the limited time allocation (Prastika et al., 2017).

In the post-pandemic COVID-19 era, schools face the ongoing challenge of refining learning activities, often resorting to distance or limited face-to-face learning due to safety concerns. This situation particularly affects laboratory practicum sessions, which can be difficult to conduct in traditional settings. However, digital media has emerged as a solution, providing alternatives such as virtual laboratory experiences (Pratama et al.,2020). While the adoption of digital media in various fields has been rapid, its integration into art therapy practices has been slower, partly due to limited research on its effectiveness. To bridge this gap, comprehensive training in digital tools and their incorporation into art therapy programs is crucial. Platforms like YouTube have played a significant role in disseminating educational information during past disease outbreaks, highlighting their importance in health education(Yüce et al., 2020). Moreover, YouTube has demonstrated its effectiveness in improving listening skills and enhancing the overall teaching and learning process, emphasizing the role of digital media in education during and beyond the pandemic.

Using a virtual laboratory can be an alternative to implementing practicum in schools. In addition to supporting the use of digital media in the learning process, the shift from traditional laboratories to virtual laboratories is promising because it offers a more effective and efficient experimental process (Sapriati et al., 2023). By conducting virtual laboratory experiments, students are arguably engaged with procedures, equipment, and safety guidelines (Gautam et al., 2016). Additionally, traditional laboratory experiments do not provide desirable learning outcomes such as problem-solving skills, critical thinking, designing and implementing experiments, and the capacity to implement knowledge in real-life situations (Cavinato, 2017).

Digital media such as the Titration Screen Experiment is a virtual laboratory-based learning media (https://virtual.edu.rsc.org/titration/experiment/2) that can be used wherever and whenever, so it is more efficient to facilitate students to practice chemistry. This media was developed by the Royal Society of Chemistry (RSC) and is freely accessible online. Virtual laboratory media can make it easier for students and teachers to carry out practicals anywhere. Titration Screen Experiments can support students to master the acid-base titration material. The advantage of this media is that students can carry out experiments that cannot be carried out using original equipment ideally (RSC, 2022).

As a virtual laboratory, the Titration Screen experiment can be used as digital media in learning to support students' digital literacy. Students can understand and think critically about chemical concepts by promoting digital literacy. Spante et al. (2018) found that higher computer hardware and software skills positively impacted high student learning outcomes. Furthermore, Anisimova (2020) emphasized the influence of students' skills and activities in digital-based learning on their experiences, giving the significance of digital literacy in chemistry education. Therefore, this study aims to conduct experimental research on the impact of the Titration Screen Experiment becoming highly compelling. Moreover, investigating the effects of integrating digital media on students' digital literacy and learning outcomes in acid-base titration material can offer valuable insights. A well-designed experimental study has the potential to shed light on the effectiveness of virtual laboratories in enhancing digital literacy and academic achievements in chemistry education. While the initial argument presented the potential benefits of using the Titration Screen Experiment in chemistry education, it lacked depth and empirical evidence. By incorporating robust evidence from Spante et al. (2018) and Anisimova (2020) and providing a more explicit analysis of the literature gap, the argument can be strengthened to justify further research in this area.

2. RESEARCH METHOD

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Quantitative methods were used in this study with a quasi-experimental form of Post-test Only Nonequivalent Control Group Design (Hotman et al., 2018). The study was conducted in one of the public high schools in Surakarta in the 2021/2022 academic year with 2 sample classes using cluster random sampling. The use of cluster random sampling in this study was employed to address potential sources of bias and increase the generalizability of the findings (Raudenbush, 1997). Cluster random sampling involves dividing the population into clusters (in this case, classes) and randomly selecting a sample of clusters to participate in the study. This sampling method was often used when it was not feasible or practical to sample individuals directly. For instance, classes or schools served as natural clusters in educational settings. The research design was shown in Table 1.

Table 1. Research Design

Class	Treatment	*Posttest*
Experimental	X	**O_2**
Control	-	**O_1**

Remarks:
O_1 = Posttest in control class
O_2 = Posttest in experimental class
X = learning using Titration Screen Experiment Media

The data collection for assessing digital literacy involved a questionnaire encompassing five dimensions: information, communication, content creation, safety, and problem-solving (Ferrari, 2013). The questionnaire consisted of 21 questions, each offering four answer options. Students were allowed to select multiple options; each assigned a score of 1. Before data collection, the questionnaire underwent validity and reliability tests, yielding favorable results with a high validity score of 0.857 and a very high-reliability score of 0.953. As displayed in Table 2, a digital literacy questionnaire grid was formulated to facilitate the testing process.

Table 2. Digital Literacy Grid

Dimension	Indicator	No. Question
Information	Browsing, searching, and filtering information	1
	Evaluating information	2
	Storing and retrieving information	3
Communication	Interacting through technologies	4
	Sharing information and content	5
	Engaging in online citizenship	6
	Collaborating through digital channels	7
	Behavioral norms in online interaction	8
	Managing digital literacy	9
Content creation	Developing content	10
	Integrating and re-elaborating	11
	Copyright and licenses	12
	Programming	13
Safety	Protecting devices	14
	Protecting personal data	15
	Protecting health	16
	Protecting the environment	17
Problem-solving	Solving technical problem	18

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Identifying needs and technological responses	19
Innovating and creatively using technology	20
Identifying digital competence gaps	21

The data analysis technique used to test the hypothesis was the Manova Test using SPSS 25 software. In addition, a multivariate test was used to determine the effect on digital literacy and learning outcomes simultaneously. At the same time, the Test of Subject Effects was used to assess the impact on each digital literacy and learning outcome.

3. RESULTS AND DISCUSSION

This study aims to determine the effect of the digital learning media Titration Screen Experiment on digital literacy and student learning outcomes on acid-base titration material. The Titration Screen Experiment from the Royal Society of Chemistry (RSC) is a free digital experiment resource. This media is designed to increase students' understanding of volumetric analysis and improve practical skills related to titration in the laboratory. The resources have been developed using the latest HTML5 technologies without plug-ins or installations. This product also works on touchscreen devices such as Android tablets and smartphones using the Chrome browser and iPads using the Safari browser.

Digital literacy skills were measured using a questionnaire containing 21 questions with a score range of 1-4 for each question. The learning outcomes in this study focused on the cognitive domain. Students did the post-test after attending the chemistry lesson with ten multiple-choice questions. Digital literacy and learning outcomes data from the experimental and control classes were presented in Table 3. Table 3 shows that the average score of the experimental class was higher than the control class for digital literacy data and learning outcomes.

Table 3. Digital Literacy and Learning Outcomes Data for Experiment Class and Control Class

Data Statistics	**Digital literacy**		**Learning outcomes**	
	Experimental class	**Control Class**	**Experimental Class**	**Control Class**
Highest score	77.00	62.00	100.00	100.00
Lowest score	42.00	23.00	60.00	50.00
Mean	56.50	41.70	84.00	76.67

The effect of using Titration Screen media on digital literacy and learning outcomes was tested using the Manova Test. To perform the MANOVA test, the data met the test requirements (i.e., normality and homogeneity tests). A normality test was done to find out whether the data from the experimental and the control class values were normally distributed. Using the Kolmogorov-Smirnov test in SPSS 25, the indicator form normality test used "if the Sig. Value > 0.050 means that the data are normally distributed". From Table 4, the digital literacy data and learning outcomes for the experimental and control classes showed a significance value of > 0.050, so it could be concluded that the data were typically distributed.

Table 4. Normality Test Results

Data	**Class**	**Sig.**	**Test decision**
Digital literacy	Experimental class	0.140	Normal
	Control class	0.200	Normal
Learning outcomes	Experimental class	0.057	Normal
	Control class	0.116	Normal

A homogeneity test was conducted to determine the similarity of the variance in both classes using the Levene statistical test with the assistance of SPSS 25 software. Levene test data was considered homogeneous if Sig. Value > 0.050. The homogeneity test results for digital literacy data and learning outcomes are shown in Table 5. From Table 5, digital literacy data and learning outcomes indicated a significance value of > 0.050, so it

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could be concluded that the data were declared homogeneous.

Table 5. Homogeneity Test Results

Data	Sig.	Decision Test
Digital literacy	0.162	Homogeneous
Learning outcomes	0.499	Homogeneous

The Manova test was done to determine whether there was a difference in the students' digital literacy and learning outcomes in both classes. In addition, a multivariate test was conducted to see the effect of the independent variables on the two dependent variables simultaneously. The results of the Multivariate Test are portrayed in Table 6.

Table 6. Multivariate Test Results

Statistic Test	Sig.
Pillai's Trace	0.000
Wilks' Lambda	0.000
Hotelling's Trace	0.000
Poy's Largest Root	0.000

Table 6 informed the Multivariate Test with statistical tests, namely Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. The results reported Sig. 0.000 on the four statistical tests, 0.000 < 0.050. Then, the test decision showed the effect of Titration Screen Experiment Media on digital literacy and learning outcomes on acid-base titration material. In addition to the Multivariate Test, a Test of Subject Effects was also carried out to determine the effect of the independent variables on each dependent variable. The results of the Multivariate Test are represented in Table 7.

Table 7. Participants' Test of Effects on Digital Literacy and Learning Outcomes

Statistic Test	Sig.
Digital literacy	0.000
Learning outcomes	0.045

Table 7 demonstrates clearly that the use of Titration Screen Experiment Media significantly impacts both digital literacy and learning outcomes related to acid-base titration. Regarding digital literacy, employing Titration Screen Experiment Media significantly enhances participants' digital literacy of acid-base titration. Similarly, for the learning outcomes variable, this teaching method significantly improves participants' understanding of acid-base titration material. These findings highlight the effectiveness of integrating Titration Screen Experiment Media into the teaching process, indicating its potential to positively influence digital literacy and academic performance in the context of acid-base titration studies.

The potential of digital media in learning and teaching must be utilized further because every student needs to develop their digital skills. Moreover, basic digital skills need to be addressed as part of the core transferable skills that every human being should be able to create. Digital communication has changed literacy-related practices and has gained significant relevance in developing knowledge in the 21st century (Gutiérrez-Ángel et al., 2022). For this reason, digital literacy was an essential requirement for development in society related to looking for, acquiring, processing, and communicating information. These aspects have been consolidated as literacy in the twenty-first century (Gutiérrez-Martín & Tyner, 2012).

Titration Screen Experiment as a digital media was recommended to develop digital literacy (Amhag et al., 2019). The results showed that the Titration Screen Experiment affected students' digital literacy. These findings agreed with a prior study by Alt and Raichel (2020) and Listiawati et al. (2022). They found that digital media, such as virtual labs, can significantly affect digital literacy. In this study, the differences in the scores of the experimental and control classes on each dimension of digital literacy are visualized in Figure 1.

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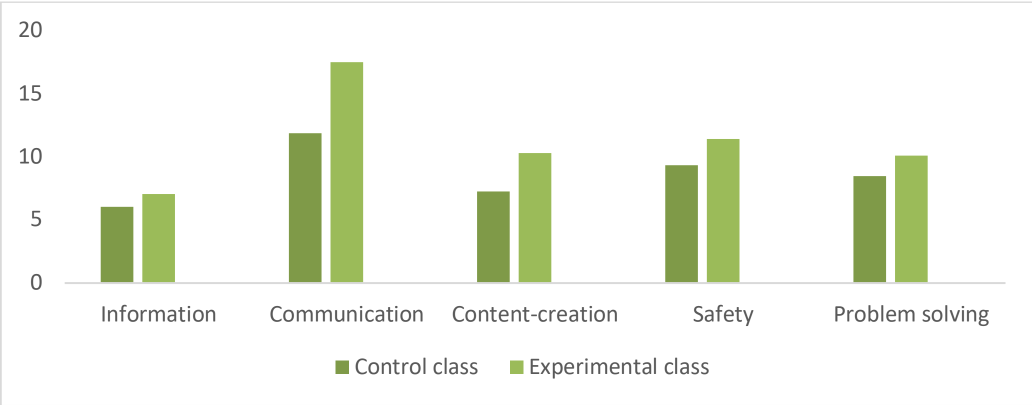
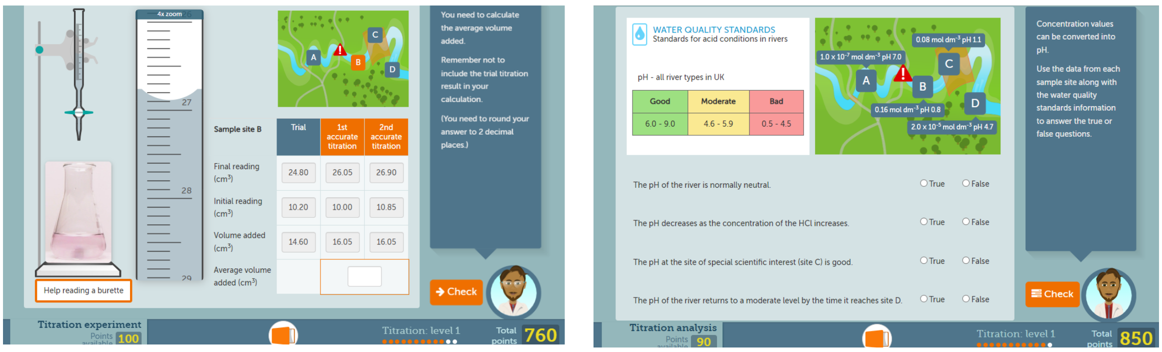


Figure 1. The score of digital literacy on each dimension

In the information dimension, students knew how to identify, locate, retrieve, store, organize, and analyze digital information, judging its relevance and purpose (Ferrari, 2013). These skills were essential for students because they allowed them to filter the data optimally and they used to build knowledge (Ferrari, 2013). Students indicated higher information dimension scores in the experimental class than in the control class. As a learning media, the Titration Screen Experiment helped students evaluate the obtained information. In this media, students were asked to collect data regarding titration. Then, they processed it to calculate the acid or base concentration and determined the water quality, as shown in Figure 2. To assess water quality standards based on experimental data, students critically reflected on data collection, processing, and concluding. From this, students evaluated the collected information to understand more about theory beyond the experiments. Virtual laboratories are oriented on how students' skills are facilitated through virtual laboratory activities and how students know and understand what they do in authentic contexts. To support an all-digital virtual laboratory, students require a deeper understanding of digital literacy, including existing features (Listiawati et al., 2022).



(a) (b)

Figure 2. (a) Data collection based on experimental results; and (b) determine water quality.

Figure 3 shows that students had quizzes before experimenting in the Titration Screen Experiment. The quizzes are related to the information dimension, where students must find relevant information, evaluate it critically, and retrieve the most appropriate information to answer questions. In taking quizzes, students engaged

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in independent learning as they collaboratively navigated information requirements. Through this process, students drew on their prior knowledge and worked together to identify gaps within themselves. Students need literate information to determine the nature and extent of the information needed. Then, they obtain, evaluate, process, and use information to answer their problems (Shultz & Li, 2016). These skills significantly influenced the process of students building perceptions and knowledge, so it was crucial to identify students' interactions with digital media by looking for information to solve problems. (Weber et al., 2018).

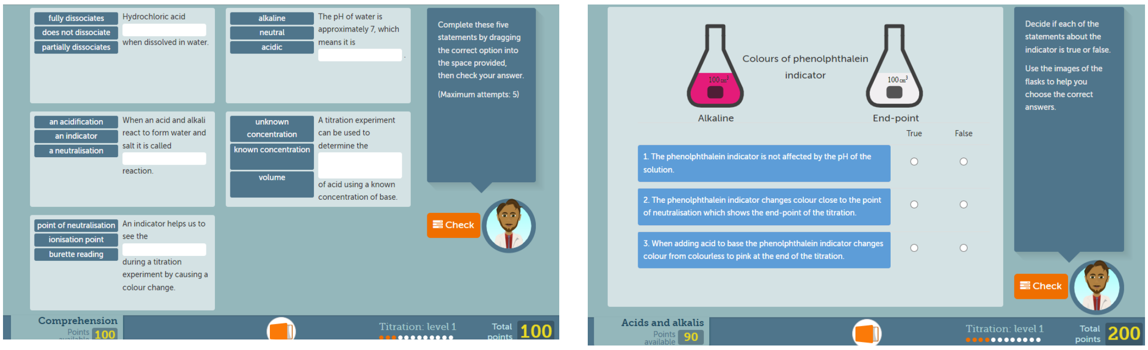

Figure 3. Examples of quizzes in Titration Screen Experiment

th others and collaborate, interact with and participate in communities and networks, and develop cross-cultural awareness (Ferrari, 2013). Furthermore, the Internet could eliminate distance, where people worldwide could connect with the Internet. Therefore, students must determine and operate appropriate digital communication technologies and understand and apply internet ethics in online interaction (Putri et al., 2022). The experimental class also found a higher average score on the communication dimension than the control class, as shown in Figure 1. When students practiced experiments through the Titration Screen Experiment, they could collaborate on experiments in groups with other students, as shown in Figure 4. Later, each student in the group could receive a report on the experiment's results.

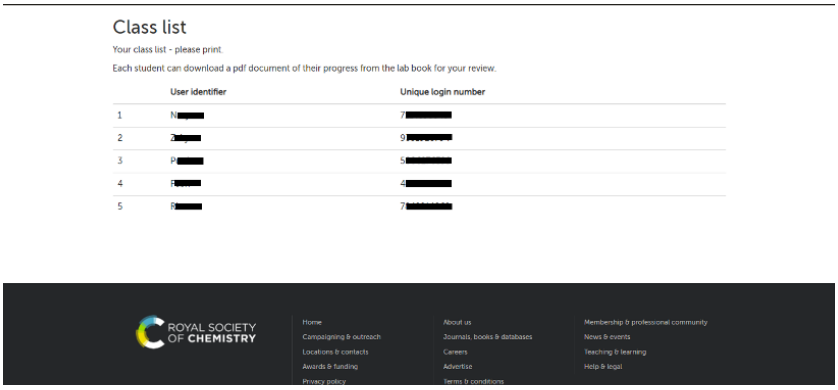

Figure 4. Group registration on Titration Screen Experiment

The Titration Screen Experiment allowed students to collaborate using digital media. In addition, students in one group could share information and content, and they accessed Lab Reports. In implementing online practicums, students could see the role of the media in facilitating online collaboration by paying attention to norms and ethics. In a lesson, four essential scopes focused on developing collaboration skills: 1 learning strategies, 2) learning models, 3) learning media, and 4) learning evaluation (Malik & Ubaidillah, 2021). Digital media has made more accessible communication for students to generate interaction and strengthen social

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relationships (van Laar et al., 2020). Students could easily exchange ideas, information, and experiences using digital media, such as virtual labs.

In the content creation dimension, students knew how to create and edit new content (from word processing to images and video); integrated and elaborated previous knowledge and content; produced creative expressions, media outputs, and programming; and engaged with intellectual property rights and licenses (Ferrari, 2013). Digital content was crucial for students to acquire information and build knowledge. However, the truth of digital content is one of the essential keys to disseminating and understanding information as one of the digital literacy competencies (Putri et al., 2022). Figure 1 shows that the score of the content creation dimension of the experimental class was higher than that of the control class. Students engaged in how to use the Titration Screen Experiment. It could train students' ability to know the program beyond a computer. In addition, the Titration Screen Experiment contained information regarding licenses and copyrights, as shown in Figure 5. This could be notified to students to apply for and respect licenses and copyrights of content or works.

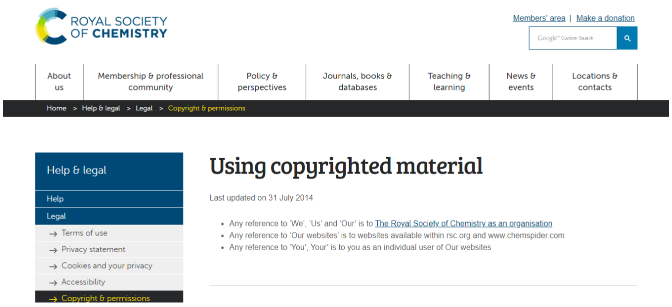
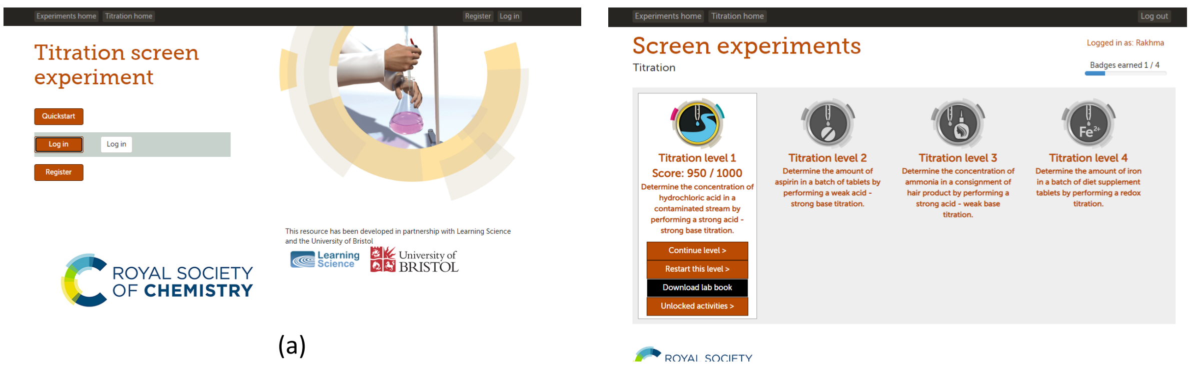


Figure 5. Copyright of Titration Screen Experiment

In a less pressured learning environment, students must know how to do personal protection, data protection, digital identity protection, security measures, and sustainable use (Ferrari, 2013). Figure 1 shows that the safety score of the experimental class was higher than that of the control class. Using the Titration Screen Experiment, students could protect personal data by registering. In addition to protecting personal data, students could save the progress of the experimental activities, as shown in Figure 6. When the practical progress was saved, students did not need to repeat the experiment from the beginning to continue to the next level. It saved more energy and protected the environment. In addition, the Titration Screen Experiment also had a privacy policy for its users using Google Cookies and various regulatory and protection information on the website, as shown in Figure 7. Using the Titration Screen Experiment, students could learn about safety and security in the online environment.



(a) (b)

Figure 6. (a) Login and register options; and (b) progress saved when having an account on the Titration Screen Experiment

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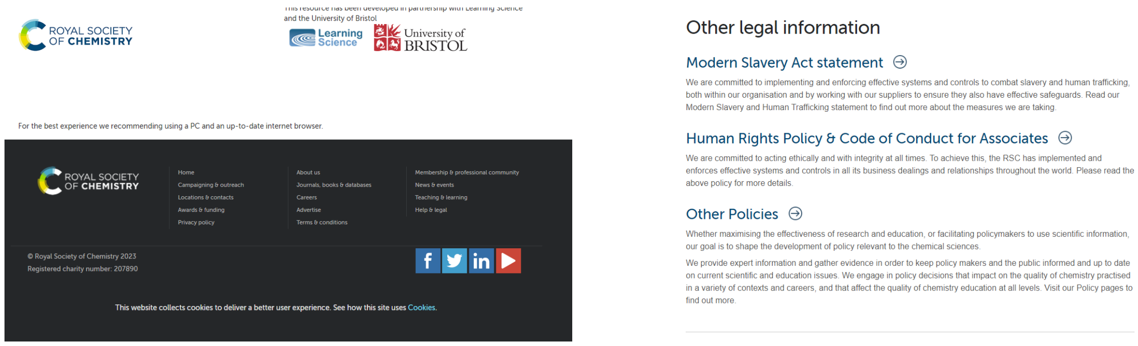
Today, digital security is as important as any issue related to offline threat prevention. To protect students' digitally safe (e.g., regardless of age) required a certain level of digital literacy. The basic knowledge and skills associated with minimizing electronic threats in personal data protection, understanding online threat mechanisms, and problematic Internet use have caused issues related to digital literacy. Digital literacy involves students' fluency in digital media, ICTs awareness, online behavior, and risk-taking behavior (Watulak, 2016). Digital literacy is a multi-faceted construct involving the technical ability to use devices and websites, browse information, secure data, set up tools, and update knowledge of new electronic threats. However, the higher the awareness and literacy in one field, the higher the level of expertise in other areas and the reduction of the dangers accompanying it (Tomczyk, 2020).



(a) (b)

Figure 7. (a) Cookie Protection on websites; dan (b) legal information about the website.

In the problem-solving dimension, students needed to know how to identify digital needs and resources. Therefore, they could make decisions regarding appropriate digital tools based on learning objectives or students' needs. Moreover, students could solve conceptual problems through digital media, creatively use technologies, solve technical issues, and update their competencies (Ferrari, 2013). Problem-solving requires the use of a variety of tools and sources of information. However, an overwhelming variety of tools and sources of information could potentially add more problems, for instance, when a student has limited knowledge and experience using devices and technology. Students needed to have online problem-solving skills to formulate a problem or find a strategy to determine the best solution to their problem. They needed skills to find multiple solutions, solve unusual problems, and transfer knowledge to new situations (Barak, 2018). ICT is essential for accessing and connecting information and solving problems.

In Figure 1, it can be seen that the experimental class had a higher problem-solving dimension score than the control class. First, students encountered technical problems using the Titration Screen Experiment when they did not know how to use virtual laboratory equipment. Therefore, students looked for how to solve existing technical problems. The Titration Screen Experiment provided a helping option for students who did not know how to use the device virtually. For example, when students did not know how to read a burette in a virtual lab, students could read the instructions to solve the problem, as shown in Figure 8.

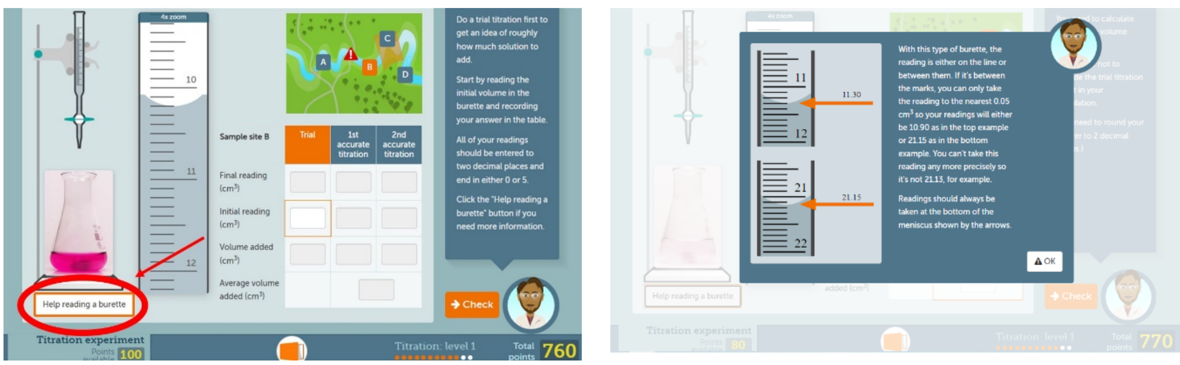


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Figure 8. Instructions on how to read a burette.

In addition to solving technical problems, students could analyze their needs and utilize technology to fulfill them using the Titration Screen Experiment. During laboratory sessions, it's essential for students to receive feedback on their performance, whether it's satisfactory or not, as this can significantly enhance their learning experience. In the Titration Screen Experiment, students have access to the Lab Book, which displays their scores for each evaluated skill, as depicted in Figure 9. This enables them to evaluate their performance and consider revisiting specific sections if they are unsatisfied with their scores. The introduction of the digital media Titration Screen Experiment assists students in recognizing the technology that best suits their educational needs, fostering awareness and informed decision-making.

Figure 9. The example of Lab Book

Digital literacy skills empower students to perform at a minimum level in society. These skills were known as essential skills to perform basic tasks such as understanding hardware (e.g., how to use a keyboard and operate touch screen technology), software (e.g., word processing, how to manage files on a laptop, how to manage privacy settings on a cell phone), and basic online operations (e.g., how to manage e-mail, search, or how to fill out online forms). Digital literacy skills enable students to use technology in meaningful and valuable ways. It included critically evaluating technology or creating content (Abbas et al., 2019). Students with greater digital literacy could use their component skills or familiarity with ICT-mediated activities to learn more (Lei et al., 2021). These results were based on students' digital literacy skills to (a) access information as a building block for learning, (b) manage it for more efficient learning, (c) evaluate it to recognize correct ideas or to detect and correct errors, or (d) communicate it to demonstrate their knowledge of the assessment clearly (Hwang et al., 2012).

The virtual laboratory was one of the digital learning media where conventional laboratories were simulated, and theoretical knowledge was converted into practice to provide opportunities for students to experiment. The learning process by acting in a virtual laboratory occurred with user interaction with the simulation. The various programs used in the virtual laboratory allowed visualization of concepts that could not be observed with the naked eye (Avcı, 2022). Studying acid-base titration should provide opportunities for students to have direct experience in observing phenomena related to titrations. Through experience and direct observation, students are expected to be able to build concepts and connect them to the knowledge.

Titration Screen Experiment was a virtual laboratory that could help conduct virtual acid-base titration experiments. The results showed that the Titration Screen Experiment influenced student learning outcomes. This was in line with the prior research undertaken by Mohammed et al. (2021) and Al-nakhle (2022), which revealed that learning using the virtual lab had a significant effect on learning outcomes because of the improvement of students' levels of knowledge, skills, self-efficacy, and motivation (Al-nakhle, 2022). Furthermore, indicators of achievement in acid-base titration by the control and experimental classes also showed different results, as shown in Figure 10.

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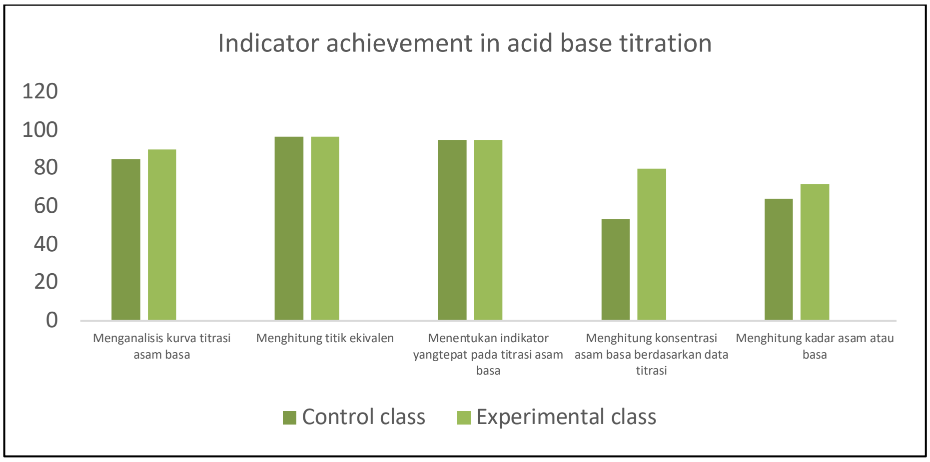
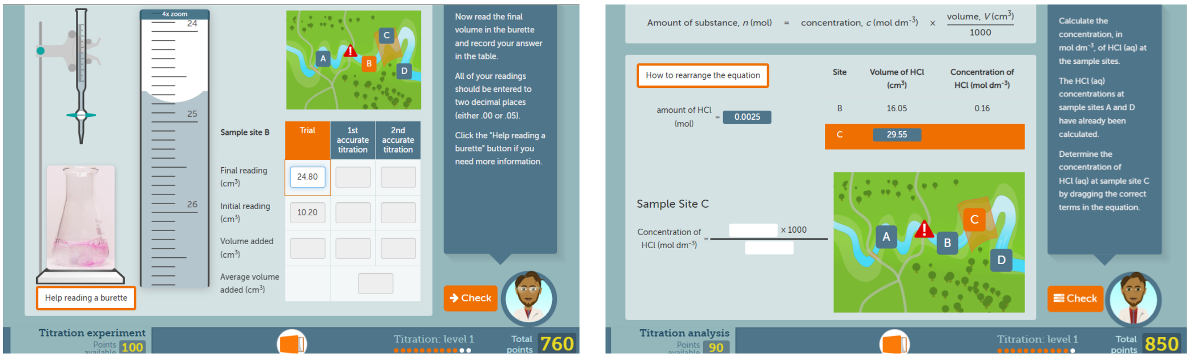


Figure 10. Indicator achievement in control and experimental class

Figure 10 portrayed the most significant differences in calculating acid-base concentration and level indicators. It related to the primary learning outcomes provided by the Titration Screen Experiment, namely calculating the concentration of a solution, determining the attention of an unknown solution, and using stoichiometry to determine the amount of substance. When conducting virtual experiments, students could directly experience phenomena related to titrations to help students understand the material. The findings of the learning experience found that students who took part in virtual simulation-based learning had a positive experience of learning chemistry through a virtual lab that allowed students to 1) visualize chemistry concepts, 2) motivate them to learn, 3) conduct laboratory experiments like a natural laboratory environment (Peechapol, 2021).



(a) (b)

Figure 11. Simulation on Titration Screen Experiment when: (a) collecting titration data and (b) calculating sample concentration.

Mayer's (2014) cognitive theory of multimedia learning was employed to understand how virtual laboratory simulations affect student learning outcomes, such as motivation and metacognition skills (Figure 12). To acquire meaningful knowledge, learners interacted with the information presented in the media. When students actively process information, they gain cognitive knowledge to reflect, conclude, and apply these conclusions in real-life situations (Mayer, 2014).

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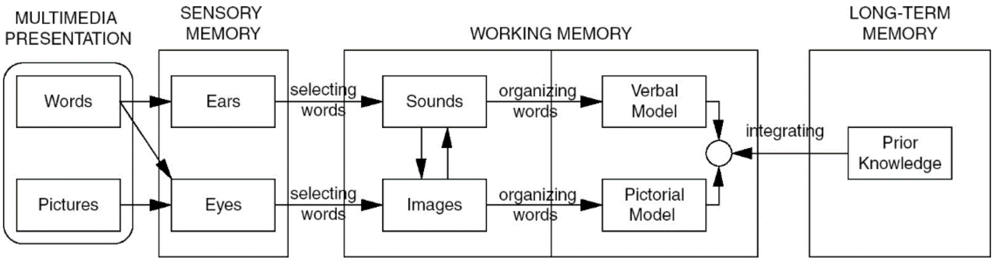

Figure 12. Cognitive theory of multimedia learning (Mayer, 2014)

In the Titration Screen Experiment used in the experimental class, students could directly carry out the processes involved in acid-base titrations. In addition, students were also given the steps for calculating the moles and molarity of solutions in titrations. Activities that involved students directly by carrying them out in systematic stages would reinforce the theory of acid-base titrations so that students would understand it more easily. In addition, it also provided opportunities to conduct repeated laboratory experiments that allowed students to learn chemistry concepts through practice and visualization. In this case, students could continue to practice calculating the concentration of an acid or base regarding the experimental data.

Virtual labs involving images, dynamic visuals, animations, and simulations activated students' visual systems, potentially increasing a student's capacity to store more information and enhancing cognitive processes (Banda & Nzabahimana, 2022). Virtual labs showed better results when students needed to reason and apply chemistry concepts to solve problems (Makransky et al., 2019). In addition, virtual labs could provide dynamic visualizations in the sub-microscopic domain while offering an interactive platform for students. This combination of visual support and high levels of interactivity engaged learners to develop a deeper understanding of learning content (Chan et al., 2021).

Interactivity and autonomous learning were aspects of virtual chemistry labs, making this learning environment constructivist and student-centered. This allowed the learner to understand better chemistry concepts (Chan et al., 2021). For instance, in applying the Titration Screen Experiment Media for acid-base titration, students faced problems related to river pollution, as shown in Figure 13. From the problem, students were asked to determine the concentration of river water contamination using titration. Studies revealed that using virtual labs to replace or complement physical lab facilities supports ubiquitous learning from any place, time, and pace in a flexible environment (Hassan et al., 2022).

Figure 13. Examples of problems are presented in the Titration Screen Experiment

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Students were asked to examine their thinking and learning processes using the virtual lab to collect, record, and analyze data. They were also measured by formulating and testing hypotheses, reflecting on previous understandings, and constructing their meaning. They were the principle of constructivist learning. By adopting a constructivist approach to online learning, students build their knowledge using different cognitive abilities to learn and interact with others. Constructivist environments shape students' evaluation and active, context-specific, and social learning. Based on constructivist theory, students actively construct meaning for themselves in the learning process (Sejzi & Aris, 2012).

The Titration Screen Experiment allowed students to understand chemistry concepts through interactive experiments and successfully perform tasks through virtual lab experiments. In addition, the Titration Screen Experiment was also a medium for students to work in a digital environment. These results indicated that virtual lab simulations could effectively improve digital literacy and chemistry learning outcomes through learning and practice in virtual labs.

4. CONCLUSION

Chemistry is a subject that requires practical activities to test various existing theories and laws. However, several conditions made it impossible to carry out the practicum. Thus, the chemistry virtual laboratory appeared to be very helpful for students. The virtual laboratory can provide students with meaningful virtual experiences and present essential concepts, principles, and processes. Based on the research results, using the Titration Screen Experiment as a virtual lab can improve digital literacy and student learning outcomes. From these results, it is hoped that teachers can utilize ICT as a learning medium and continue assisting students online.

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