CHEMISTRY EDUCATION PRACTICE

Available online at: jurnalfkip.unram.ac.id

VALIDATION OF INSTRUMENT TO MEASURE GEN-Z PRE-SERVICE TEACHER CHEMISTRY VIRTUAL LAB ACCEPTANCE AND USE

Jumriani [1] *, Hilman Qudratuddarsi[2], Nur Rahmah[3], Dyah Puspitasari Ningthias[4], Nor Indriyanti[6]

[1 2 3 5] Program Studi Pendidikan IPA, Universitas Sulawesi Barat. Jalan Prof. Dr. Baharuddin Lopa, S.H, Talumung, Majene, Sulawesi Barat 91412, Indonesia.

[4] Program Studi Pendidikan Kimia, Universitas Mataram. Jalan Majapahit No. 62 Mataram, NTB 83112, Indonesia.

* Coressponding Author. E-mail: jumriani31@unsulbar.ac.id

Received: 3 Maret 2025 **Accepted: 31 Mei 2025** **Published: 31 Mei 2025**

doi: 10.29303/cep.v8i1.8701

Abstract

This study aims to validate the instrument to measure Gen-Z Pre-service Science Teacher Virtual Lab Acceptance and Use using Rasch model. This study is quantitative survey design with 83 participants from science education major in a new public university in Sulawesi. Instrument of the study is adopted which developed based on the Unified Theory of Acceptance and Use of Technology 2 and the Theory of Planned Behavior. Students are requested to fill up the questionnaire after experimenting basic chemistry courses using pHET virtual laboratory. The instrument has satisfactory reliability (person reliability 0.95, item reliability 0.78 and Cronbach alpha 0.98), separation (person separation 4.32 and item separation 1.68). All item are accepted based on the suitability of item fit statistics by referring to mean square, Z tolerated standard, and point measure correlation. Based on its unidimensionality, the instrument can explained 57.7% variance from item variance 22.7% and person variance 30%. Based on the findings that the instrument is valid and reliable to measure science teacher virtual lab acceptance and use. The findings suggest that validated instruments for measuring virtual lab acceptance can guide educators and policymakers in effectively integrating technology into science teacher training programs, ultimately enhancing educational practices and outcomes

Keywords: *Virtual lab, Rasch model, Assessment, Gen Z, Science Teacher*

INTRODUCTION

Laboratory practice is an integral component of science education, forming an essential part of its identity. Without practical sessions, the teaching of science loses its distinctive character (Jumriani and Prasetyo, 2022). Through hands-on experimentation, students can deepen their understanding of abstract concepts by directly observing phenomena in action (Dewi, Qudratuddarsi, Ningthias, and Cinthami, 2024). Additionally, practical work hones essential skills, such as critical thinking, problem-solving, and teamwork. These experiences not only enhance students' knowledge but also equip them with professional competencies relevant to the workforce (Syskowski, Wilfinger, and Huwer, 2024). However, traditional laboratory practices are often challenging to implement due to several constraints: 1) Schools may lack adequate facilities. 2) There is often no dedicated budget for the maintenance and provision of equipment and materials. 3) There may be no specialized staff to assist teachers in preparing for complex practical sessions, placing an additional burden on educators (Jhuang, Lin, and Lin, 2024).

Virtual laboratory can be essential solution of problem with traditional laboratory practices. One of the most widely recognized examples of virtual laboratories is PhET Simulation, a technology-based platform designed to provide interactive simulations for learning science, mathematics, and other disciplines (Sapriati, Suhandoko, Yundayani, Karim, Kusmawan, Mohd Adnan, and Suhandoko, 2023). Developed by the University of Colorado Boulder, PhET is specifically created to help students grasp complex concepts through engaging visualizations and interactivity (Banda and Nzabahimana, 2021). These simulations enable users to conduct virtual experiments that are safe, easily accessible, and do not require physical laboratory equipment (Diab, Daher, Rayan, Issa and Rayan, 2024). A key strength of PhET is its ability to bridge theory and practice intuitively, supporting both independent and group learning. Its simple and user-friendly interface makes it suitable for learners at various educational levels.

By encouraging students to actively experiment, observe, and analyze, PhET fosters deeper conceptual understanding (Taibu, Mataka and Shekoyan, 2021). Moreover, its free access and compatibility across different devices enhance its practicality in supporting modern education. Beyond PhET, numerous other popular virtual laboratory platforms are available, including physics, math and statistics, chemistry, earth and space and biology.

The use of virtual laboratories is particularly well-suited for Gen Z teachers, who will likely begin their careers educating Gen Alpha students (Rahmah, Jumriani, and Qudratuddarsi, 2024). Generation Z (born approximately between 1997 and 2012) is often described as digital natives, having grown up with technology and demonstrating high proficiency in using digital tools. As educators, they tend to integrate technology into teaching, utilizing tools such as social media, e-learning platforms, and educational apps (El Kharki, Berrada and Burgos, 2021). Their teaching style is typically creative and flexible, emphasizing interactive and relevant methods that resonate with students' real-life experiences (Fadli, Surjono, Sari, Eliza, Hakiki, Hidayah and Samala, 2024).

Gen Z teachers also value diversity and inclusivity, fostering learning environments that are welcoming and adaptable. However, one challenge they face is the need to strengthen direct interpersonal skills, as they are accustomed to digital communication (Szymkowiak, Melović, Dabić, Jeganathan and Kundi, 2021). Generation Alpha (born after 2012) represents the first generation to grow up entirely in the digital age. As students, they are highly familiar with technology from a young age and tend to learn more effectively through interactive media such as videos, apps, and educational games. They exhibit strong multitasking abilities but often have shorter attention spans (Kaplan, 2022). Gen Alpha also prefers personalized, technology-based learning, such as simulations or online modules tailored to their individual needs. Despite their technological strengths, they require support in developing social and emotional skills, as much of their interaction occurs in virtual spaces (Gupta, Kumar, Tewary and Virk, 2022).

The use of virtual laboratories holds significant potential for educational contexts in Indonesia, particularly in enhancing science teaching and learning experiences (Prasetya, Syahri, Fajri, Wulansari and Fortuna, 2023). Virtual labs offer interactive and flexible learning environments that can overcome common challenges faced by traditional laboratories, such as limited equipment, safety concerns, and space constraints (Radhamani, Kumar, Nizar, Achuthan, Nair and Diwakar, 2021).

However, despite their potential benefits, the acceptance and use of virtual laboratories by Gen Z teachers in Indonesia remain uncertain. This raises an important question: why is this the case? Gen Z teachers, born and raised in the digital era, are generally tech-savvy and accustomed to utilizing digital tools in their daily lives (Dewi, Pahriah and Purmadi, 2021). Nonetheless, their willingness to adopt virtual labs for teaching might be influenced by several factors, including perceived ease of use, usefulness, self-efficacy, and institutional support (Kuleto, Stanescu, Ranković, Šević, Păun and Teodorescu, 2021).

Understanding these factors is crucial for effective integration of virtual labs into science education. In the Indonesian context, no standardized instrument currently exists to measure Gen Z teachers' acceptance and readiness to use virtual labs, particularly for science education . Validating such an instrument is essential to identify potential barriers and enablers for effective implementation . It can also provide valuable insights into teacher training needs, ensuring that virtual laboratories are used to their full potential to enhance student learning outcomes in science (Ravista, Sutarno and Harlita, 2021).

The validation of this study using the Rasch model is highly beneficial and important for several reasons. The Rasch model is a powerful tool for measuring latent traits, such as attitudes, perceptions, or abilities, which makes it particularly suitable for validating instruments designed to assess Gen Z teachers' acceptance and readiness to use virtual laboratories (Avinç and Doğan, 2024). Firstly, the Rasch model provides a robust measurement framework that ensures the reliability and validity of the instrument. It converts raw scores into interval-level data, allowing for more precise and meaningful interpretation of results (Chan, Looi and Sumintono, 2021).

This is crucial for accurately measuring the complex constructs related to technology acceptance and usage among Gen Z teachers. Secondly, the Rasch model offers the advantage of item and person fit analysis, enabling researchers to evaluate how well individual items and respondents fit the expected measurement pattern (Muslihin, Suryana, Suherman and Dahlan, 2022). This helps identify any problematic items that may not be measuring the intended construct, ensuring the instrument's validity and enhancing its overall quality (Silvia, Rodriguez, Frith, Kaufman, Loprinzi and Reiter-Palmon, 2021). Moreover, the Rasch model supports the assessment of unidimensionality, confirming that the instrument measures a single underlying trait. This is particularly important for this study, as it ensures that the scale accurately captures the intended aspects of virtual lab acceptance without being influenced by unrelated variables. Therefore, research questions of this study: does the instrument to measure gen-z pre-service teacher chemistry virtual lab acceptance and use.

METHOD

Research Design

The study employed a quantitative survey design, focusing on the collection and analysis of numerical data derived from survey responses. It qualifies as a survey design, as it examines pre-service teachers' perceptions on the usage of virtual labs for chemistry experiments at a specific point in time without altering any characteristics of the sample (Ramadhana and Qudratuddarsi, 2024). This cross-sectional approach allows for a focused exploration of participants' views, providing a clear understanding of their attitudes toward virtual labs in the context of chemistry experiment for science teachers. By concentrating on a single point in time, the study avoids the complexities associated with longitudinal designs, such as participant attrition or changes in external factors that could influence perceptions.

Additionally, the use of a quantitative approach ensures that the data collected is objective and measurable, enabling the researchers to draw statistically valid conclusions about the trends and patterns in pre-service teachers' perceptions. This methodological choice aligns with the study's goal of generating generalizable insights that can inform the broader adoption of virtual labs in teacher training programs.

Participants

Eighty-three Generation Z pre-service science teachers participated in this study, engaging in experimental activities through virtual laboratories. This involvement is particularly significant, as many of these participants had limited prior experience conducting science experiments in their high school education, making their perspectives on virtual labs especially insightful for understanding the potential of this technology in bridging gaps in practical science training.

The participants were selected through convenience sampling, as they were students of the researchers, ensuring accessibility and ease of data collection. However, this sampling method may limit the generalizability of the findings, as the sample may not fully represent the broader population of pre-service science teachers.

The demographic breakdown of the sample, as shown in Table 1, reveals a predominance of female participants (85.54%), with males comprising only 14.46% of the group. Additionally, the age distribution indicates that the majority of participants were either 18 or 19 years old, reflecting the typical age range of students in teacher training programs. This demographic information provides context for interpreting the results, as it highlights the characteristics of the group whose perceptions are being studied.

The study's focus on Generation Z participants is particularly relevant, as this generation is known for its familiarity with digital technologies, which may influence their attitudes toward virtual labs.

Table 1. Sample of the study

Sample	N	Percentage
Gender		
Male	12	14.46%
Female	71	85.54%
Age		
18 years old	37	44.58%
19 years old	46	55.42%
Total	83	100%

Instrument

The instrument used in this study was adapted from the work of Habibi et al., which explored the use and acceptance of ChatGPT, a technology-based tool. Since the original instrument was already published in high-impact journals and was available in Bahasa Indonesia, translation was unnecessary, saving time and ensuring the preservation of the original meaning and context of the items. This instrument was particularly suitable for the current study because it is grounded in established theoretical frameworks related to technology acceptance, such as the Unified Theory of Acceptance and Use of Technology (UTAUT), which aligns well with the study's objective of examining the integration of technology, specifically virtual labs, for conducting science experiments. To ensure the instrument's validity and relevance to the current context, it was rigorously reviewed by two experts with extensive backgrounds and experience in science education assessment. Their feedback helped confirm that the instrument accurately measured the intended constructs and was appropriate for the target population of pre-service science teachers.

The instrument comprises several key constructs, each designed to capture different dimensions of technology acceptance and usage. These include Performance Expectancy (4 items), which measures the degree to which participants believe virtual labs will enhance their performance in conducting experiments; Effort Expectancy (4 items), which assesses the perceived ease of using virtual labs; Social Influence (3 items), which evaluates the impact of peers, mentors, or societal norms on participants' willingness to adopt virtual labs; Hedonic Motivation (4 items), which explores the enjoyment or satisfaction derived from using the technology; Habit (5 items), which examines the extent to which using virtual labs becomes a routine part of participants' practice; Behavioral Intention (4 items), which gauges participants' willingness to use virtual labs in the future; and ChatGPT Use (3 items), which, although originally focused on ChatGPT, was adapted to assess participants' familiarity and comfort with technology tools in general.

These constructs collectively provide a comprehensive framework for understanding pre-service teachers' perceptions and acceptance of virtual labs in science education. By leveraging this well-established instrument, the study ensures a robust and theoretically grounded approach to data collection and analysis.

Data Collection

Data were collected directly using Google Forms to minimize paper usage and support environmentally friendly initiatives, aligning with contemporary efforts to reduce the environmental impact of research activities. The use of an online platform also facilitated efficient data collection and organization, allowing for real-time access to responses and reducing the likelihood of data entry errors (Hidayat, Imami, Liu, Qudratuddarsi, and Saad, 2024). The researcher observed the process in person to ensure that participants understood each item and to address any questions they had, thereby enhancing the reliability and validity of the data collected. This direct observation also helped create a supportive environment, encouraging participants to provide thoughtful and accurate responses.

Participation in this study remained voluntary, and participants were informed that their involvement would not affect their grades, ensuring that their responses were not influenced by external pressures or concerns about academic consequences. Additionally, participants were assured of the confidentiality of their responses, which helped foster an atmosphere of trust and openness. These measures were crucial in maintaining the integrity of the study and ensuring that the data reflected the genuine perceptions and experiences of the pre-service teachers.

Data Analysis

Following data collection, the information was organized and tabulated using Microsoft Excel 2019 to facilitate data analysis with Winsteps (Linacre, 2018), version 3.7.3. This analysis assessed reliability, separation, item fit statistics, unidimensionality, and rating scale calibration. Each sub-construct of ChatGPT use and acceptance was analyzed independently, employing Rasch analysis as the methodological framework. Reliability was evaluated to determine the consistency of the measurement instrument, while separation statistics provided insights into the ability of the test to distinguish between different levels of the construct being measured. Item fit statistics were crucial in identifying any items that did not align well with the underlying construct, ensuring the validity of the measurement scale.

Unidimensionality was assessed to confirm that the scale measured a single underlying trait, which is essential for the integrity of the Rasch model. Finally, rating scale calibration ensured that the response categories were functioning as intended, providing meaningful distinctions between levels of the construct. This comprehensive approach to data analysis ensured robust and reliable findings, which are critical for drawing valid conclusions about ChatGPT use and acceptance.

RESULT AND DISCUSSION

To address the research question, "Is the adopted virtual lab acceptance and use instrument valid and reliable for the Gen Z pre-service science teacher context using Rasch modeling?" we evaluated the instrument's reliability and separation, unidimensionality, and item fit statistics.

Reliability and Separation

Rasch analysis is widely used to validate questionnaires, relying on a mathematical model that establishes a linear relationship between items and individuals based on latent traits. For the Chemistry Virtual Laboratory Acceptance and Use Instrument, reliability estimates calculated using Winsteps software demonstrated robust results: item reliability was 0.74, person reliability was 0.95, and Cronbach's alpha was an impressive 0.98. In addition to reliability metrics, separation indices, which measure the ability to distinguish between items and individuals, also met the satisfactory thresholds.

The instrument achieved an item separation of 1.69 and a person separation of 3.71, both exceeding the minimum requirement of 1.5. These findings underscore the internal consistency and discriminative capacity of the instrument. Furthermore, the Rasch model fit statistics provided strong evidence supporting the instrument's validity, with a chi-square statistic of 4853.63 (degrees of freedom = 2315, $p < .0001$). These results collectively affirm the questionnaire's reliability and its potential for effective application in measuring acceptance and use in the context of a virtual chemistry laboratory.

Table 2. Reliability and Separation fit Statistics

Indicator	Indices
Item Reliability	0.74
Person Reliability	0.95
Cronbach Alpha	0.98
Item Separation	1.69
Person separation	3.71
Chi-square	4853.63 (degrees of freedom = 2315, p < .0001).

Based on the data in table 2 about reliability and separation fit statistics, we can show that the instruments are very high internal consistency and can reliably differentiate between people with different trait levels (high person reliability and separation). However, the items themselves may lack sufficient spread in difficulty (lower item separation), and their estimates are only moderately reliable. There is a statistically significant misfit to the model, which warrants further investigation.

The assessment of item fit statistics, including mean square (MNSQ), Z-tolerated standard (ZSTD), point-measure correlations (Pt Mea Corr), provides evidence of construct validity (Table 2). MNSQ evaluates the degree of randomness or discrepancies within the data, while Pt Mean Corr examines the partial correlation between each item and the overall measure score, along with separation statistics and item reliability (Alkhadim et al., 2021). Acceptable ranges for these metrics include an MNSQ value between 0.5 and 1.5 and a Pt Mean Corr value between 0.4 and 0.85 (Boone et al., 2014).

The assessment of item fit statistics, including mean square (MNSQ), Z-tolerated standard (ZSTD), and point-measure correlations (Pt Mea Corr), provides evidence of construct validity (Table 2). MNSQ evaluates the degree of randomness or discrepancies within the data, indicating how well each item fits the Rasch model. A value close to 1.0 suggests a good fit, while values significantly higher or lower may indicate misfit. ZSTD provides a standardized measure of fit, with values typically expected to fall within the range of -2.0 to +2.0 for acceptable fit. Pt Mea Corr examines the partial correlation between each item and the overall measure score, reflecting how well the item contributes to the measurement of the underlying construct.

In the provided table, most items fall within the acceptable ranges for MNSQ (0.5 to 1.5) and Pt Mea Corr (0.4 to 0.85), indicating a good fit to the model and strong construct validity. For example, items like PE2 and EE4 show MNSQ values within the acceptable range and high Pt Mea Corr values, suggesting they effectively measure the intended construct. However, some items, such as FC1 and FC4, have MNSQ values slightly above the upper limit, indicating potential misfit, which may warrant further investigation.

Separation statistics and item reliability are also crucial in this analysis. Separation statistics help determine the ability of the test to distinguish between different levels of the construct, while item reliability indicates the consistency of the item measurements. Overall, the table demonstrates that the majority of items are performing well, contributing to a reliable and valid measurement instrument.

This comprehensive evaluation ensures that the data can be confidently used to draw meaningful conclusions about the constructs being studied.

Table 3. Result of Item Fit Statistics

Item	MNSQ		ZSTD		Pt Mea
	Infit	Outfit	Infit	Outfit	Corr
PE	1.09	0.90	0.6	-0.5	0.75
PE	0.75	0.67	-1.5	-1.9	0.79
PE	0.99	1.27	0.00	1.4	0.70
PE	0.80	0.76	-1.3	-1.3	0.77
EE	1.13	1.08	0.8	0.5	0.72
EE	1.16	1.35	0.9	1.7	0.74
EE	0.91	0.81	-0.5	-1.0	0.73
EE	0.65	0.65	-2.3	-2.2*	0.79
SI1	1.00	0.94	0.1	-0.3	0.73
SI2	1.04	1.02	0.3	0.2	0.71
SI3	1.15	1.28	0.9	1.6	0.70
FC	1.60	1.54*	3.1	2.7*	0.64
FC	0.77	0.77	-1.5	-1.3	0.74
FC	0.89	1.00	-0.6	0.1	0.75
FC	1.48	1.69*	2.6	3.2*	0.65
H1	1.19	1.53*	1.1	2.5*	0.71
H2	1.11	1.19	0.7	1.1	0.73
H3	0.89	0.79	-0.6	-1.1	0.77
H1	1.29	1.40	1.7	2.2	0.61
H2	0.90	0.85	-0.6	-0.8	0.73
H3	1.04	1.19	0.3	1.1	0.71
H4	0.74	0.78	-1.7	-1.3	0.79
H5	0.63	0.75	-2.5	-1.5	0.80
BI1	0.67	1.12	-2.2	0.7	0.78
BI2	0.94	0.86	-0.3	-0.7	0.78
BI3	1.44	1.65*	2.4	3.2*	0.64
BI4	0.80	1.03	-1.2	0.2	0.77
GP	1.19	1.34	1.2	1.9	0.66
GP	0.91	0.97	-0.5	-0.1	0.74
GP	0.80	0.90	-1.2	-0.5	0.76

Unidimensionality

The unidimensionality of an instrument is a critical indicator of its validity in measuring the intended constructs. In this study, the unidimensionality of the Instrument to Measure Gen-Z Pre-Service Teacher Chemistry Virtual Lab Acceptance and Use was evaluated using the Rasch model, which included Principal Component Analysis (PCA) of standardized residuals. The choice of the Rasch model is appropriate because it not only assesses the measurement properties but also examines the structural validity of the instrument.

According to Purnami et al. (2021), an instrument is considered to have acceptable unidimensionality if the raw variance explained exceeds 24%. The findings from this study indicate that the explained variance for the instrument is 57.7%, well above this threshold. This high percentage suggests that the majority of the variance in the data is attributable to the primary construct being measured, reinforcing the instrument's construct validity. Specifically, the raw variance explained by persons is 35.0%, while the raw variance explained by items is 22.7%. These values indicate a balanced contribution from both respondents and item characteristics, which supports the robustness of the instrument's measurement model.

Furthermore, the unexplained variance in the first contrast is 4.8%, significantly lower than the recommended maximum of 15%. This indicates minimal multidimensionality, suggesting that the residual variance is not driven by secondary dimensions or nuisance factors. Consequently, the low unexplained variance supports the unidimensionality assumption, confirming that the instrument effectively captures a single underlying construct.

The results underscore the instrument's validity and reliability for assessing Gen-Z pre-service teachers' acceptance and use of virtual chemistry labs. By demonstrating strong unidimensionality, the instrument ensures that the observed scores are primarily reflective of the intended construct, minimizing measurement error. Therefore, this instrument can be confidently used in educational research to explore virtual lab acceptance and use among Gen-Z pre-service teachers.

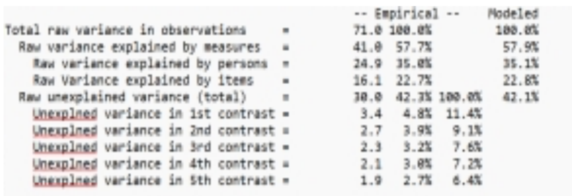

Figure 1. Standardized Residual Variance
Wright Map

The Wright Map, also known as the person-item map, is a graphical representation used in Rasch analysis to display the relationship between persons and items along the same latent trait scale. The Wright Map, also referred to as the person-item map, is a powerful graphical representation commonly used in Rasch analysis to illustrate the relationship between persons and items along a shared latent trait scale (Qudratuddarsi et al., 2024). This map provides a clear visual depiction of how item difficulties and person abilities align on the same measurement continuum, enhancing the interpretability of the instrument's measurement properties.

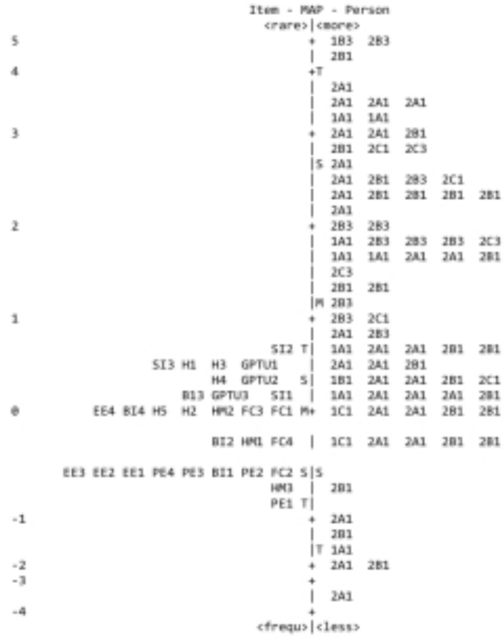

Figure 2. The Wright Map

The Wright Map displayed above provides a visual representation of the relationship between person abilities and item difficulties along the same latent trait scale. This map is an essential tool in Rasch analysis, as it helps evaluate the targeting and overall functionality of the instrument. Left Side (Items): The left side of the map shows the distribution of item difficulties, labeled with item codes. Items at the top are the most difficult, while those at the bottom are the easiest. Right Side (Persons): The right side displays the distribution of person abilities. Individuals with higher abilities are located towards the top, whereas those with lower abilities are at the bottom.

The map shows a reasonable alignment between person abilities and item difficulties, indicating that the test is generally well-targeted for the sample.

- the test is likely to provide precise measurements for most respondents.
- However, the lack of items at the highest and lowest extremes could reduce the measurement precision for individuals at these ability levels.

CONCLUSION

The conclusion from the result is the Wright Map illustrates that the instrument effectively measures the targeted construct for most respondents. It also highlights some areas for improvement, such as the potential need for more difficult items to better differentiate high-ability respondents and easier items to capture lower-ability levels more accurately. These insights can guide future item development and refinement to enhance the instrument's validity and reliability.

REFERENCES

Avinç, E., & Doğan, F. (2024). Digital literacy scale: Validity and reliability study with the rasch model. *Education and information Technologies*, 1-47.

Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical review physics education research*, *17*(2), 023108.

Chan, S. W., Looi, C. K., & Sumintono, B. (2021). Assessing computational thinking abilities among Singapore secondary students: a Rasch model measurement analysis. *Journal of Computers in Education*, *8*(2), 213-236.

Dewi, C., Pahriah, P., & Purmadi, A. (2021). The urgency of digital literacy for generation Z students in chemistry learning. *International Journal of Emerging Technologies in Learning (IJET)*, *16*(11), 88-103.

Dewi, H. R., Qudratuddarsi, H., Ningthias, D. P., & Cinthami, R. D. D. (2024). The Current Update of ChatGPT Roles in Science Experiment: A Systemic Literature Review. *Saqbe: Jurnal Sains dan Pembelajarannya*, *1*(2), 74-85.

Diab, H., Daher, W., Rayan, B., Issa, N., & Rayan, A. (2024). Transforming Science Education in Elementary Schools: The Power of PhET Simulations in Enhancing Student Learning. *Multimodal Technologies and Interaction*, *8*(11), 105.

El Kharki, K., Berrada, K., & Burgos, D. (2021). Design and implementation of a virtual laboratory for physics subjects in Moroccan universities. *Sustainability*, *13*(7), 3711.

Fadli, R., Surjono, H. D., Sari, R. C., Eliza, F., Hakiki, M., Hidayah, Y., ... & Samala, A. D. (2024). Effectiveness of Mobile Virtual Laboratory Based on Project-Based Learning to Build Constructivism Thinking. *International Journal of Interactive Mobile Technologies*, *18*(6).

Gupta, A., Kumar, J., Tewary, T., & Virk, N. K. (2022). Influence of cartoon characters on generation alpha in purchase decisions. *Young consumers*, *23*(2), 282-303.

Hidayat, R., Imami, M. K. W., Liu, S., Qudratuddarsi, H., & Saad, M. R. M. (2024). Validity of engagement instrument during online learning in mathematics education. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *8*(2).

Jumriani, J., & Prasetyo, Z. K. (2022). Important roles of local potency based science learning to support the 21st century learning. *European Journal of Formal Sciences and Engineering*, *5*(1), 38-51.

Jhuang, Z. J., Lin, Y. C., & Lin, Y. T. (2024). Effects of Developing an Interactive AR Plant Structure Experiment System for Elementary Natural Science Course. *International Journal of Information and Education Technology*, *14*(8), 1145-1154.

Kaplan-Berkley, S. (2022). Digital tools and streaming media converge to inspire social interactions of generation alpha. *International Journal of Early Childhood*, *54*(2), 185-201.

Kuleto, V., P, M. I., Stanescu, M., Ranković, M., Šević, N. P., Păun, D., & Teodorescu, S. (2021). Extended reality in higher education, a responsible innovation approach for generation y and generation z. *Sustainability*, *13*(21), 11814.

Muslihin, H. Y., Suryana, D., Suherman, U., & Dahlan, T. H. (2022). Analysis of the Reliability and Validity of the Self-Determination Questionnaire Using Rasch Model. *International Journal of Instruction*, *15*(2), 207-222.

Purnami, W., Ashadi, A., Suranto, S., Sarwanto, S., Sumintono, B., & Wahyu, Y. (2021). Investigation of person ability and item fit instruments of eco critical thinking skills in basic science concept materials for elementary pre-service teachers. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 127-137.

Prasetya, F., Syahri, B., Fajri, B. R., Wulansari, R. E., & Fortuna, A. (2023). Utilizing Virtual Laboratory to Improve CNC Distance Learning of Vocational Students at Higher Education. *TEM Journal*, *12*(3).

Qudratuddarsi, H., Ramadhana, N., Indriyanti, N., & Ismail, A. I. (2024). Using Item Option Characteristics Curve (IOCC) to unfold misconception on chemical reaction. *Journal of Tropical Chemistry Research and Education*, *6*(2), 105-118.

Radhamani, R., Kumar, D., Nizar, N., Achuthan, K., Nair, B., & Diwakar, S. (2021). What virtual laboratory usage tells us about laboratory skill education pre-and post-COVID-19: Focus on usage, behavior, intention and adoption. *Education and information technologies*, *26*(6), 7477-7495.

Rahmah, N., Jumriani, J., & Qudratuddarsi, H. (2024). Pelatihan Pemanfaatan Laboratorium Virtual (Virtual Laboratory) sebagai Media Praktikum IPA Berbasis Digital. *Beru'-beru': Jurnal Pengabdian kepada Masyarakat*, *3*(1), 49-57.

Ramadhana, N., & Qudratuddarsi, H. (2024). Analisis Self Efficacy Mahasiswa pada Mata Kuliah Biologi Sel. *Saqbe: Jurnal Sains Dan Pembelajarannya*, *1*(1), 33-38.

Ravista, N., Sutarno, S., & Harlita, H. (2021). Validity and practicality of guided inquiry-based e-modules accompanied by virtual laboratory to empower critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 331-339.

Sapriati, A., Suhandoko, A. D. J., Yundayani, A., Karim, R. A., Kusmawan, U., Mohd Adnan, A. H., & Suhandoko, A. A. (2023). The effect of virtual laboratories on improving students' SRL: an umbrella systematic review. *Education sciences*, *13*(3), 222.

Silvia, P. J., Rodriguez, R. M., Beaty, R. E., Frith, E., Kaufman, J. C., Loprinzi, P., & Reiter-Palmon, R. (2021). Measuring everyday creativity: A Rasch model analysis of the Biographical Inventory of Creative Behaviors (BICB) scale. *Thinking Skills and Creativity*, *39*, 100797.

Syskowski, S., Wilfinger, S., & Huwer, J. (2024). Impact and Classification of Augmented Reality in Science Experiments in Teaching—A Review. *Education Sciences*, *14*(7), 760.

Szymkowiak, A., Melović, B., Dabić, M., Jeganathan, K., & Kundi, G. S. (2021). Information technology and Gen Z: The role of teachers, the internet, and technology in the education of young people. *Technology in society*, *65*, 101565.

Taibu, R., Mataka, L., & Shekoyan, V. (2021). Using PhET simulations to improve scientific skills and attitudes of community college students.