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Integrating Virtual Laboratories in Chemistry Education: Vocational Students' Responses to Cation Qualitative Analysis

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Abstract
Research on student responses and the challenges of implementing virtual laboratories in qualitative cation analysis practicums within vocational pharmacy education remains limited. This study aims to explore student responses to the use of virtual laboratories as an alternative learning tool and to identify the challenges faced during its implementation. A qualitative approach with a case study method was employed. Data were collected through questionnaires and classroom observations during the learning process. The participants were 41 Grade XII students of the Pharmacy Program at SMK Galang Insan Mandiri Binjai, who engaged in virtual laboratory-based learning for qualitative cation analysis. The results indicate that virtual laboratories enhance student engagement and comprehension of the subject matter. Students responded positively to the use of virtual labs, reporting increased motivation and interest in developing technology-related skills. However, challenges such as limited digital literacy and infrastructure issues were also identified. The study suggests that virtual laboratories should be complemented with hands-on practicum sessions to provide a balanced and realistic learning experience. These findings offer valuable insights into the potential and limitations of virtual laboratory implementation in vocational pharmacy education.

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INTRODUCTION

Vocational High Schools (SMK) play a crucial role in preparing students to enter the workforce, particularly in the health sector. One of the most widely developed expertise programs in vocational education today is the field of pharmacy (Mumpuni et al., 2021; Santika et al., 2023). Education in vocational schools is focused on equipping students with practical skills and knowledge, where laboratory-based practical learning is more dominant than theoretical instruction. Through this approach, students gain hands-on learning experiences, interact directly with materials, and observe real-world phenomena (Yanto et al., 2023). Furthermore, vocational education aims to develop high-quality and competitive human resources while encouraging students to be critical, creative, innovative, communicative, and collaborative (Gunawan et al., 2021; Siregar et al., 2022).

Despite its importance, chemistry learning in vocational schools still faces various challenges. According to Penn & Ramnarain (2019), chemistry is often difficult for students to understand due to its abstract nature and the lack of connection to everyday life, compounded by the limited laboratory resources in schools with constrained budgets. Ideally, students are expected to identify problems, formulate hypotheses, design and conduct experiments, analyze data, and communicate findings both orally and in writing (Theresia et al., 2023). Laboratories play an essential role in this process by training students' abilities in demonstrations, experimentation, and scientific development (Rahman et al., 2020).

However, based on observations at the GIM Binjai Health Vocational School, particularly in the Pharmacy department, laboratory equipment and chemical reagents remain limited. These limitations hinder the implementation of qualitative cation analysis experiments. Restricted access to practical materials presents a significant barrier to developing students' scientific skills. Moreover, laboratory activities are often confined to basic experimental procedures, which impedes students' comprehensive understanding of the subject matter and restricts opportunities for creativity, experimentation under varied conditions, or skill practice prior to actual laboratory work, thereby affecting their confidence (Shamsulbahri & Zulkiply, 2021; Widarti et al., 2022;Alkan, 2021).

The use of technology in education offers an opportunity to overcome these obstacles. One of the innovations that is developing is the use of virtual laboratories (Santos & Prudente, 2022). Virtual labs, as evidenced by Widarti et al., (2022), have been shown to improve students' comprehension and improve their thinking skills, allowing online practicum anytime and anywhere without time or space limitations. Virtual laboratories are needed to support practical learning in Vocational High Schools (SMK), providing a safe and controlled environment for students to prepare before entering physical laboratories (Eskawati et al., 2021). Zaturrahmi et al., (2020), eported that virtual labs help overcome students' limited understanding and lack of confidence when performing real laboratory experiments, with a recorded 7.8% improvement in learning outcomes. Haryanti et al.,(2023) also highlighted that virtual labs assist students in grasping chemical concepts and solving problems more effectively. Furthermore, Darojat, (2022) emphasized that virtual labs can improve students' psychomotor skills and conceptual understanding.

Given these findings, teachers must keep up with technological developments and focus on their competence in teaching learning topics using virtual laboratories. Virtual laboratories can also be used as a low-cost alternative to real laboratories (Siregar et al., 2022). While previous studies have confirmed the benefits of virtual laboratories (Clarinda et al., 2022; Darojat, 2022; Lestari et al., 2023; Manyilizu, 2023), limited research has focused specifically on how vocational pharmacy students respond to using this technology in qualitative cation analysis. The results of this study are expected to provide input for teachers and curriculum developers in designing more effective and contextualized chemistry learning in vocational high schools (SMK), particularly on the topic of qualitative cation analysis (Fathonah et al., 2015; Haryani et al., 2022; Jannah et al., 2022). For this reason, this study explored how students respond to using virtual labs to learn qualitative analysis of cations. Understanding students' responses to this technology is expected to help find solutions to overcome obstacles in practicum-based chemistry learning and increase the effectiveness of learning at vocational schools.

METHOD

This research was conducted using a descriptive qualitative method with a case study approach to analyze the response of Health Vocational School students to learning qualitative analysis of cations using virtual lab technology. The descriptive qualitative method with a case study approach is a research strategy that aims to understand phenomena in a real-world context using data collection techniques, such as in-depth interviews, questionnaires, participatory observations, and document analysis (Priya, 2020).

This study's subject is 41 students in grade XI of Pharmacy SMK Galang Insan Mandiri Binjai who have carried out qualitative analysis of cations learning using a virtual lab.

The procedure in this study consists of 3 stages, namely (1) Introduction of virtual lab technology to students and provision of access to qualitative analysis of cations experiments; (2) Data collection through student response questionnaires and observations when students participate in learning sessions with virtual labs; and (3) Data analysis to identify the main parts of student responses, such as concept understanding, involvement in learning, ease of use, independent learning, practical learning, technology skills, learning motivation, impressions of the virtual lab and learning evaluation.

This research instrument uses a closed questionnaire of student responses using the Likert scale with four assessment criteria and student behavior observation sheets. The student response questionnaire consisted of 21 questions and 9 question indicators. The observation sheet consists of nine aspects of assessment with a choice of "yes" and "no" answers. The questionnaire was validated by three experts, comprising two university lecturers in chemistry education and one senior vocational school chemistry teacher. The validation process involved content validation, reviewing the relevance of indicators to learning objectives, and the clarity of item wording. The results indicated that all items were appropriate, with minor revisions made to enhance clarity and readability.

Data from the questionnaire were analyzed using descriptive quantitative statistics, including frequency, percentage, and average scores. After the data is collected and analyzed, the research results will be presented through tables and graphs, making it easier to understand the research results (Safitri, 2023). The percentage was calculated to measure students' responses to each indicator using the following formula:

$$\text{Percentage} = \frac{Number\ of\ Score}{maximum\ Number\ of\ Score} \times 100\%$$

Where:

- Total Score Obtained = the cumulative score from all student responses for a given indicator.
- Maximum Possible Score = number of respondents × highest possible score per item × number of items in the indicator.

To determine the criteria based on each indicator, the data score interpretation is carried out to determine the appropriate criteria based on Table 1.

Table 1. Data Interpretation Criteria

No	Score Interval (%)	Criteria
1	81-100	Very Good
2	61-80	Good
3	41-60	Enough
4	21-40	Less
5	0-20	Very Less

(Kartini & Putra, 2020)

Data from the observation sheet were analyzed by calculating the frequency of achievement for each behavioral aspect observed during the virtual lab learning sessions. The research results were presented in the form of tables and graphs to facilitate interpretation and comparison.

RESULTS AND DISCUSSION

This study investigated the responses of grade XI pharmacy students to using virtual laboratories to learn qualitative cation analysis at SMK Kesehatan Galang Insan Mandiri. Data was obtained through a response questionnaire provided to students online using Google Forms. Overall, the results of the study indicated that the use of virtual laboratories to learn qualitative cation analysis was successful, and students were highly enthusiastic throughout the learning process. Grade XI pharmacy students responded very positively to the use of virtual laboratories in the learning process.

Student Responses to the Use of Virtual Laboratories

The study revealed that students responded positively to the use of virtual laboratories in learning qualitative analysis of cations. Overall, the students' responses fell into the "good" to "very good" category, as shown in Figure 1. Based on Figure 1, the percentage of learning evaluation aspects is 75.61%; the aspect of impressions of virtual lab is 75.3%; the learning motivation aspect is 80.49%; the technology skills aspect is 79.57%; practical skills aspect is 78.66%; the independent learning aspect of 71.04%; the ease of use aspect is 72.24%; The student engagement aspect was 75.81% and the understanding concepts aspect was 78.66%.

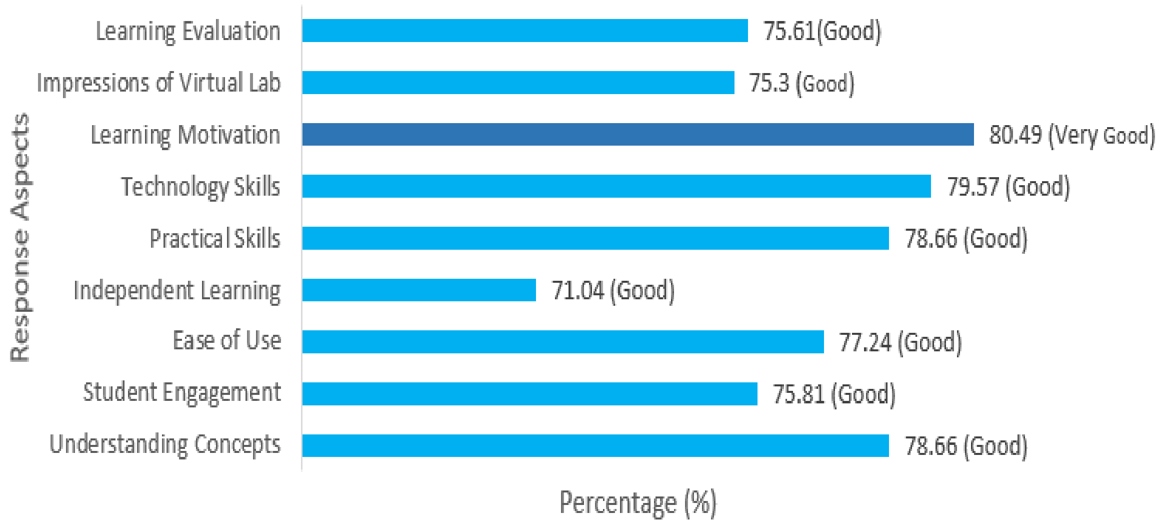

Figure 1. Graph of percentage of student responses to the use of virtual laboratories

Of the nine response aspects, the highest percentage was obtained from the learning motivation aspect, with a "very good" category. Virtual laboratories greatly increase student motivation to study qualitative analysis of cations materials. In addition, using a virtual laboratory can overcome the problem of limited facilities of tools and materials for cationic qualitative analysis practicum so that students become more motivated in learning because they can do the practicum visually without the barriers of facilities (Jeffery et al., 2022; Li & Liang, 2024; Wu et al., 2022).

The use of this virtual laboratories also improves student understanding. The graph in Figure 1 shows that the concept understanding aspect scored 78.66%, categorized as good. Based on the data of Table 2, on average, 24% of students strongly agree (SS), and 70.5% agree that virtual laboratories help students understand the basic concepts of cationic qualitative analysis.

Other aspects, such as ease of use and technological skills, also received high scores, 77.24%, and 79.57%, respectively, in the good category. This support shows that the use of virtual laboratories provides an accessible practicum experience and allows students to develop technological skills and abilities.

Analysis of Student Response Aspect

Table 2 provides a detailed breakdown of student responses based on individual statements related to aspects of motivation, understanding, skills, and independence.

Table 2. Percentage of students' answers to the use of virtual laboratories

Response Aspects	Question	Percentage (%)			
		SS	S	TS	STS
Understanding Concepts	The use of Virtual Lab helped me understand the basic concepts of qualitative analysis of cations in pharmaceutical chemistry	20.9	72.1	7	0
	I find it easier to understand how to conduct qualitative analysis of cations through Virtual Lab technology	23.2	72.1	4.7	0
	Virtual Lab technology allows me to understand better the steps of qualitative analysis of cations in a pharmaceutical context	27.9	67.4	4.7	0
	Average	24.0	70.5	5.5	0
Student Engagement	Learning using the Virtual Lab makes me more active in learning qualitative analysis of cations related to pharmacy	16.3	69.7	9.3	4.7
	I feel more involved in the qualitative analysis of cations by using Virtual Lab technology in pharmaceutical chemistry	23.3	60.4	11.6	4.7
	Group discussions on the results of the Virtual Lab increased my involvement in understanding the qualitative analysis of cations in pharmaceutical chemistry	23.3	69.7	4.7	2.3
	Average	21.0	66.6	8.5	3.9
Ease to Use	I find it easy to use Virtual Lab to conduct qualitative analysis of cations in pharmaceutical chemistry	14	81.3	4.7	0
	The use of Virtual Lab makes it easy to conduct experiments that are difficult to do in physical laboratories in the context of pharmaceutical chemistry	16.3	83.7	0	0
	I had no trouble following the steps of the qualitative analysis of cations in the Virtual Lab in the subject of pharmaceutical chemistry	11.6	81.4	7	0
	Average	14.0	82.1	3.9	0.0
Independent Learning	The Virtual Lab allows me to conduct qualitative analysis of cations experiments independently without direct guidance from the teacher	4.7	48.7	41.9	4.7
	I feel more confident in conducting qualitative analysis experiments of cations independently using the Virtual Lab in pharmaceutical chemistry	16.3	72.1	11.6	0
	Average	10.5	60.4	26.8	2.4
Practical Skills	With the Virtual Lab, I can practice practical skills in conducting qualitative analysis of cations even though I am not in a physical laboratory	23.3	69.7	7	0
	The Virtual Lab helped me to understand how qualitative analysis of cations is done in the real	18.6	79.1	2.3	0

Response Aspects	Question	Percentage (%)			
		SS	S	TS	STS
	world and its applications in the pharmaceutical field				
	Average	21.0	74.4	4.7	0
Technology Skills	Learning using the Virtual Lab improved my skills in using technology in pharmaceutical chemistry learning	20.9	79.1	0	0
	Virtual Lab helps me feel more comfortable in using technological devices in pharmaceutical chemistry experiments	18.6	81.4	0	0
	Average	19.8	80.3	0	0
Learning Motivation	The use of Virtual Lab increased my motivation to study qualitative analysis of cations in pharmaceutical chemistry	18.6	79.1	2.3	0
	I felt more interested in studying pharmaceutical chemistry after using the Virtual Lab for qualitative analysis of cations experiments	27.9	69.8	2.3	0
	Average	23.3	74.5	2.3	0
Impressions of Virtual Lab	Overall, I feel happy and satisfied using the Virtual Lab to learn qualitative analysis of cations in pharmaceutical chemistry	18.6	81.4	0	0
	I prefer to learn qualitative tests of cations using a Virtual Lab compared to traditional laboratory experiments in pharmaceutical chemistry	9.3	58.2	30.2	2.3
	Average	14.0	69.8	15.1	1.2
Learning Evaluation	Learning with a Virtual Lab provides a more engaging experience compared to conventional learning in pharmaceutical chemistry	9.3	76.7	14	0
	I feel that learning using the Virtual Lab is very helpful in understanding difficult pharmaceutical chemistry materials, such as qualitative analysis of cations	18.6	79.1	2.3	0
	Average	14.0	77.9	8.2	0.0
	Overall Average	18.2	73.0	8.0	0.9
	Criteria	Very Good			

Based on the data of Table 2, on average, 24% of students strongly agree (SS), and 70.5% agree that virtual laboratories help students understand the basic concepts of cationic qualitative analysis. Other aspects, such as ease of use and technological skills, also received high scores, 77.24%, and 79.57%, respectively, in the good category. This support shows that the use of virtual laboratories provides an accessible practicum experience and allows students to develop technological skills and abilities.

Learning Motivation

The motivation aspect achieved the highest score at 80.49% (Figure 1). This data is also consistent with the results in Table 2, where 23.3% of students strongly agree (SS) and 74.5% agree (S) that virtual labs increase their motivation in chemistry. This supports the findings of Zhang et al. (2021), who emphasized that interactivity and visualization in virtual learning environments enhance student motivation.

Conceptual Understanding

With a percentage of 78.66% (Figure 1), students expressed that the virtual lab helped them better understand the material. Table 2 also shows that 70.5% of students agreed or strongly agreed with this statement. Chen et al., (2024) also noted that the use of virtual laboratories can maximize students' understanding of concepts and skills. Other research has also shown that virtual laboratories have a greater impact on improving students' conceptual understanding of chemical concepts than traditional laboratories (Ramnarain, 2019). In addition, according to a study by Clarinda et al., (2022), virtual laboratories have been proven effective in enhancing students' conceptual understanding of chemistry learning. Students also consider this medium practical and engaging. These findings indicate that virtual laboratories improve theoretical comprehension and provide an interactive and immersive learning experience.

Skill Development

Students' perception of skills enhancement scored 76.96% (Figure 1), indicating a positive view. As noted in Table 2, a significant proportion of students reported improved analytical and observational skills. Other aspects, such as ease of use and technological skills, also received high scores, 77.24%, and 79.57%, respectively, in the good category. This support shows that the use of virtual laboratories provides an accessible practicum experience and allows students to develop technological skills and abilities. These results align with the findings Kerimbayev et al., (2023) that using technology in education will enrich learning, making it more interactive and engaging for students. This is in line with the findings of Lestari et al., (2023), which shows that virtual laboratories significantly improve students' critical thinking skills and participation in the learning process. In addition, learning using technology has also become popular and important in the context of modern learning.

Learning Independence

The lowest aspect score was learning independence (71.04% in Figure 1). In Table 2, only 10.5% of students strongly agreed that virtual laboratories supported independent learning, while 60.4% agreed. This suggests a need for better scaffolding to encourage independent exploration. According to the researcher, this indicates that while virtual laboratories have potential, their current implementation may not sufficiently promote student autonomy without proper instructional support.

Positive student responses showed that virtual laboratories are an effective medium in complementing chemistry learning, especially in learning cationic qualitative analysis, but still cannot replace the physical laboratory as a whole. The advantage of virtual laboratories is that they can provide innovative and interesting learning experiences. At the same time, the disadvantages are the limitations in providing hands-on experience and the limitations in providing in-depth understanding without the support or guidance of teachers. The researcher believes that these strengths and weaknesses highlight the importance of using virtual laboratories as a complement, not a substitute, for physical labs. Therefore, combining virtual laboratories with hands-on practice is the best step in improving the quality of chemistry learning and helping students improve their motivation and understanding of concepts and skills (Peechapol, 2021). The virtual laboratory shows that students have a strong positive attitude, create a positive learning environment, improve student learning outcomes, and positively impact student achievement (Samosa, 2021).

Observation of Student Skills

During observations, several student competencies were assessed, such as communication, collaboration, and problem-solving. The results in Figure 2 that communication skills scored the highest at 100%, followed by problem-solving at 93.3%. However, student independence was still considered moderate, at 70.73%. This finding supports previous response analysis results, suggesting that although students are actively engaged in the learning process, their ability to work independently still needs further development.

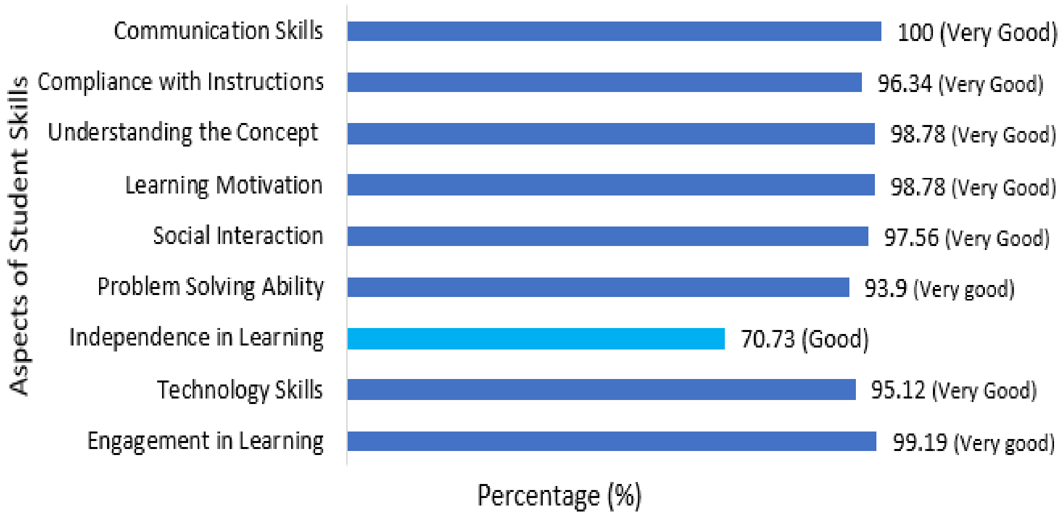

Figure 2. Graph of percentage of students' skill observation towards the use of virtual laboratories

Student engagement in the learning aspect was also recorded as very high, with a percentage of 99.19% in the "very good" category, while learning motivation reached 98.78%, also in the "very good" category. These results suggest that the use of virtual laboratories provides an engaging and enjoyable learning experience, consistent with the known advantages of virtual labs in offering innovative and interactive learning environments.

However, the data in Table 2 reveal that students' confidence in conducting qualitative cation tests independently without teacher guidance remains suboptimal. Many students argued that virtual laboratories should not be used in isolation but rather in combination with hands-on laboratory activities. This perspective is supported by data showing that 48.7% of students agreed with this statement, while 41.9% disagreed. These percentages reflect a degree of uncertainty among students about performing independent experiments, likely due to limited experience or the inherent limitations of virtual labs.

Hu-Au & Okita, (2021) also suggest that virtual laboratories may reduce student involvement in safe procedural behavior during the practicum. This supports the observation and questionnaire findings, indicating that while students demonstrate high levels of engagement and communication in virtual settings, independent learning remains a critical area for improvement. Arsani et al., (2024) argue that structured, project-based tasks within virtual environments can effectively enhance students' independent learning skills.

The implementation of virtual laboratories in qualitative cation analysis has proven to be beneficial, particularly in situations where there are limitations in physical tools and materials. Virtual labs allow students to carry out experiments visually, enabling them to gain scientific experience even without access to conventional laboratories. Aroch (2024) emphasizes that virtual labs can serve as replacements, complements, or supplements to traditional laboratories—especially during emergencies or for experiments that are complex, hazardous, or difficult to access.

Furthermore, Sarwono & Lyau, (2023) highlight that virtual labs help students develop essential skills relevant to their future careers, supporting the formation of competent graduates aligned with their areas of specialization. In another study, Manyilizu, (2023) found that students who first used virtual laboratories exhibited better practical skills in real laboratories compared to those who started directly with physical labs. Although face-to-face practicals cannot be completely replaced, Gungor et al., (2022) provide evidence that virtual chemistry labs are effective complementary tools significantly improving learning outcomes.

Overall, this study demonstrates that virtual laboratories are effective in enhancing student motivation, understanding, and engagement in chemistry education, particularly in vocational school contexts. However, to address the relatively low level of learning independence, a blended approach that integrates both virtual and physical labs is strongly recommended.

CONCLUSION

The study found that the use of virtual laboratories in learning qualitative analysis of cations had a positive impact on students' motivation, independence, conceptual understanding, as well as their technological and practical skills. However, direct hands-on experience remains essential to strengthen laboratory competencies and deepen understanding. Virtual laboratories serve as a relevant alternative in addressing the limitations of physical laboratory facilities in vocational schools. To maximize their effectiveness, virtual labs should be strategically integrated with other instructional models. This study's limitation lies in its narrow scope, involving only one school and a limited sample, which restricts the generalizability of the findings. Further research with broader coverage and more diverse approaches is recommended to assess the effectiveness of combining virtual and physical laboratory learning in enhancing students' outcomes and skills.

RECOMMENDATIONS

Future studies should expand the sample scope, integrate virtual and physical laboratories, address technological and accessibility challenges, enhance teacher training, and develop more interactive and realistic virtual laboratory designs to maximise learning outcomes in vocational chemistry education.

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BIBLIOGRAPHY

Alkan, F. (2021). Analytical Chemistry Laboratory Qualitative Analysis Process Examination: Links Between Experimental Data And Calculation. *Jurnal Ilmiah Peuradeun*, *9*(3), 719–742. https://doi.org/10.26811/peuradeun.v9i3.663

Aroch, I. , K. D. , & B. R. (2024). Modes of technology integration in chemistry teaching: theory and practice. *Chemistry Education Research and Practice*, *25*(3), 843–861.

Arsani, I. A. A., Manuaba, I. B. P., Darma, I. K., & Yusuf, M. (2024). Virtual Laboratory and Self-Efficacy in Optimizing Problem-Solving Skills: A Case in Applied Chemistry Learning in Vocational College. *Jurnal Teknologi Pendidikan*, *26*(1), 171–182. https://doi.org/10.21009/JTP2001.6

Chen, S., Xue, S., Yang, D., Zhu, L., & Ye, M. (2024). Exploring Differences in Student Learning and Inquiry Skills Between Hands-On and Virtual Chemistry Laboratories. *Journal of Chemical Education*, *101*(10), 4102–4113. https://doi.org/10.1021/acs.jchemed.4c00557

Clarinda, C., Novalina, N., Gu, M., & Faradiba, F. (2022). Efektivitas Penggunaan Virtual Laboratory Terhadap Peningkatan Hasil Belajar Siswa SMA Di Era New Normal. *Edumatsains*, *6*(2), 257–266. http://ejournal.uki.ac.id/index.php/edumatsains

Darojat, A. (2022). Studi Literatur Efektivitas Penggunaan Virtual Laboratory Dalam Pembelajaran Kimia Secara Luring. *International Journal of Educational Resources*, *3*(3), 359–364.

Eskawati, M. B., Siregar, E., & Kusumawardani, D. (2021). Need Analysis of Virtual Laboratory for Vocational School Learning Practices During Covid-19 Pandemic. *Journal of Educational Research and Evaluation*, *5*(2), 192–199. https://ejournal.undiksha.ac.id/index.php/JERE

Fathonah, R., Masykuri, M., & Saputro, D. S. (2015). Pengembangan Multimedia Simulatif Kimia Berbasis Inkuiri Terbimbing Pada Materi Analisis Kualitatif Kation Golongan 1. *JURNAL INKUIRI*, *4*(3), 120–126. http://jurnal.fkip.uns.ac.id/index.php/sains

Gunawan, A. I., Kania, R., & Senalasari, W. (2021). Analisis Peluang Bisnis Start-Up Konsultan UMKM dari Akademisi dan Institusi Pendidikan Vokasi. *Bhakti Persada*, *7*(1), 11–16. https://doi.org/10.31940/bp.v7i1.2328

Gungor, A., Kool, D., Lee, M., Avraamidou, L., Eisink, N., Albada, B., van der Kolk, K., Tromp, M., & Bitter, J. H. (2022). The Use of Virtual Reality in A Chemistry Lab and Its Impact on Students' SelfEfficacy, Interest, Self-Concept and Laboratory Anxiety. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(3). https://doi.org/10.29333/ejmste/11814

Haryani, S., Prasetya, A. T., Dewi, S. H., & Fadillah, A. (2022). Penyusunan Bahan Ajar SMK Terintegrasi Konteks Kejuruan pada Pembelajaran Kimia. *Jurnal Inovasi Pendidikan Kimia*, *16*(2), 131–137.

Haryanti, I., Kurniawati, Y., & Lubis, F. H. (2023). Penerapan Virtual Laboratory dengan Menggunakan Model Problem Based Learning (PBL) untuk Mendukung Proses Pembelajaran Kimia. *Journal of Chemistry Education and Integration*, *2*(1), 42–49. https://doi.org/10.24014/jcei.v2i1.21771

Hu-Au, E., & Okita, S. (2021). Exploring Differences in Student Learning and Behavior Between Real-life and Virtual Reality Chemistry Laboratories. *Journal of Science Education and Technology*, *30*(6), 862–876. https://doi.org/10.1007/s10956-021-09925-0

Jannah, F. F., Khamidinal, K., & Suprihatiningrum, J. (2022). Pengembangan Media Virtual Lab sebagai Alternatif Praktikum Kimia dalam Pembelajaran Daring di Masa Pandemi COVID-19. *Jurnal Inovasi Pendidikan Kimia*, *16*(2), 97–103. http://journal.unnes.ac.id/nju/index.php/JIPK

Jeffery, A. J., Rogers, S. L., Pringle, J. K., Zholobenko, V. L., Jeffery, K. L. A., Wisniewski, K. D., Haxton, K. J., & Emley, D. W. (2022). Thinglink and the Laboratory: Interactive Simulations of Analytical Instrumentation for HE Science Curricula. *Journal of Chemical Education*, *99*(6), 2277–2290. https://doi.org/10.1021/acs.jchemed.1c01067

Kartini, K. S., & Putra, I. N. T. A. A. (2020). Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android. *Jurnal Pendidikan Kimia Indonesia*, *4*(1), 12–19. https://ejournal.undiksha.ac.id/index.php/JPK/index

Kerimbayev, N., Umirzakova, Z., Shadiev, R., & Jotsov, V. (2023). A student-centered approach using modern technologies in distance learning: a systematic review of the literature. In *Smart Learning Environments* (Vol. 10, Issue 1). Springer. https://doi.org/10.1186/s40561-023-00280-8

Lestari, L., Aprilia, L., Fortuna, N., Cahyo, R. N., Fitriani, S., Mulyana, Y., & Kusumaningtyas, P. (2023). Review: Laboratorium Virtual untuk Pembelajaran Kimia di Era Digital. *Jambura Journal of Educational Chemistry*, *5*(1), 1–10. https://doi.org/10.34312/jjec.v5i1.15008

Li, J., & Liang, W. (2024). Effectiveness of Virtual Laboratory in Engineering Education: A Meta-analysis. *PLOS ONE*, *19*(12), e0316269-. https://doi.org/10.1371/journal.pone.0316269

Manyilizu, M. C. (2023). Effectiveness of Virtual Laboratory vs. Paper-Based Experiences to The Hands-On Chemistry Practical in Tanzanian Secondary Schools. *Education and Information Technologies*, *28*(5), 4831–4848. https://doi.org/10.1007/s10639-022-11327-7

Mumpuni, E., Esti, M., Nurhidayati, L., Zaidan, S., & Purwanggana, A. (2021). Pengayaan Ketrampilan Siswa SMK Kesehatan melalui Pelatihan Visualisasi Molekul Kimia dengan Software ChemDraw. *CAPACITAREA : Jurnal Pengabdian Kepada Masyarakat Universitas Pancasila*, *1*(3), 121–130. https://doi.org/10.30874/capacitarea.2021.3

Peechapol, C. (2021). Investigating the Effect of Virtual Laboratory Simulation in Chemistry on Learning Achievement, Self-efficacy, and Learning Experience. *International Journal of Emerging Technologies in Learning*, *16*(20), 196–207. https://doi.org/10.3991/ijet.v16i20.23561

Penn, M., & Ramnarain, U. (2019). A Comparative Analysis of Virtual and Traditional Laboratory Chemistry Learning. *Perspective in Education*, *37*(2), 80–93. https://doi.org/10.18820/2519593X/pie

Priya, A. (2020). Case Study Methodology of Qualitative Research: Key Attributes and Navigating the Conundrums in Its Application. *Sociological Bulletin*, *70*(1), 1–17. https://doi.org/10.1177/0038022920970318

Rahman, G., Fitriani Nasution, R., Rizkina Lubis, A., Novira, P., Rahman, L., Hartina Ria Sinaga, E., Ibna Maghfirah Thaharah, P., Nur Afrida, S., Dwi Suyanti, R., Darmana, A., & Silaban, S. (2020). Analysis of constraints and alternative solutions to the implementation of chemical practicums in several high schools in Medan. *Jurnal Pendidikan Kimia*, *12*(1), 44–51. https://doi.org/10.24114/jpkim.v12i1.17744

Ramnarain, U. (2019). A Comparative Analysis of Virtual and Traditional Laboratory Chemistry Learning. *Perspective in Education*, *37*(2), 80–97. https://doi.org/10.18820/2519593X/pie

Safitri, Y. (2023). Kepuasan Belajar Siswa Dalam Pembelajaran IPAS (Kimia) Berbasis Seminar Kelas X SMK Abdurrab Pekanbaru : Implementasi Kurikulum Merdeka. *Jurnal Pendidikan Kimia Dan Terapan*, *7*(2), 103–105. https://doi.org/10.24014/konfigurasi.v7i2.24462

Samosa, R. C. (2021). Mobile Virtual Laboratory as Innovative Strategy to Improve Learners' Achievement, Attitudes, and Learning Environment in Teaching Chemistry. *International Journal of Multidisciplinary: Applied Business and Education Research*, *2*(5), 398–400. https://doi.org/10.11594/ijmaber.02.05.04

Santika, A., Riris Simanjuntak, E., Amalia, R., Kurniasari, S. R., & Artikel, R. (2023). Peran Pendidikan Sekolah Menengah Kejuruan dalam Memposisikan Lulusan Siswanya Mencari Pekerjaan. *Paedagoria : Jurnal Kajian, Penelitian Dan Pengembangan Kependidikan*, *14*(1), 84–94. https://doi.org/10.31764

Santos, M. L., & Prudente, M. (2022). Effectiveness of virtual laboratories in science education: A meta-analysis. *International Journal of Information and Education Technology*, *12*(2), 150–156. https://doi.org/10.18178/ijiet.2022.12.2.1598

Sarwono, E., & Lyau, N.-M. (2023). Virtual Labs in Electrical Engineering Education During the Covid-19 Pandemic: A Systematic Literature Review. In *Proceedings of the 4th Vocational Education International Conference (VEIC 2022)* (pp. 52–59). Atlantis Press SARL. https://doi.org/10.2991/978-2-494069-47-3_8

Shamsulbahri, M. M., & Zulkiply, N. (2021). The Effect Of Direct Activity Rerlated To Texts (DARTs) And Gender On Student Achievement In Qualitative Analysis In Chemistry. *Malaysian Journal of Learning and Instruction*, *18*(1), 157–181. https://doi.org/10.32890/MJLI2021.18.1.7

Siregar, E., Kusumawardani, D., & Bunyamin, E. M. (2022). Virtual Laboratory for Practical Learning in Vocational Education Using Nine Events of Instruction Approach. *Journal of Education Research and Evaluation*, *6*(3), 457–467. https://doi.org/10.23887/jere.v6i3.47691

Theresia, C., Hartati, Y., & Lestari, Y. (2023). The Effectiveness of The Use Of Chemcollective Virtual Laboratory Media With Guided Inquiry Learning Models On Students Learning Outcomes On Acid-Base Titration Material. *Prosiding Seminar Nasional Kimia 2023 Jurusan Kimia FMIPA UNMUL*, 30–39.

Widarti, H. R., Hakim, M. I., & Rokhim, D. A. (2022a). The Development of a Virtual Laboratory on Qualitative Chemical Practicum Analysis. *Jurnal Ilmiah Peuradeun*, *10*(3), 785–804. https://doi.org/10.26811/peuradeun.v10i3.760

Widarti, H. R., Hakim, M. I., & Rokhim, D. A. (2022b). The Development of a Virtual Laboratory on Qualitative Chemical Practicum Analysis. *Jurnal Ilmiah Peuradeun*, *10*(3), 785–804. https://doi.org/10.26811/peuradeun.v10i3.760

Wu, Q., Wang, Y., Lu, L., Chen, Y., Long, H., & Wang, J. (2022). Virtual Simulation in Undergraduate Medical Education: A Scoping Review of Recent Practice. In *Frontiers in Medicine* (Vol. 9). Frontiers Media S.A. https://doi.org/10.3389/fmed.2022.855403

Yanto, D. T. P., Sukardi, Kabatiah, M., Zaswita, H., & Candra, O. (2023). Analysis of Factors Affecting Vocational Students' Intentions to Use a Virtual Laboratory Based on the Technology Acceptance Model. *International Journal of Interactive Mobile Technologies*, *17*(12), 94–111. https://doi.org/10.3991/ijim.v17i12.38627

Zaturrahmi, Z., Festiyed, F., & Ellizar, E. (2020). The Utilization of Virtual Laboratory in Learning: A Meta-Analysis. *Indonesian Journal of Science and Mathematics Education*, *3*(2), 228–236. https://doi.org/10.24042/ijsme.v3i2.6474