13 (3) (2024) 224-238

Unnes Science Education Journal

Accredited Sinta 2

https://journal.unnes.ac.id/journals/usej

A Portrait of Basic Laboratory Skills among Grade XII Students at SMAN 1 Rasau Jaya

Siti Nurhasanah✉, Wolly Candramila, Asriah Nurdini Mardiyyaningsih

DOI: http://dx.doi.org/10.15294/usej.v13i1.15766

Universitas Tanjungpura, Indonesia

Article Info

Submitted 2024-11-04
Revised 2024-11-26
Accepted 2024-12-30

Keywords

Practical Activities; Basic Laboratory Skills; Laboratory Equipment Knowledge; Basic Laboratory Skills Practice; Pearson Correlation Test

Abstract

School laboratories are vital for building students' understanding and scientific skills through hands-on activities. However, the laboratory at SMAN 1 Rasau Jaya in Kubu Raya Regency is underutilized, potentially reducing students' motivation and skills. This study aims to evaluate the basic laboratory knowledge and skills of students at SMAN 1 Rasau Jaya, focusing on measurement, weighing, and dilution. This research utilizes a descriptive quantitative survey method to assess the basic laboratory knowledge and skills of Grade XII science students at SMAN 1 Rasau Jaya, with a purposive sample of 35 students. Data analysis was conducted to describe laboratory knowledge and skills as well as their relationship. The study found students' laboratory knowledge to be generally moderate, with average scores of 41% for measurement, 45% for weighing, and 43% for dilution skills. Practically, 34.3% of students were rated as good and 8.6% as very good in measurement skills. Weighing skills were stronger, with 68.6% in the very good category, while dilution skills need improvement, with only 31.4% very good and 17.1% moderate. A low but significant correlation ($r = 0.376$, $p = 0.026$) suggests that theoretical knowledge hasn't fully translated into practical ability. In conclusion, the study highlights a gap between students' theoretical knowledge and practical skills, suggesting a need for increased hands-on practice to enhance scientific proficiency and motivation among students at SMAN 1 Rasau Jaya.

How to Cite

Nurhasanah, S, Candramila, W., & Mardiyyaningsih, A. N. (2024). A Portrait of Basic Laboratory Skills Among Grado XII Students at SMAN 1 Rasau Jaya. *Unnes Science Education Journal*, 13(3), 224-238.

✉ Correspondence Author:
E-mail: wolly.candramila@fkip.untan.ac.id

p-ISSN 2252-6617
e-ISSN 2502-6232

INTRODUCTION

Laboratories play a crucial role in the learning process. Laboratory activities not only support conceptual understanding but also foster critical, analytical, and creative thinking skills essential for solving scientific problems (Putri et al., 2022; Uwitonze & Nizeyimana, 2022; Wei et al., 2019). Practical work allows students to explore and deepen their understanding of scientific concepts taught in class, enhancing their scientific skills. In line with the Standards for Primary and Secondary Education Processes outlined in Permendikbud No. 22 of 2016, learning should follow a scientific approach emphasizes hands-on practice. Laboratories as learning facilities enable students to engage directly in learning process, building knowledge and skills through real-life experiences (Acut, 2024; Jannah & Sontani, 2018).

Mastering laboratory skills is a key focus of science education at the secondary level. These skills encompass fundamental aspects such as operating equipment, conducting experiments according to proper procedures, and analyzing observational data. Nurhayati (2022), laboratories significantly enhance students' scientific knowledge and skills, which are closely related to the scientific processes that support experiment-based learning. Additionally, Pramesti et al. (2018) revealed that knowledge of laboratory equipment is a critical indicator of students' readiness to engage in laboratory practical work.

Students are more skilled and find it easier to conduct experiments if they have a foundational knowledge of the tools, including their names, functions, and how to use them (Padari et al., 2022). Students can hinder their experiments if they do not understand these tools. Students who are proficient with the equipment will work more effectively and safely during practical sessions, allowing them to achieve the desired results. Thus, mastering the tools enhances students' psychomotor skills (Juvitasari et al., 2019). Research by Matias et al., (2023) supports this, stating that knowledgeable students exhibit better psychomotor abilities. To ensure practical activities run smoothly and objectives are met, students must have a solid foundational knowledge of laboratory equipment (Pramesti et al., 2018).

Laboratory skills are fundamental competencies that students must acquire in secondary science education. This study specifically examines skills related to measuring, weighing, and diluting solutions—essential techniques required for conducting various scientific experiments (Wijayaningrum, 2020). Mastery of these laboratory skills not only deepens students' understanding of scientific concepts but also provides a critical foundation for addressing challenges in advanced scientific studies. However, students often face barriers to mastering these skills. Insufficient laboratory facilities, limited access to practical materials, and restricted time allocated for hands-on activities are common challenges encountered by educational institutions (Amba et al., 2014; Pareek, 2019; Rahmah et al., 2021). Furthermore, previous research indicates that many students do not achieve proficiency in basic laboratory skills due to inadequate practice opportunities and limited availability of equipment in schools (Hensiek et al., 2016; Kartini, 2019) . In addition, students are expected to develop fundamental laboratory competencies such as proper handling of laboratory equipment, accurate measurement techniques, and maintaining safety protocols—skills crucial for ensuring precision and reliability in experimental outcomes.

State Senior High School 1 Rasau Jaya in Kubu Raya Regency has a well-equipped laboratory; however, it is seldom utilized. Despite the availability of resources to facilitate practical science learning, students have never engaged in hands-on experiments. This situation highlights a disconnect between the presence of educational facilities and their effective use in teaching and learning activities. The absence of practical activities in science education is troubling, as it adversely affects students' comprehension of biology and other scientific disciplines.

School laboratories are essential for promoting effective and interactive learning (Alnaser & Forawi, 2024; Ambusaidi et al., 2018; Jannah & Sontani, 2018). They should serve as the hub for scientific activities, encouraging students to experiment, observe, and practice fundamental laboratory skills (Putri et al., 2022). When laboratories remain unused, students miss the chance for hands-on engagement, which can diminish their motivation and hinder their mastery of basic laboratory skills (Rahmah et al., 2021). This situation underscores the necessity for schools to reassess their teaching strategies, particularly in optimizing laboratory use to enhance students' understanding of scientific concepts (Ali et al., 2022; Hamidu et al., 2014).

The study focuses on assessing basic laboratory skills such as measuring, weighing, and diluting, which are fundamental to science education. Understanding students' current proficiency provides insights into existing gaps in their practical learning, especially at a school like SMAN 1 Rasau Jaya, where laboratory use is limited. This is crucial for ensuring students are prepared for higher education and scientific careers.

Research on basic laboratory skills has been extensively conducted, particularly in evaluating students' abilities to use tools such as electronic balances, pipettes, and graduated cylinders. Several studies also focus on practical exercises like solution dilution, titration, and handling laboratory materials. These studies have demonstrated that performance assessments and repeated practice significantly improve students' skills and enhance their understanding of scientific concepts (Coleman, 2015). However, most of these studies are conducted at the college level or in schools with well-equipped and frequently utilized laboratories. This study offers novelty by being conducted at SMAN 1 Rasau Jaya, a school where the laboratory is rarely used despite the availability of equipment. It also explores the correlation between students' theoretical knowledge and their practical laboratory skills, a dimension that limited attention in previous research.

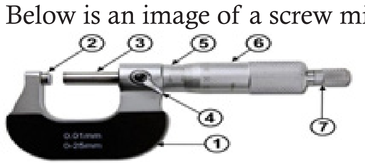
Furthermore, this study aims to provide actionable recommendations to improve the quality of laboratory-based learning in schools, particularly under conditions of limited time and resources. The findings are expected to contribute to the development of more effective practical learning strategies, supporting students in mastering essential laboratory skills.

METHOD

This study used a survey method mixed with laboratory skill test. The mixed survey-and-test method is conducted to collect information related to the research variables, namely knowledge and basic laboratory skills. We used a quantitative descriptive approach to describe the knowledge and basic laboratory skills of students, as well as the relationship between the two variables through statistical tests. This research was conducted in the odd semester of the 2024/2025 academic year at SMAN 1 Rasau Jaya, Rasau Jaya District, Kubu Raya Regency.

The sample in this study consists of one group of class XII science students in the 2024/2025 academic year, totaling 35 individuals. The sampling technique used is purposive sampling, meaning the sample is deliberately chosen based on the teacher's knowledge to represent the population relevant to the research objectives. The research instruments used are a written test sheet to assess knowledge of basic laboratory skills and a practical assessment sheet to evaluate basic laboratory practice skills. The written test includes questions about measuring skills, weighing skills, and diluting skills. A practical test is also conducted to assess these three skills. In this study, measuring skills are performed using calipers and screw micrometers, weighing skills are assessed using analytical balances, while diluting skills involve the use of measuring cups, dropper pipettes, and measuring flasks. The written test questions consist of three indicators: parts of the tools, functions of the tools, and how to use the tools. For the practical skills assessment, students are observed for their adherence to the correct procedural steps. Examples of the written test questions and practical assessment criteria below.

Table 1. Example of written test questions and instructions in the practical test of basic laboratory skills in science used in this study. The test question is given in Indonesian

Instrument	Indicator	Example of written test questions and instructions
Written Test	Components of the equipment	2. Below is an image of a screw micrometer.  According to the number sequence in the image, the names of the parts of the measuring instrument above are .... a. Fixed spindle, frame, movable spindle, locking mechanism, main scale, vernier scale, ratchet wheel b. Frame, fixed spindle, movable spindle, locking mechanism, main scale, vernier scale, ratchet wheel c. Fixed spindle, ratchet wheel, vernier scale, locking mechanism, frame, movable spindle, main scale d. Ratchet wheel, vernier scale, main scale, locking mechanism, movable spindle, fixed spindle, frame e. Frame, fixed spindle, movable spindle, locking mechanism, main scale, ratchet wheel, vernier scale

Instrument	Indicator	Example of written test questions and instructions
	Function of the equipment	13. Please refer to the image below.  In the dilution activity, the main function of the tool above is … a. Heating the solution b. Measuring the weight of a solid substance c. Measuring the volume of a solution d. Carrying out a chemical reaction e. Stirring the solution
	How to use the equipment	1. Weighing activities involve several steps. Below, the one that is not included in the weighing steps is …. a. Ensuring the scale shows zero first b. Placing the object to be weighed on the weighing plate c. Reading the number displayed on the digital screen according to the scale unit d. Removing the object being weighed after the scale returns to zero e. Weighing until the mass is constant
Practice Test	Preparing the instrument (digital scale)	Prepare the digital scale that will be used.
	Weighing the prepared materials	Weigh 10 grams of sugar as requested.
	Turn off the instrument (digital scale) that has been used.	Turn off the scale that has been used.

The data collection technique used in this study is the administration of written tests in the form of multiple-choice questions and practical tests of basic laboratory skills. The written test is administered before the start of the skill practices. The time allocated for filling out the test is 20 minutes, assuming 5 minutes for filling in personal information and checking answers, and 1 minute for answering each question. A total of 15 multiple-choice questions are provided. Observations are conducted to gather data on basic laboratory skills through direct practice. Students are tested to perform hands-on practice in the laboratory related to three basic laboratory skills to be measured: measuring, weighing, and diluting. Assessment is carried out by observing the conformity of the practice steps for the three skills based on the established guidelines.

The data collected from the written tests and observations of laboratory skills practices are analyzed to obtain a clear picture of the knowledge and basic skills of the students. Data analysis is conducted by calculating the average score of basic laboratory skills knowledge, referring to the formula according to Sudijono (2007) as follows:

$$\bar{x} = \frac{\sum x}{N}$$

Description:

$\bar{x}$ = Average value

$\sum x$ = Total score of all samples

N = Total samples

For the data on basic laboratory skills practice, data analysis is performed by calculating the percentage according to Purwanto (2010) as follows:

$$NP = \frac{R}{SN} \times 100$$

Description:
NP = The percentage value sought
R = The raw scores obtained by students
SM = Maximum score

The percentage of basic laboratory skills for written test and practice results is then categorized into levels such as "very good," "good," "satisfactory," "poor," and "very poor," based on Arikunto (2016) (Table 2). This categorization helps in assessing students' competencies in laboratory skills and provides a clear framework for evaluating their performance in practical tasks and written test.

Table 2. Categorization of Basic Laboratory Skills Test

Interval Score	Interpretation
81%-100%	Very Good
61%-80%	Good
41%-60%	Fairly Good
21%-40%	Poor
0%-20%	Very Poor

To examine the relationship between test results of knowledge and basic laboratory skills practice, Pearson correlation test is used (Siregar, 2023). In this study, basic laboratory skills serve as the dependent variable, while knowledge of laboratory tools is the independent variable. This test is appropriate because it analyzes the linear relationship between two interval or ratio variables. The magnitude of the correlation coefficient obtained is then interpreted based on the categories described (Table 3).

Table 3. Rule of Thumb for Interpreting the Size of a Correlation Coefficient

Size of Correlation	Interpretation
0.90 to 1.00 (-0.90 to -1.00)	Very high positive (negative) correlation
0.70 to 0.90 (-0.70 to -0.90)	High positive (negative) correlation
0.50 to 0.70 (-0.50 to -0.70)	Moderate positive (negative) correlation
0.30 to 0.50 (-0.30 to -0.50)	Low positive (negative) correlation
0.00 to 0.30 (0.00 to -0.30)	Negligible correlation

RESULT AND DISCUSSION

The basic laboratory skills knowledge of students at SMAN 1 Rasau Jaya in activities such as measuring, weighing, and diluting is generally in the "adequate" category, with average percentages of 41%, 45%, and 43%, respectively. In measurement skills, the ability to identify instrument functions averaged 40%, while identifying instrument parts averaged 34%, and explaining instrument use reached 44.5%. For weighing skills, identifying instrument functions averaged 38.5%, identifying instrument parts averaged 54%, and explaining instrument use reached 49%. In dilution skills, identifying instrument functions scored an average of 36%, while identifying instrument parts reached 74%, and explaining instrument use scored 26%. Overall, these results indicate that students still demonstrate a theoretical gap in their foundational laboratory skills.

Table 4. Test Scores on Basic Laboratory Skills Knowledge of Students at SMAN 1 Rasau Jaya

No.	Knowledge Indicator	Percentage	Category
1	Measuring Skills	41%	Fairly Good
	a. Determining the function of the instrument	40%	Poor
	b. Identifying parts of the instrument	34%	Poor
	c. Explaining the usage method	44,5%	Fairly Good
2	Weighing Skills	45%	Fairly Good
	a. Determining the function of the instrument	38,5%	Poor
	b. Identifying parts of the instrument	54%	Fairly Good
	c. Explaining the usage method	49%	Fairly Good
3	Dilluting Skills	43%	Fairly Good
	a. Determining the function of the instrument	36%	Poor
	b. Identifying parts of the instrument	74%	Good
	c. Explaining the usage method	26%	Poor

Students' knowledge of practical laboratory instruments is crucial for the effective execution of laboratory activities in schools. When students understand how to correctly use these instruments, they become more skilled and efficient in conducting experiments, allowing them to achieve desired outcomes and work safely to prevent accidents (Hendrawan et al., 2021; Irwanto et al., 2019). At SMAN 1 Rasau Jaya, students' knowledge of basic laboratory skills is currently at a 'satisfactory' level, indicating that their understanding of these skills has not yet reached optimal levels. This means that while students possess some level of understanding and ability in laboratory skills, their knowledge is not yet at an ideal or optimal level. Essentially, they meet the minimum expectations, but there is significant room for improvement in mastering these skills to a higher standard. Walker & Sampson (2016) The importance of authentic science-based laboratory learning lies in providing opportunities for students to design their own experiments and analyze data. Without such opportunities, students are unlikely to develop advanced skills essential for scientific inquiry and problem-solving.

The difficulty students face in understanding basic laboratory concepts theoretically suggests that adequate laboratory practice has not been fully realized. Fantinelli et al. (2024) found that limited direct practical experience can undermine students' confidence in applying theory to real-world situations, often negatively impacting the quality of laboratory results. Additional factors, such as restricted laboratory time and limited access to equipment, further hinder the enhancement of students' practical skills (Iyer et al., 2021). Research indicates that increasing direct practical experience is essential, as regular laboratory activities improve both technical skills and understanding of practical concepts (Shana & Abulibdeh, 2020; Sroczynski, 2023). Therefore, schools must ensure that students have sufficient access to laboratories and ample opportunities for hands-on experiments to develop strong practical skills and foster a comprehensive understanding of scientific concepts.

However, a contrasting trend was observed in the basic laboratory skills practical test results, where scores in several practical aspects were actually higher than those in theoretical knowledge tests. This suggests that students are capable of performing practical tasks proficiently, despite their limited theoretical understanding of laboratory instruments. When confronted with practical situations, they find it easier to grasp how these instruments function. Several factors appear to influence students' practical abilities, including a preference for kinesthetic learning, effective observational skills, and clear, structured instructions during practical activities. This situation implies the need for improvement in their education or training. Possible areas for enhancement include more hands-on practice, clearer theoretical explanations, or improved teaching strategies.

Robles (2023) demonstrated that kinesthetic learning, which involves physical movement and manipulation of objects, is particularly effective in helping students comprehend complex concepts. For instance, in science or mathematics, engaging in hands-on activities allows students to understand concepts more concretely than through verbal or visual means, thereby enhancing their ability to apply theory in practice. Oliveira & Bonito (2023) emphasized that strong observational skills are fundamental to science education; students who cultivate these skills tend to perform better in laboratory experiments. Effective observation fosters critical thinking and attention to detail, improving both the quality of experimental results and conceptual understanding. Furthermore, Hammond & Moore (2018) asserted that teachers should provide clear and explicit instructions, including step-by-step examples and specific guidance necessary for students to tackle problems and complete tasks requiring critical thinking.

According to Rahmawati & Astuti, (2017), practical activities positively influence students' learning success by enabling direct observation of phenomena, fostering scientific thinking skills, and developing scientific attitudes. Through these activities, students can more easily acquire new knowledge, understand concepts, and create lasting memories, while also sharpening their process skills (Pranaja & Astuti, 2019). This occurs as students utilize available resources, conduct experiments, observe outcomes, and record their own results, thereby enhancing their thinking abilities and reinforcing previously learned theories. Robani et al. (2021) emphasize that the learning process should focus on the active engagement of students, allowing them to directly grasp information related to the material presented by the teacher through observation and hands-on practice. Oktay et al. (2023) demonstrates that STEM-based laboratory activities significantly enhance competence perceptions in 21st-century skills, such as critical thinking, problem-solving, and the ability to use technology for analyzing and sharing information. STEM also supports the development of higher-level skills more effectively compared to traditional approaches.

Table 5. Practical Scores of Basic Laboratory Skills of Students at SMAN 1 Rasau Jaya

Indicator	Percentage of Students in Each Category					Average Percentage
	Very Good	Good	Fairly Good	Poor	Very Poor	
Measuring Skills	8.6%	34.3%	40%	11.4%	5.71%	58%
Weighing Skills	68.6%	25.7%	5.7%	0%	0%	81%
Dilluting Skills	31.4%	40%	17.1%	11.4%	0%	73%

The observations during practical activities indicate that most students have mastered basic laboratory skills, such as measuring, weighing, and diluting (see Table 5). However, some students still require reinforcement in specific areas. In measuring skills, 40% are classified as 'adequate,' suggesting a need for improvement. While 34.3% are rated as 'good' and 8.6% as 'very good,' approximately 17.1% fall into the 'poor' and 'very poor' categories, indicating that mastery of these skills is not evenly distributed.

In weighing skills, 68.6% of students are rated as 'very good,' while 25.7% are classified as 'good,' indicating strong mastery among the majority, with no students in the 'poor' or 'very poor' categories. However, 5.7% fall into the 'adequate' category, suggesting room for improvement through additional support. In contrast, 40% of students are rated as 'good' in dilution skills, and 31.4% as 'very good.' Yet, 17.1% are classified as 'adequate,' and 11.4% as 'poor,' indicating that dilution skills require more attention. As a more complex skill, dilution necessitates increased practical training and guidance to enhance students' proficiency.

Overall, the observations of the three skills reveal a gap in mastery, particularly in measuring and diluting. These aspects require increased attention through additional practice and more intensive support. Shana & Abulibdeh (2020) note that mastery of basic laboratory skills is often uneven among students; some excel in certain areas while others struggle, especially with complex tasks like precise measurements or accurate dilutions (Keen & Sevian, 2022). Skills such as measuring volume or mass with laboratory tools (e.g., pipettes, burettes, or balances) necessitate a deep understanding of instrument function and consistent practice. Similarly, dilution involves concepts like molarity and concentration, requiring structured practice for students to achieve true mastery (Raviolo et al., 2021).

Repetition and hands-on practice are crucial for deepening students' understanding of complex laboratory skills, such as measuring and diluting solutions. For instance, experiments involving blood pressure measurement, respiration, or the dilution of solutions in physiological contexts illustrate the importance of practical application. Repeated practical exercises, coupled with supervision and additional instruction, are vital for improving both understanding and skills (Silverthorn. 2018).

Table 6. Correlation Test between Knowledge Assessment and Basic Laboratory Skills Practice

		Knowledge	Practice
Knowledge	Pearson Correlation	1	.376*
	Sig. (2-tailed)		.026
	N	35	35
Practice	Pearson Correlation	.376*	1
	Sig. (2-tailed)	.026	
	N	35	35

*. Correlation is significant at the 0.05 level (2-tailed)

The correlation test results between knowledge and basic laboratory skills practice yielded a coefficient of R = 0.376 and p = 0.026 (see Table 6). This indicates a positive correlation of low magnitude and a significant relationship between students' knowledge and their practical skills in the laboratory. The positive correlation suggests that improvements in students' knowledge of laboratory skills are accompanied by enhancements in their practical abilities. However, despite this significant correlation, the coefficient value of 0.376 falls within the low category, indicating that the relationship between knowledge and practice is not particularly strong. In other words, students' knowledge of laboratory skills does not fully translate into their practical performance. Several other factors may influence laboratory practice abilities, such as hands-on experience, motivation or the quality of guidance provided during practical sessions. Robles (2023) emphasizes the importance of active learning and direct experience in enhancing conceptual understanding. Direct experiences help students integrate new knowledge with prior experiences, which is crucial for practical learning. The quality of instruction and guidance provided by teachers is also critical for students' success in practical activities. Clear and directed instructions can help students better understand procedures and concepts.

Suciati et al. (2017) found a significant relationship between cognitive abilities and laboratory skills (p = 0.002), with a higher r value of 0.477, indicating a medium correlation. Similarly, Kasmawati et al. (2019) eported a significant correlation between practical abilities and students' learning outcomes, with an average score of 83.96. These findings suggest that practical-based learning can enhance students' learning outcomes and improve their critical thinking skills. In contrast, Saman (2022) reported no significant relationship between students' competencies and laboratory practices (p = 0.164), indicating a very weak correlation (r value within the range of 0.00-0.25). While there is evidence of a positive correlation between knowledge and practice in laboratory skills, it is categorized as low, suggesting that improvements in students' knowledge do not necessarily translate into significant enhancements in their practical abilities. To achieve optimal practical skills, factors such as hands-on experience, motivation, and the quality of guidance must also be considered. Further research is needed to explore additional factors influencing students' laboratory skills to enhance the effectiveness of practical-based learning.

CONCLUSION

The knowledge and basic laboratory skills of students at SMAN 1 Rasau Jaya are rated as adequate, with average scores of 41% in measuring, 45% in weighing, and 43% in dilution. Weighing skills showed the best results, with 68.6% of students rated 'very good,' while only 8.6% excelled in measuring skills. Correlation tests revealed a positive but low relationship between knowledge and practical skills (r = 0.376. p = 0.026), indicating that increased knowledge does not fully translate into practical ability. Thus, enhancing practical learning, especially in weaker skill areas, is essential.

REFERENCES

Acut, D. P. (2024). From classroom learning to real-world skills: an autoethnographic account of school field trips and STEM work immersion program management. *Disciplinary and Interdisciplinary Science Education Research*, 6(1). https://doi.org/10.1186/s43031-024-00111-x

Ali, N., Ullah, S., & Khan, D. (2022). Interactive Laboratories for Science Education: A Subjective Study and Systematic Literature Review. *Multimodal Technologies and Interaction*, 6(10). https://doi.org/10.3390/mti6100085

Alnaser, D. S. A., & Forawi, S. (2024). Investigating the Effects of Virtual Laboratories on Students' Motivation and Attitudes Toward Science. *Science Education International*, 35(2), 154–162. https://doi.org/10.33828/sei.v35.i2.9

Amba, Neji, H., John.O, U., & Cecilia. O, N. (2014). Evaluating the Adequacy of laboratory facilities on students' academic Performance in Secondary School in Calabar, Nigeria. *IOSR Journal of Research & Method in Education (IOSRJRME),* 4(3), 11–14. https://doi.org/10.9790/7388-04331114

Ambusaidi, A., Al Musawi, A., Al-Balushi, S., & Al-Balushi, K. (2018). The impact of virtual lab learning experiences on 9th grade students' achievement and their attitudes towards science and learning by virtual lab. *Journal of Turkish Science Education,* 15(2), 13–29. https://doi.org/10.12973/tused.10227a

Arikunto. S. (2016). *Manajemen Penelitian*. Jakarta: Rineka Cipta.

Bransford. J. D.. Brown. A. L.. & Cocking. R. R. (2000). *How people learn (Vol. 11).* Washington. DC: National academy press.

Coleman, A. (2015). Practical Assessment of Basic Skills in High-Enrollment Biology Lab Courses. *Tested Studies for Laboratory Teaching*, 36, 1–2. http://www.ableweb.org/volumes/vol-36/v36reprint.php?ch=27

Fantinelli, S., Cortini, M., Di Fiore, T., Iervese, S., & Galanti, T. (2024). Bridging the Gap between Theoretical Learning and Practical Application: A Qualitative Study in the Italian Educational Context. *Education Sciences*, 14(2). https://doi.org/10.3390/educsci14020198

Hamidu, M. Y., Ibrahim, A. I., & Mohammed, A. (2014). The Use of Laboratory Method in Teaching Secondary School Students: a key to Improving the Quality of Education. *International Journal of Scientific & Engineering Research*, 5(9), 81–86. http://www.ijser.org/

researchpaper%5CThe-Use-of-Laboratory-Method-in-Teaching-Secondary-School-Students-a-key-to-Improving-the-Quality-of-Education.pdf

Hammond, L. S., & Moore, W. M. (2018). Teachers taking up explicit instruction: The impact of a professional development model including directive instructional coaching. *Australian Journal of Teacher Education*, 43(7), 110–133. https://doi.org/10.14221/ajte.2018v43n7.7

Hendrawan, E., Hadi, L., Sahputra, R., Enawaty, E., & Rasmawan, R. (2021). Deskripsi Pengetahuan Alat – Alat Praktikum Kimia Peserta *Didik. Edukatif : Jurnal Ilmu Pendidikan*, 3(5), 3385–3396. https://doi.org/10.31004/edukatif.v3i5.731

Hensiek, S., Dekorver, B. K., Harwood, C. J., Fish, J., O'Shea, K., & Towns, M. (2016). Improving and Assessing Student Hands-On Laboratory Skills through Digital Badging. *Journal of Chemical Education,* 93(11), 1847–1854. https://doi.org/10.1021/acs.jchemed.6b00234

Irwanto, Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2019). Using inquiry-based laboratory instruction to improve critical thinking and scientific process skills among preservice elementary teachers. *Eurasian Journal of Educational Research*, 2019(80), 151–170. https://doi.org/10.14689/ejer.2019.80.8

Iyer, H. S., Wolf, N. G., Flanigan, J. S., Castro, M. C., Schroeder, L. F., Fleming, K., Vuhahula, E., & Massambu, C. (2021). Evaluating urban-rural access to pathology and laboratory medicine services in Tanzania. *Health Policy and Planning*, 36(7), 1116–1128. https://doi.org/10.1093/heapol/czab078

Jannah, S. N., & Sontani, U. T. (2018). Sarana Dan Prasarana Pembelajaran Sebagai Faktor Determinan Terhadap Motivasi Belajar Siswa. *Jurnal Pendidikan Manajemen Perkantoran*, 3(1), 210. https://doi.org/10.17509/jpm.v3i1.9457

Juvitasari, P. M., Melati, H. A., & Lestari, I. (2019). Deskripsi Pengetahuan Alat Praktikum Kimia Dan Kemampuan Psikomotorik Siswa Man 1 Pontianak. *Jurnal Pendidikan Dan Pembelajaran*, 7(7), 1–13.

Kartini, K. S. (2019). Deskripsi Perkembangan Keterampilan Dasar Kerja Laboratorium Kimia Siswa SMA Negeri 1 Singaraja. *Hydrogen: Jurnal Kependidikan Kimia*, 6(1), 21. https://doi.org/10.33394/hjkk.v6i1.1596

Keen, Clarissa; Sevian, H. (2022). Qualifying domains of student struggle in undergraduate general chemistry laboratory. *Chemistry Education Research and Practice*, 23(1), 12–37. https://doi.org/10.1039/D1RP00051A

Matias, A. R., Almeida, G., Veiga, G., & Marmeleira, J. (2023). Child Psychomotricity: Development, Assessment, and Intervention. *Children*, 10(10), 9–11. https://doi.org/10.3390/children10101605

Oktay, O., Koçak, G., & Seven, S. (2023). The Impact of STEM-based Laboratory Activities on Preservice Science Teachers' Competence Perceptions in 21 st-Century Skills and STEM Awareness. *J.Sci.Learn*. 6(3), 244–255. https://doi.org/10.17509/jsl.v6i3.54992

Oliveira, H., & Bonito, J. (2023). Practical work in science education: a systematic literature review. *Frontiers in Education*, 8. https://doi.org/10.3389/feduc.2023.1151641

Padari, P. S., Muharini, R., & Hadi, L. (2022). Deskripsi Pengetahuan Alat Praktikum Kimia Peserta Didik SMA Kristen Abdi Wacana. *Edukatif : Jurnal Ilmu Pendidikan*, 4(5), 7279–7285. https://doi.org/10.31004/edukatif.v4i5.3262

Pareek, R. B. (2019). An Assessment of Availability and Utilization of Laboratory Facilities for Teaching Science at Secondary Level. *Science Education International*, 30(1), 75–81. https://doi.org/10.33828/sei.v30.i1.9

Peraturan Menteri Pendidikan dan Kebudayaan. (2016). *Peraturan Menteri Pendidikan dan Kebudayaan Nomor 21 Tahun 2016 tentang Standar Isi Satuan Pendidikan Dasar dan Menengah*. Jakarta: Permendikbud. Diunduh dari https://peraturan.bpk.go.id/Details/224181/permendikbud-no-21-tahun-2016.

Pramesti, N., Ayuni, B., Zunaena, M., Oktaviani, R. D., & Kristinah, N. (2018). Pengetahuan Mahasiswa Pendidikan Biologi Tentang Peralatan Laboratorium Biologi. *Pendidikan Biologi,* 1(1), 1–7.

Pranaja. A.. & Astuti. Y. (2019). Pengaruh Lembar Kerja Praktikum Terhadap Keterampilan Proses Sains Siswa Kelas IV SD. *Jurnal Ilmu Pendidikan*. 1(3). 294-302. DOI: 10.31004/Edukatif.V1i3.41.

Putri, W. A., Astalini, A., & Darmaji, D. (2022). Analisis Kegiatan Praktikum untuk Dapat Meningkatkan Keterampilan Proses Sains dan Kemampuan Berpikir Kritis. *Edukatif : Jurnal Ilmu Pendidikan*, 4(3), 3361–3368. https://doi.org/10.31004/edukatif.v4i3.2638

Rahmah, N., Iswadi, I., Asiah, A., Hasanuddin, H., & Syafrianti, D. (2021). Analisis Kendala Praktikum Biologi di Sekolah Menengah Atas. *Biodik*, 7(2), 169–178. https://doi.org/10.22437/bio.v7i2.12777

Rahmawati, A. S., & Astuti, A. P. (2017). Pengaruh Kompetensi Profesional Guru Kimia terhadap Keterampilan Pembelajaran Laboratorium Siswa Kelas XII SMA N 11 Semarang. *Jurnal Pendidikan Sains*, 5(1), 47–55.

Raviolo, A., Farré, A. S., & Schroh, N. T. (2021). Students' understanding of molar concentration. *Chemistry Education Research and Practice*, 22(2), 486–497. https://doi.org/10.1039/d0rp00344a

Robles, A. (2023). *Digital Commons @ CSUMB Digital Commons @ CSUMB Capstone Projects and Master's Theses Mathematics (STEM) Education for Kinesthetic Learners Mathematics (STEM) Education for Kinesthetic Learners.* https://digitalcommons.csumb.edu/caps_thes_all

Saman, A. (2022). Hubungan kompetensi mahasiswa terhadap praktik laboratorium dan praktik klinik pada mata kuliah keperawatan dasar. *Salando Health*, 1(1), 1–8. https://jurnal.poltekkespalu.ac.id/index.php/snj/article/view/1618

Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, 10(2), 199–215. https://doi.org/10.3926/JOTSE.888

Silverthorn. D. U. (2018). *Human physiology: An integrated approach. Pearson Higher Ed*.

Sroczynski, E. (2023). Science Labs and Their Positive Impacts on Students ' Understanding of Science Concepts. *Learning to Teach Language Arts, Mathematics, Science, and Social Studies Through Research and Practice*, 69–74.

Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung : Alfabeta.

Uwitonze, D., & Nizeyimana, G. (2022). Effects of Virtual Laboratories on Students' Conceptual Understanding of Biology in Selected Secondary Schools of Rwamagana District, Rwanda. *Journal of Research Innovattion and Implications in Education,* 6(4), 249–258. www.jriiejournal.com

Walker, Sampson, S. and E. (2016). Using the laboratory to engage all students in science practices. *Chemistry Education Research and Practice,* 17(4), 1098–1113. https://doi.org/10.1039/C6RP00093B

Wei, J., Treagust, D. F., Mocerino, M., Lucey, A. D., Zadnik, M. G., & Lindsay, E. D. (2019). Understanding interactions in face-to-face and remote undergraduate science laboratories: a literature review. *Disciplinary and Interdisciplinary Science Education Research*, 1(1), 1–16. https://doi.org/10.1186/s43031-019-0015-8

Wijayaningrum. A. N. (2020). Profil Keterampilan Dasar Laboratorium Biologi Peserta Didik Di SMAN Kota Tangerang Selatan. *[Skripsi].* Diperoleh dari https://repository.uinjkt.ac.id/dspace/ha

In Table 12, the infit MNSQ and outfit MNSQ values have improved, as they approach the ideal value of 1.00. The infit ZSTD and outfit ZSTD values indicate good item quality, as they

Table 13. Person Reliability Data for the Mindset Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	23.6	8.0	1.39	0.61	0.98	-0.1	1.00	-0.1
P.SD	5.1	0.0	1.36	0.31	0.79	1.2	0.78	1.2
REAL RMSE	0.68	True SD	1.18	Separation	1.73	Person Reliability	0.75	0.67
S.E Of Person Mean = 0.16								
Person Raw Score-To-Measure Correlation = 0.92								
Cronbach Alpha (KR-20) Person Raw Score "Test" Reliability = 0.80								

Next, the person reliability values for the mindset aspect of sustainability literacy are presented in Table 13. In the table, it is observed that the mean values for infit MNSQ and outfit MNSQ for the person table have improved, approaching the ideal value of 1.00, thereby categorizing them as good. The infit ZSTD and outfit ZSTD values in the Person Table also indicate improved quality, as they approach the ideal value of 0.00. The person reliability value obtained suggests that the consistency of respondents' answers falls into the sufficient category. The interaction between respondents and items, as indicated by the Cronbach's alpha value of 0.80, is categorized as good (Sumintono & Widhiarso, 2015).

Table 14. Item Reliability Data for the Mindset Aspect of the Instrument

Total Score		CNT	Measure	REAL S.E	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	SZTD
Mean	206.1	70.0	0.00	0.18	1.02	0.0	1.00	-0.1
P.SD	23.1	0.0	0.67	0.03	0.26	1.40	0.26	1.4
REAL RMSE	0.18	True SD	0.65	Separation	3.65	Item Reliability	0.93	0.67
S.E Of Item Mean = 0.25								

The item reliability for the mindset aspect of sustainability literacy is shown in Table 14. In the table, it is evident that the infit MNSQ and outfit MNSQ values have improved, approaching the ideal value of 1.00. The infit ZSTD and outfit ZSTD values also reflect better item quality, as they approach the ideal value of 0.0. The item reliability value obtained is 0.93, indicating that the item quality is excellent for measuring the intended construct.

An example of a mindset aspect question is shown below. The item addresses the commitment to respect and care for energy sources available in human life. The mindset aspect is evident in students' views on the statement that excessive use of fossil fuel energy will increase greenhouse gases on Earth, which are known to cause global warming and significantly impact sustainable living (Isah, 2013).

"Excessive use of fossil fuels will increase the concentration of greenhouse gases in the atmosphere.
a. Strongly agree
b. Agree
c. Slightly agree
d. Disagree
e. Strongly disagree"

Consequently, the sustainability literacy assessment instrument on alternative energy topics is effective in measuring students' awareness of their beliefs and commitment to initiating environmental changes towards sustainable living. This aligns with Décamps et al. (2017), who state that the concept of sustainability is a way to empower students to initiate and commit to making decisions that build a sustainable future. Therefore, the sustainability literacy assessment instrument on the mindset aspect can effectively measure students' mindsets towards sustainable living.

The validity and reliability analysis indicates that the sustainability literacy assessment instrument on alternative energy topics is generally valid, reliable, and appropriate for use. This instrument helps to understand students' sustainability capabilities, encourages critical thinking, and increases sustainability awareness (Kuehl et al., 2023; Décamps et al., 2017).

Discussion

The findings from this study provide significant insights into the development and validation of a sustainability literacy assessment tool focused on alternative energy topics for high school students in Indonesia. The validation process, which included expert evaluations, readability tests, and piloting testing to students as internal consistency checks, has demonstrated the reliability and validity of the instrument, as stated by Mason (2019). These results contribute to the growing body of literature on sustainability education by offering a robust tool that is both contextually relevant and pedagogically sound.

A key aspect of this study was the application of the Rasch Model, selected due to its significant advantages in providing more accurate and reliable measurements compared to classical methods. The Rasch Model's ability to transform raw scores into interval data allows for a more precise interpretation of students' abilities and the quality of the items used in the instrument (Babcock & Hodge, 2020). Furthermore, the Rasch Model ensures that measurement results are invariant across different respondent groups, enhancing the validity and reliability of the instrument (Adam et al., 2021). This is particularly crucial in the educational context of developing countries like Indonesia, where student backgrounds and learning environments may vary significantly.

A detailed analysis of how the instrument measures sustainability literacy related to alternative energy was conducted by examining its three main dimensions: knowledge, skills, and mindset (Décamps et al., 2017). In the knowledge dimension, indicators include recognizing renewable and non-renewable energy sources, analyzing the global effects of energy usage, and identifying individual actions for energy transition to more sustainable alternatives. These indicators aim to enhance students' understanding of the environmental, social, and economic impacts of energy choices.

For the skills dimension, the instrument evaluates students' ability to address energy-related challenges through creativity, strategic thinking, and systemic analysis. Key indicators include proposing innovative solutions to energy crises, understanding the importance of collaboration for systemic change, participating in energy-saving activities, and analyzing both local and global impacts of energy use. This dimension measures students' practical and analytical skills essential for tackling real-world energy issues effectively (Milovanovic et al., 2021).

The mindset dimension focuses on students' attitudes and commitment to sustainability, such as their willingness to engage in sustainable practices and their confidence in initiating change. By measuring these attitudes, the instrument provides valuable insights into how well students internalize sustainability concepts and their readiness to take action in their communities (Wang et al., 2022).

In the context of high school physics and science education in Indonesia, the topic of alternative energy is integrated into the curriculum as part of the broader discussion on energy sources. Within this framework, students are introduced to both traditional fossil-based energy sources and their environmental impacts, such as contributions to climate change. The curriculum also emphasizes the importance of energy conservation and the utilization of alternative (renewable) energy sources, which are crucial for mitigating environmental damage and promoting sustainable development (Mittenzwei et al., 2019). Educational programs should not only improve knowledge but also focus on shaping attitudes and behaviors to foster comprehensive energy literacy (Cotton et al., 2015; Lee et al., 2022). Therefore, the development of an assessment instrument that effectively measures students' literacy of these concepts is essential for enhancing the effectiveness of physics education in addressing current global challenges.

Comparing these findings with previous studies, it becomes evident that the development of sustainability literacy instruments is a critical area of educational research. For example, Waltner et al. (2019) developed and validated an instrument to measure students' sustainability competencies across various topics, including environmental protection and resource conservation. However, their study did not specifically address alternative energy topics, a significant focus of the present research. The inclusion of alternative energy in this instrument aligns with global educational goals and fills a gap in existing research, particularly within the context of developing nations like Indonesia (Sutanto, 2017).

Moreover, the expert validation scores in this study, which categorized the instrument as "Very Good," align with findings from similar studies that emphasize the importance of expert feedback in refining educational tools. This highlights the instrument's strength in terms of construction, content, and language, ensuring that it meets the high standards required for effective educational assessment (Kuehl et al., 2023). The readability test results also underscore the instrument's accessibility to high school students, which is crucial for its successful implementation. Previous research has shown that readability is a key factor in the effectiveness of educational materials (Gill & Sharps, 2020). The high readability scores observed in this study suggest that the instrument is well-suited to the target audience, thereby enhancing its utility in real-world educational settings.

The iterative process of revising the instrument based on both expert and student feedback also underscores the importance of continuous improvement in educational research. This process, informed by both quantitative and qualitative data, ensures that the final product is both reliable and responsive to the needs of its users. Such an approach is consistent with best practices in educational research, where stakeholder input is essential for creating effective educational tools (Wang & Parker, 2018).

In the specific context of high school physics and science education, the validated instrument developed in this study provides a valuable tool for assessing students' sustainability literacy, particularly in the context of alternative energy. This is critical as it supports educators in effectively integrating sustainability concepts into the physics curriculum, thereby preparing students to engage with and address the energy challenges of the future. The instrument not only helps in evaluating students' current understanding but also guides instructional strategies aimed at enhancing their competencies in this vital area.

Overall, this study adds to the existing literature by providing a validated and reliable instrument specifically designed to measure sustainability literacy in the context of alternative energy. The implications of this research are significant, as it provides educators with a tool that can be used to assess and improve students' competency of critical sustainability issues within the framework of high school physics and science education. Future research could explore the application of this instrument in different educational settings and its potential impact on students' sustainability knowledge and behaviors, particularly in line with global sustainability objectives (IPCC, 2021).

However, there are certain limitations to this study that should be acknowledged. First, the sample size used in this research, while appropriate for the scope of this initial validation, may limit the generalizability of the findings. The participants were drawn from a specific group of high school students, and their experiences may not fully represent students from different educational contexts or geographic regions. A larger, more diverse sample would be necessary to confirm the instrument's broader applicability.

CONCLUSION

The sustainability literacy instrument centered on alternative energy has been carefully validated through expert evaluations, ensuring that its language, structure, and content satisfy educational requirements. A reading test was also performed to ensure the clarity for students. Empirical testing, including Rasch analysis, confirmed the instrument's high validity and reliability. The 24-item measure accurately examines students' knowledge, abilities, and attitudes toward sustainability literacy. Rasch analysis findings demonstrate great item quality, with infit and outfit MNSQ values near 1.00 and ZSTD values close to 0.00, indicating a solid model fit. Reliability scores for knowledge, skills, and mindset were 0.67, 0.70, and 0.75, respectively, with item reliability above 0.90 in all areas. This instrument is a valuable tool for testing sustainability literacy in high school science and physics classrooms, particularly in regard to alternative energy, and is a critical part for the effort of climate change and energy education in general. However, more testing in various educational situations is suggested to widen its usefulness and improve sustainability teaching.

ACKNOWLEDGMENT

This research is part of a research project funded by the Grant for Applied Research from the Directorate of Research, Technology, and Community Service, Ministry of Education, Culture, Research, and Technology, Indonesia, No. 574/UN26.21/PN/2024.

REFERENCES

Adam, W., Permanasari, A., & Hamidah, I. (2021). Sustainability Literacy of Student's Junior High School at Science Learning in Schools. *Jurnal Pendidikan MIPA*, 22(2), 206-214.

Al Qattan, M., & Gray, R. (2023). *Assessing the sustainability literacy of undergraduate students in Kuwait*. SpringerLink.

Afriyanti, Y., Sasana, H., & Jalunggono, G. (2018). Analisis Faktor-Faktor Yang Mempengaruhi Konsumsi Energi Terbarukan di Indonesia. *Directory Journal of Economic*, 2(3), 865-884.

Aikowe, L., & Mazancová, J. (2022). Pro-environmental awareness of university students – assessment through sustainability literacy test. *International Journal of Sustainability in Higher Education*. https://doi.org/10.1108/ijshe-06-2021-0219.

Anggraini, D., Abdurrahman, & Herlina, K. (2022). Development of Learning Program Based on Multiple Representations Integrated with PJBL George Lucas and STEM to Foster Students' Sustainability Literacy. *Jurnal Pendidkan Fisika dan Keilmuan (JPFK)*, 8(2), 253-279.

Anselmi, P., Colledani, D., & Robusto, E. (2019). A comparison of classical and modern measures of internal consistency. *Frontiers in Psychology*, 10, 2714. https://doi.org/10.3389/fpsyg.2019.02714

Babcock, B., & Hodge, K. J. (2020). Rasch versus classical equating in the context of small sample sizes. *Educational and Psychological Measurement*, 80(4), 678-703. https://doi.org/10.1177/0013164419878483

Baierl, T. M., & Bogner, F. X. (2024). Cognitive learning about forests: the key role of environmental attitude. *International Journal of Science Education*, 1-21. https://doi.org/10.1080/09500693.2024.2323917.

Bond, T. G., & Fox, C. M. (2015). *Applying the Rasch model: Fundamental measurement in the human sciences (3rd ed.)*. Routledge.

Bond, T., Yan, Z., & Heene, M. (2020). *Applying the Rasch model: Fundamental Measurement in the Human Sciences*. New York: Routledge. 376 Pages.

Boone, W. J., Staver, J. R. & Yale, M. S. (2014). *Rasch Analysis in the Human Sciences*. Dordrecht: Springer. 478 Pages.

Darman, D. R., Suhandi, A., Kaniawati, I., Samsudin, A., & Wibowo, F. C. (2024). Development and validation of scientific inquiry literacy instrument (SILI) using Rasch measurement model. *Education Sciences*, 14(3), 322. https://doi.org/10.3390/educsci14030322

Chen, C., An, Q., Zheng, L., & Guan, C. (2022). Sustainability Literacy: Assessment of Knowingness, Attitude and Behaviour Regarding Sustainable Development among Students in China. *Sustainability,* 14(9), 4886. https://doi.org/10.3390/su14094886.

Cotton, P., Miller, D., Winter, D., Bailey, D., & Sterling, P. (2015). Developing students' energy literacy in higher education. International *Journal of Sustainability in Higher Education,* 16, 456-473. https://doi.org/10.1108/IJSHE-12-2013-0166.

Décamps, A., Barbat, G., Carteron, J. C., Hands, V., & Parkes, C. (2017). Sulitest: A Collaborative Initiative to Support and Assess Sustainability Literacy in Higher Education. *The International Journal of Management Education*, 15(1), 138-152.

Eshiemogie, S., Banji, T., & Ighalo, J. O. (2022). Knowledge, Perception and Awareness of Renewable Energy by Engineering Student in Nigeria: A Need for the Unergraduate Engineering Program Adjustment. *Leaner Engineering and Technology,* 6(1), 1-28.

Hawa, N., Zakaria, S., Razman, M., & Majid, N. (2021). Geography Education for Promoting Sustainability in Indonesia. *Sustainability*, 13, 4340. https://doi.org/10.3390/SU13084340.

Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate change 2021: The physical science basis*. Contribution of working group I to the sixth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896

Isa, M., Bakar, M., Hasim, M., Anuar, M., Sipan, I., & Nor, M. (2017). Data quality control for survey instrument of office investors in rationalising green office building investment in Kuala Lumpur by the application of Rasch analysis. *Facilities*, 35, 638-657. https://doi.org/10.1108/F-06-2016-0067.

Isah, Y. 2013. Green House Gases, Climate Change and Enviromental Conservation for Sustainable Development. *Academic Journal of Interdisciplinary Studies*, 2(6), 9-16

Kariri, H. D. H., Somaili, H. E., Mansour, M. E. I., Omair, A. H., & Radwan, O. A. (2023). Rasch and confirmatory factor analyses of the Arabic version of the Psychological Empowerment Scale (PsyES): A multicultural approach for measurable sustainability. *Sustainability*, 15(3), 1-13. https://doi.org/10.3390/su15075928.

Kuehl, C., Sparks, A. C., Hodges, H., & Smith, E. R. (2021). The incoherence of sustainability literacy assessed with the Sulitest. *Nature Sustainability,* 4(6), 555-560.

Kuehl, C., Sparks, A. C., Hodges, H., & Smith, E. R. N. (2023). Exploring sustainability literacy: developing and assessing a bottom-up measure of what students know about sustainability. *Front. Sustain*. 4(1), 1- 10. https://doi.org/10.3389/frsus.2023.1167041

Lee, Y., Nguyen, H., & Sung, H. (2022). Energy literacy of high school students in Vietnam and determinants of their energy-saving behavior. *Environmental Education Research*, 28, 907 - 924.

https://doi.org/10.1080/13504622.2022.2034752.

Marcinkowski, T. & Reid, A. (2019). Reviews of Researc on The Attitude-Behavior Retionship and Their Implications for Future Environmental Education Research. *Environmental Education Research*, 25(4), 459-471

Mason, A. (2019). *Sulitest®: a mixed-method, pilot study of assessment impacts on undergraduate sustainability-related learning and motivation.* https://digitalcommons.pittstate.edu/cgi/viewcontent.cgi?article=1006&context=communication_faculty

Mensah, J. (2019). Sustainable Development: Meaning, History, Principles, Pillars, and Implications for Human Action: Literature Review. *Cogent Social Sciences*, 5(1), 1-21.

Milovanovic, J., Shealy, T., & Katz, A. (2021). Higher Perceived Design Thinking Traits and Active Learning in Design Courses Motivate Engineering Students to Tackle Energy Sustainability in Their Careers. *Sustainability*. https://doi.org/10.3390/su132211322

Mittenzwei, D., Bruckermann, T., Nordine, J., & Harms, U. (2019). The Energy Concept and its Relation to Climate Literacy. *EURASIA Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/EJMSTE/105637

Null, D., Feeser, K., & Kurtzhals, G. (2021). An assessment of environmental literacy, behaviours, attitudes and lifestyle factors of college students. *Journal of American College Health*, 71, 2485 - 2494. https://doi.org/10.1080/07448481.2021.1975720.

Oranga, J., Gisore, B., & Areba, G. (2023). Barriers to Transformative Climate Change Education: Mitigation and Resilience-Building. *International Journal of Social Science*, 3(3), 389-396. https://doi.org/10.14738/assrj.109.15390

Ozdemir, O. (2021). A scale development of the sustainability literacy. Education, *Sustainability & Society*, 4(2), 66-72. https://doi.org/10.26480/ess.02.2021.66.72

Qureshi, S. (2020). Learning by sustainable living to improve sustainability literacy. International *Journal of Sustainability in Higher Education*, 21, 161-178. https://doi.org/10.1108/ijshe-01-2019-0001.

Sumintono, B. & Widhiarso, W. (2015). *Aplikasi Model Rasch Untuk Penelitian Ilmu Sosial*. Cimahi: Trim Komunikata. 142 hlm.

Sutanto, H. P. (2017). Education for Sustainable Development in West Nusa Tenggara. *Cakrawala Pendidikan*, 36(3), 320-341.

Szczytko, R., Stevenson, K., Peterson, M. N., Nietfeld, J., & Strnad, R.L. (2018). Development and Validation of the Environmental Literacy Instrument for Adolescents. *Environmetal Education Research,* 25(2), 193-210.

Thiagarajan, S., Semmel, D.S. & Semmel, M.I. (1974). *Instructional Development for Training Teachers of Exceptopnal Children*. Indiana: Indiana University Bloomington. 192 Pages.

Tristanada, P. W. (2018). Membumikan Education for Sustainable Development (ESD) di Indonesia dalam Menghadapi Isu-Isu Global. *Purwadita*, 2(2), 42-49.

Vesterinen, M., & Ratinen, I. (2023). Sustainability competences in primary school education – a systematic literature review. *Environmental Education Research*, 30, 56 - 67. https://doi.org/10.1080/13504622.2023.2170984.

Waltner, E., Riess, W., & Mischo, C. (2019). Development and Validation of an Instrument for Measuring Student Sustainability Competencies. *Sustainability.* https://doi.org/10.3390/SU11061717.

Wang, Y., Sommier, M., & Vasques, A. (2022). Sustainability education at higher education institutions: pedagogies and students' competences. *International Journal of Sustainability in Higher Education*. https://doi.org/10.1108/ijshe-11-2021-0465.

Zainordin, N., Ismail, S., & Omar, A. F. (2023). Critical success factors (CSF) of sustainability implementation in Malaysia. *Malaysian Construction Research Journal*, 18(1), 267–277.

Zwickle, A., & Jones, K. (2018). *Sustainability knowledge and attitudes—Assessing latent constructs*. Handbook of sustainability and social science research, 435-451.