Validation of an AI-Based Automatic Assessment System for Scientific Literacy Instruments on Green Chemistry Integrated with Ethnochemistry

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Abstract
This study aims to measure the content validity of an AI-based automatic assessment system for scientific literacy instruments on green chemistry integrated with ethnochemistry using Aiken's V index. The research design adopts the R&D model with the ADDIE approach, limited to the analysis, design, and development stages. A combination of quantitative and qualitative descriptive methods was utilized through purposive sampling, engaging 10 experts—chemistry education lecturers from UNS, UNY, UM, and high school chemistry teachers in Surakarta. Data were obtained through Focus Group Discussions (FGD), focusing on three aspects: context, language, and construct. Essay-based instrument items were rated using four relevance categories: irrelevant, less relevant, quite relevant, and relevant. Items with an Aiken index ≥ 0.73 were considered valid. The results showed that 1 question item had moderate validity and 14 question items had high validity, making them suitable for further testing. The questions were designed to assess students' understanding of green chemistry principles and their ability to relate these to ethnochemistry practices—local cultural knowledge that supports sustainability. The formulation of the questions also demonstrated how the application of local culture can be interpreted through green chemistry to enhance scientific awareness and environmental responsibility. Based on the content validation results and subsequent revisions, the instrument is deemed ready to move forward to the limited trial stage.

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1. Introduction

In the 21st-century education era, mastery of scientific literacy is very important for students. Scientific literacy is not only an understanding of basic scientific concepts; but also includes the ability to identify complex problems, analyze data critically, and apply scientific knowledge in everyday contexts related to life (Seema, 2024) Scientific literacy in Indonesia, the results of the Programme for International Student Assessment (PISA) show that the scientific literacy skills of Indonesian students are still relatively low, with an average score in 2022 of 398, far below the average of OECD countries, which reached 485 (OECD, 2022)

To solve this problem, the application of a more contextual approach that is by students' daily lives must be considered. Creating science problems based on ethnochemistry can deepen students' understanding of the application of science in the context of their culture and environment (Jihannita et al., 2024). Integrating a variety of learning methods and using technology can boost students' enthusiasm for learning (Alamin et al., 2024). Building a strong literacy culture where students are regularly engaged in reading and analyzing information is an essential step toward enhancing science literacy across Indonesia (Marmuah et al., 2022).

On the other hand, local context-based learning approaches, such as ethnochemistry, have been shown to be highly effective in helping students better understand abstract scientific concepts. This suggests that combining science with local culture can promote more active student participation, making learning more relevant and meaningful (Wardani et al., 2023). When students are encouraged to explore science through a

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cultural context they are familiar with, their understanding tends to be deeper and more impactful (Prayogi et al., 2023). This approach highlights the significance of cultural values in science education, which is in line with the principles of holistic learning and development.

In line with the increasing global concern about the environment, the relationship of sustainable chemistry in education has become a major concern. The aim is to support students in understanding the basic principles of desirability. Green chemistry aims to reduce the use of hazardous materials, prevent pollution, and support sustainable design practices in the education and industrial sectors (Jain et al., 2024). Studies have shown that students who understand green chemistry and environmental issues are more likely to adopt environmentally responsible behaviors (Santosa et al., 2023). In addition, incorporating the concept of environmentally friendly chemistry into the curriculum, especially at the secondary education level, not only increases environmental awareness but also supports the achievement of the Sustainable Development Goals (SDGs) (Ibrahim et al., 2025).

Artificial intelligence (AI) technology is creating exciting opportunities in science literacy assessment. It can improve process efficiency, reduce bias, and provide quick, personalized feedback that supports students in understanding where they are. With AI, you can automate assessments and tailor feedback to individual needs, making the entire experience more engaging and personal (Bulut et al., 2024). However, there are also significant ethical issues such as the presence of bias in algorithms, lack of transparency about decision-making processes, and the potential for perpetuating existing inequities, especially when assessing students from diverse cultural backgrounds (Farrelly & Baker, 2023). AI tools often fail to take into account cultural or local context, which is crucial in educational methods like ethnochemistry. While AI has the potential to improve personalized learning, we need more validation in the field and caution should be exercised in culturally diverse applications (Bedmutha et al., 2024).

The results of teacher interviews in several secondary schools indicate that the green chemistry summative exam is still limited to measuring material understanding, without assessing scientific literacy skills as a whole or linking to the actual relevant ethnochemistry context. To address this, an AI-based integrated ethnochemistry scientific literacy instrument was developed, which was designed to measure aspects of students' knowledge, beliefs, motivation, and Higher Order Learning Skills (HOLS), including content, context, and attitudes (Shwartz et al., 2006). The instrument in the form of essay questions was chosen because it can express students' understanding in depth, although manual assessment takes time and can be biased. AI technology emerged as an answer to carry out fast and accurate automatic evaluation (Mardiana & Risnanto, 2022).

While approaches like AI, ethnochemistry, and green chemistry have each shown success independently, combining these elements into a single science literacy tool remains quite rare. That said, integrating all three has great potential to offer more contextual and comprehensive assessments that meet the demands of the 21st century. Several studies have highlighted the effectiveness of AI-powered automated assessment in sustainable chemistry (Yamtinah et al., 2024) and the use of ethnoscience in authentic testing (Hastuti et al., 2022). However, the application of the combination of these three methods is still minimal, indicating the need for a creative interdisciplinary approach. This study aims to develop and validate an AI-based tool that disseminates scientific literacy by integrating the principles of green chemistry and ethnochemistry. The content validity of this tool was examined through the Aiken index, with ten raters generating indicators of questions, items, answer keys, and assessment rubrics. The goal is for this tool to demonstrate a high level of validity, increase greater student participation, and produce consistent results when compared to manual assessment.

2. Method

2.1. Research Design

This study implemented an abbreviated version of the research and development (R&D) process using the ADDIE model (Figure 1), which has been based on three main stages: analysis, design, and development. The study focused on the development of an essay-based instrument to assess scientific literacy, integrating ethnochemical and green chemistry principles. Furthermore, the tool was designed to work with an automated evaluation system powered by AI. The ADDIE model was chosen because it offers an organized yet flexible framework that can be easily adapted to meet the specific needs of students (Sánchez-García et al., 2023). The main objective of this study was to disseminate the content validity of an ethnochemical-based scientific literacy instrument, utilizing the Aiken index as a measure for expert assessment.

2.2. Participant and Sampling

This study involved 10 purposively selected experts, including chemistry education lecturers from Sebelas Maret University (UNS), Yogyakarta State University (UNY), and Malang State University (UM), as well as high school chemistry teachers from the Surakarta area. Their participation was facilitated through Focus Group

Discussions (FGDs). The selection criteria were directed at their experiences in creating science literacy tools, teaching environmentally friendly chemistry, or incorporating ethnochemical approaches into their teaching methods.

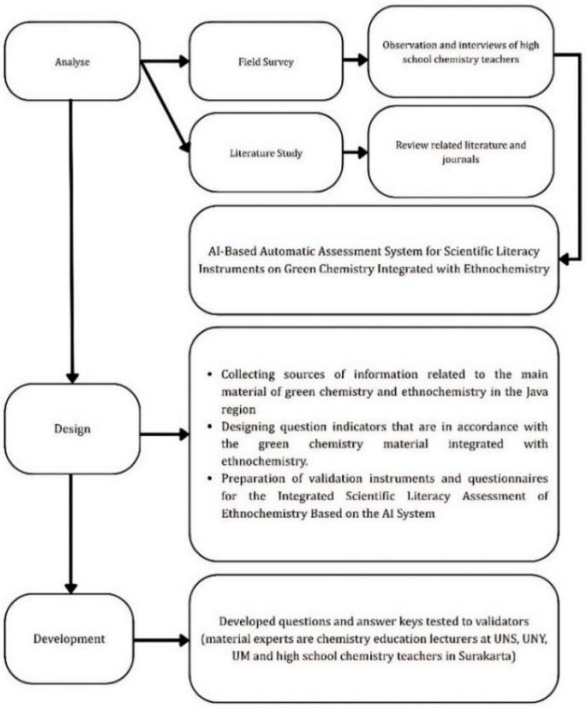

Figure 1. Initial Design of Scientific Literacy Instruments on Green Chemistry Integrated with Ethnochemistry

2.3. Instruments and Validation

The instrument developed was 15 scientific literacy essay questions that integrated ethnochemistry and green chemistry content, adapted to chemistry learning in grade XI of high school. These questions reflect the local cultural context. Validation of the instrument content was carried out by experts through Likert scale-based evaluation (1–4), and analyzed using the Aiken index.

2.4. Data Collection Procedures

Each Expert assessed 15 essay questions using a 4-point Likert scale for three aspects: (1) relevance to scientific literacy indicators, (2) clarity of language and question structure, and (3) conformity to green chemistry and ethnochemistry principles. These assessments were then used to calculate the Aiken's V index. Questions were declared valid if V ≥ 0.73 for 10 validators. Improvements were made based on expert input regarding technical terms, cultural representation, and question structure. This process ensured that the essay questions were ready to be used as test material before being assessed by the AI system.

2.5. Data Analysis Techniques

The analysis of data was performed both qualitatively and quantitatively. Qualitative data were obtained from expert comments on the suitability of content, clarity of narrative, and accuracy of ethnochemistry context. Meanwhile, quantitative data were analyzed using the Aiken index to assess the level of validity of the content of each question item. The aspects assessed include content aspects, language aspects, and construct aspects. The content aspect of the question includes the suitability of the material used with scientific truth, scientific developments, and real life. The language aspect consists of the language used communicatively, the sentences used are easy to understand with Indonesian language rules and the readability of the questions used. The presentation aspect includes the clarity of the sequence and consistency of the question structure, including instructions for working on questions that are easy to understand and do not cause many interpretations and the visual appearance of the questions used must also be clear. Questions are considered valid if the Aiken's V value ≥ 0.73 based on the assessment of 10 experts (Aiken, 1985) Here is the formula (Eq. 1):

$$V = \frac{\Sigma S}{[n(C-1)]} \text{ with } S = R - L \quad (1)$$

Description: (V): aiken validity index; (S): score given by the assessor minus the lowest score in the category; (R): score given by the assessor; (Lo): lowest assessment score (1); (C): highest assessment score (4); (n): quantity of assessors, or validators.

3. Results and Discussion

The assessment of the instrument's content validity in this study was established through consensus among experts. Agreement among experts is utilized to establish content validity, as the test or non-test instrument is deemed accurate if the experts agree that the instrument effectively measures the intended capability. The Aiken validity index can be used to determine this expert agreement (Nabil et al., 2022). The assessment of the content validity of the scientific literacy instrument that has been developed is directed at three domains: (1) content aspects, (2) language aspects, and (3) construct aspects. Table 1 presents the assessment grid for the AI-based ethnochemistry scientific literacy instrument.

Table 1. Assessment grid for AI-based Ethnochemistry Scientific Literacy Instrument on Green Chemistry Material

Aspect	Assessment grid
Content aspects	The material presented is by the field of study being taught. The concepts and information in the questions are presented accurately, relevantly, and in line with basic competencies. There are no factual errors in the questions.
Language aspects	The sentences in the text are well-structured, following correct grammar rules, making it easier for students to understand the contents of the questions. The questions are free from spelling, punctuation, or word usage errors, indicating the precision and accuracy of the language.
Constructive aspects	Questions are structured logically and sequentially, with each statement related to each other to build a clear problem-solving pattern. There are no repetitive or overlapping questions, so the flow of thought remains coherent. Instructions are clearly and systematically presented, making them easy for students to understand.

The results of the Aiken index analysis obtained from the focus group discussion (FGD) were obtained from 10 assessors through a validity sheet containing a 1-4 assessment scale on the SLA instrument that had been developed. Furthermore, the validation of the assessment results by the validator was calculated using the Aiken index, as illustrated in Table 2. Based on the results of the Focus Group Discussion (FGD) that had been carried out, the content validity value was obtained from 10 assessors using the Aiken formula as follows.

Table 2. Results of Aiken Index Analysis on AI-Based Automatic Assessment System for Scientific Literacy Instruments on Green Chemistry Integrated with Ethnochemistry

No	V Value	V Table	Conclusion
1	0,87	0,73	Valid
2	0,88	0,73	Valid
3	0,91	0,73	Valid
4	0,98	0,73	Valid
5	0,96	0,73	Valid
6	0,95	0,73	Valid
7	0,81	0,73	Valid
8	0,81	0,73	Valid
9	0,89	0,73	Valid
10	0,87	0,73	Valid
11	0,82	0,73	Valid
12	0,91	0,73	Valid
13	0,77	0,73	Valid
14	0,95	0,73	Valid
15	0,95	0,73	Valid

The level of content validity is directly linked to the appropriateness of the question items in relation to the indicators of ethnochemistry integrated science literacy skills utilizing the AI system within green chemistry topics. This study uses four answer categories to assess validity, namely irrelevant (TR) score 1, less relevant (KR) score 2, quite relevant (CR) score 3, and relevant (R) score 4, so that experts can choose from the four answer categories on each question instrument.

The validity of a question item is considered a good measuring tool according to Aiken if ten expert assessors provide four types of answers, with the Aiken index results greater than or equal to the V table value of 0.73 (Aiken, 1985) The Aiken index value (V index) is a quantitative measure that shows the level of agreement between expert assessors regarding the relevance of items to the intended indicators, and is widely used in content validity tests of educational instruments (Gabriela & Susana, 2021). Based on the analysis of

content validity calculations using the Aiken formula, the ethnochemistry integrated scientific literacy instrument based on the AI system for green chemistry material produces 15 questions that are considered valid.

The calculation results can be seen in Table 2, which relates to the results of the Aiken index calculation of the AI-based automatic assessment system for scientific literacy instruments on green chemistry integrated with ethnochemistry, which shows that 1 question item has moderate validity and 14 question items have high validity. This can be observed based on the Aiken validity index obtained from expert assessments, which can be stated as low level if the score obtained is below 0.4. The index is obtained when it ranges from 0.4 - 0.8 and has high validity if the score obtained exceeds 0.8(Aiken, 1985) The Aiken index is a measure of the content validity of a question item, where a value approaching 1.0 indicates higher relevance to the predetermined indicators (Nabil et al., 2022).

The results of the content validation from 10 assessors obtained suggestions and input. The suggestions and input are as follows. (1) The choice of words in the questions must be clear and not confusing; (2) The narrative text must not cause student misconceptions; (3) The wording in writing the narrative and questions must be by PUEBI; (4) The narrative text is equipped with images to make it clearer; Questions and answers must be relevant to the reading text; (5) It is not permissible to repeat sentences in writing the reading text; and (6) Question and question indicators must be relevant and appropriate. The researcher will then follow up on the scientific literacy instrument according to suggestions and input.

The content of the instrument not only meets quantitative content validity but also includes educational values based on the local cultural context through the integration of green chemistry and ethnochemistry principles. Traditional practices of Javanese society, such as making “jamu”, tempeh fermentation, batik coloring, sekaten festival, making essential oils, wrapping food in teak leaves and banana leaves, making woven goods from water hyacinth, making black sticky rice tape, gunungan at the Grebeg Maulud festival, to the merti desa culture, are included in the problem scenario as a real representation of chemical reactions that occur in everyday life, while reflecting ecological awareness that is passed down from generation to generation.

This approach is in line with the 12 principles of green chemistry, namely the first principle (waste prevention), the second principle (atomic economy), the third principle (less hazardous chemical synthesis), the fourth principle (designing safer chemicals), the fifth principle (safer solvents and additives), the sixth principle (design for energy efficiency), the seventh principle (use of renewable materials), the eighth principle (reduce derivatives), the ninth principle (catalysis), the tenth principle (design for degradation of chemical products), the eleventh principle (real-time analysis of pollution prevention), and the twelfth principle (inherently safer chemicals) (Anastas & Warner, 2000) as well as strengthening the values of sustainability and environmental preservation through contextual science. Thus, this tool is not only technically valid, but also socioculturally relevant, and can encourage students to understand chemical concepts in the context of sustainable local-global thinking, as supported by the research of Rahmawati et al. (2023) and Ardyansyah (2024) which emphasizes the importance of ethnochemistry-based chemistry learning in improving students' scientific literacy and environmental awareness.

Table 3 and Table 4 are examples of test items designed in an assessment product that integrates green chemistry with ethnochemistry. These questions are designed to assess students' ability to connect chemical concepts with local cultural practices and assess the suitability of actions with green chemistry principles. In table 3, the cultural context discussed is the "merti desa" tradition in in Dologan Village, Boyolali, Central Java which reflects the values of mutual cooperation and concern for environmental cleanliness. However, the process of burning waste after the village cleaning activity actually contradicts the first principle of green chemistry (Prevention) because it produces emissions of hazardous gases such as carbon monoxide, dioxin, and particles, which can pollute the air and endanger health. This inquiry encourages students to thoroughly assess cultural practices through a scientific and sustainability lens, aligning with recent demands to integrate cultural awareness into sustainability education and evaluation (Tammaro & Gragnaniello, 2024).

Table 3. Integrated Green Chemistry Ethnochemistry Questions About "Merti Desa"

The traditional practice of "merti desa" in Dologan Village, Boyolali, Central Java is a Central Javanese traditional ceremony that means deep gratitude for God's gifts after a good harvest. To make it happen, residents work together to clean the environment together. In this practice, people gather to clean streets, rivers, or other public areas from garbage and waste. To reduce waste, the garbage is collected together and then burned. Are the activities carried out by residents to reduce waste by burning it in accordance with the principles of green chemistry? Explain the reasons!

Table 4. Integrated Green Chemistry Ethnochemistry Questions About "Batik"

People in Central Java often use teak leaves as a wrapper for traditional foods, such as gudeg, pecel and nasi kucing. The use of teak leaves not only adds a distinctive aroma to the food, but is also environmentally friendly because it can decompose naturally.

From the narrative above, does the use of teak leaves as a wrapper for traditional foods in Central Java include the principles of green chemistry? Mention which principles and give reasons!

In Table 4, the context raised is the habit of Javanese people who use teak leaves as wrappers for traditional dishes such as gudeg, pecel, and nasi kucing. This practice not only preserves traditional values in culinary culture, but also demonstrates the application of green chemistry principles, such as the first principle (Prevention) through reducing plastic waste, the seventh principle (Use of Renewable Raw Materials) because teak leaves are natural materials that can be renewed, and the fourth principle (Designing Safer Chemicals) because teak leaves do not contain hazardous compounds that can contaminate food. This question encourages students to recognize that the concept of sustainability is not limited to laboratories or industries, but is also present in the daily practices of local communities. This instrument not only serves as a tool to assess cognitive abilities, but also as a medium to raise awareness of the importance of preserving cultural and environmental heritage, all through a contextualized scientific perspective. This method is in line with the views of recent literature, such as Rahmawati et al. (2023) and Wardani et al. (2023), which emphasize that ethnochemistry has great potential as a platform to integrate chemical literacy with awareness of interests in educational contexts.

After the revision of the AI-based ethnochemistry scientific literacy instrument in response to expert input, the instrument will be integrated into ChemTest (cemytest.com), an automated assessment platform designed to assist chemistry teachers in evaluating students' essay answers accurately and efficiently. The assessment is obtained from AI analysis, which is structured based on the prompt format. A prompt is a specific command or instruction that the user enters into a Large Language Model (model) to obtain the desired output or result from the user (Giray, 2023). The AI-integrated scientific literacy instrument prompt format is presented in Table 5. The results of the content validity analysis of the 15 items of the AI-based ethnochemistry scientific literacy instrument on green chemistry indicated a valid question instrument. However, of the 15 items, some changes were needed based on comments and suggestions from the people who reviewed the instrument to make it perfect so that it can be used to measure students' scientific literacy in green chemistry. If the questions are improved, a limited trial will be conducted with 5 grade XI students at each of SMA Negeri 1 Banyudono, SMA Negeri 6 Surakarta, and SMA Negeri 1 Teras Boyolali to see the further validity in the form of an integrated scientific literacy instrument construct based on an AI system on green chemistry material.

Table 5. AI-Based Scientific Literacy Instrument Prompt Format

Sub Content	Information
Role and Objective	Contains a broad concept regarding the function AI ought to have in evaluating students' answers
Question	Contains questions.
Answer Key	Contains an Answer Key.
Scoring Rubric	Contains thorough scoring instructions. To facilitate the AI system's operation, the maximum score for every question in this system is set at the same value.
Evaluation Instructions	Contains information on how the AI will assess student responses.
Example Feedback Structure	Contains instances of feedback formats that learners obtain. Here is the format: Total Score: [Insert Total Score Here] out of 10 points Scoring Breakdown: Question: [Insert Score]- [Reason for Score] Feedback: "..."
Final Comment	Contains a summary of the student's performance, emphasizing both their areas of strength and need for development.

4. Conclusion

Based on the results of the study on the Validation of an AI-based automatic assessment system for scientific literacy instruments on green chemistry integrated with ethnochemistry, based on the agreement of experts using the Aiken index calculation, it was declared valid. The content validity of the AI-based ethnochemistry integrated scientific literacy instrument on green chemistry material obtained results of 15 question items declared valid with a value of ≥ 0.73, with 1 question item having moderate validity and 14 question items having high validity. The questions formulated show that the application of local culture can be explained and understood through the principles of green chemistry to increase scientific awareness and travel. However, although considered feasible, this instrument still requires some improvements according to input and suggestions from the validators so that it can function more optimally as an evaluation tool in measuring students' scientific literacy abilities. Thus, the AI-based ethnochemistry integrated scientific literacy instrument on green chemistry material can be used for limited trials on 5 students each at SMA Negeri 1 Banyudono, SMA Negeri 1 Teras Boyolali, and SMA Negeri 6 Surakarta to see further validity in the form of the AI-based ethnochemistry integrated scientific literacy instrument construct on green chemistry material.

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References

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement, 45*(1), 131–142. https://doi.org/10.1177/0013164485451012

Alamin, A., Nurhanurawati, N., Rohman, F., & Perdana, R. (2024). Development of learning e-modules based on contextual teaching and learning on the material of changing the form of energy to improve students' science literacy. *Jurnal Penelitian Pendidikan IPA, 10*(8), 6095–6103. https://doi.org/10.29303/jppipa.v10i8.8323

Anastas, P. T., & Warner, J. C. (2000). *Green chemistry: Theory and practice*. Oxford University Press. https://doi.org/10.1093/oso/9780198506980.001.0001

Ardyansyah, A. (2024). Enhancing chemistry education through the integration of Rote Ndao cultural practices: An ethnographic exploration of ethnochemistry. *Journal of Educational Chemistry, 6*(2), 111–126. https://doi.org/10.21580/jec.2024.6.2.22321

Bedmutha, M. S., Bascom, E., Sladek, K. R., Tobar, K., Casanova-Perez, R., Andreiu, A., Bhat, A., Mangal, S., Wood, B. R., Sabin, J., Pratt, W., Weibel, N., & Hartzler, A. L. (2024). Artificial intelligence-generated feedback on social signals in patient–provider communication: Technical performance, feedback usability, and impact. *JAMIA Open, 7*(4), ooae106. https://doi.org/10.1093/jamiaopen/ooae106

Bulut, O., Beiting-Parrish, M., Casabianca, J. M., Slater, S. C., Jiao, H., Song, D., Ormerod, C., Fabiyi, D. G., Ivan, R., Walsh, C., Rios, O., Wilson, J., Yildirim-Erbasli, S. N., Wongvorachan, T., Liu, J. X., Tan, B., & Morilova, P. (2024). The rise of artificial intelligence in educational measurement: Opportunities and ethical challenges. *arXiv*. https://arxiv.org/abs/2406.18900

Farrelly, T., & Baker, N. (2023). Generative artificial intelligence: Implications and considerations for higher education practice. *Education Sciences, 13*(11), 1109. https://doi.org/10.3390/educsci13111109

Gabriela, M., & Susana, M. (2021). Content validity of a questionnaire to assess parental involvement in education. *European Journal of Psychology and Educational Research, 4*(2), 93–100. https://doi.org/10.12973/ejper.4.2.93

Giray, L. (2023). Prompt engineering with ChatGPT: A guide for academic writers. *Annals of Biomedical Engineering, 51*(12), 2629–2633. https://doi.org/10.1007/s10439-023-03272-4

Hastuti, P. W., Anjarsari, P., & Yamtinah, S. (2022). Scientific literacy assessment instrument on addictive substances topic in inquiry-based learning integrated ethnoscience. *Journal of Science Education Research, 6*(1), 31–36. https://doi.org/10.21831/jser.v6i1.48343

Ibrahim, M. M., Abas, A., Yahaya, A., Taha, H., Che Ahmad, C. N., & Yahaya, R. (2025). Exploring environmental sustainability awareness: Perspectives of rural and urban school students and teachers on green chemistry and strategies for achieving sustainable development goals. *Journal of Lifestyle and SDGs Review, 5*(3), e04946. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n03.pe04946

Jain, S. D., Awasthi, A., & Gupta, A. K. (2024). Green chemistry: A sustainable path to environmental responsibility and innovation. *Asian Journal of Research in Pharmaceutical Sciences*, *14*(1), 1–10. https://doi.org/10.5958/2231-5659.2024.00001.1

Jihannita, J., Fadly, W., Ekapti, R. F., Luthfiana, D., & Widowati, A. (2024). The development of science module integrated with ethnoscience of Singo Barong mask to improve scientific literacy and cultural preservation attitudes. *Journal of Innovation in Educational and Cultural Research*, *5*(2), 45–53. https://doi.org/10.46843/jiecr.v5i2.790

Mardiana, M. I., & Risnanto, S. (2022). Penggunaan cosine similarity dalam penilaian jawaban ujian esai otomatis. *Prosiding Seminar Sosial Politik, Bisnis, Akuntansi dan Teknik*, *4*, 361–366. https://doi.org/10.32897/sobat.2022.4.0.1942

Marmuah, S., Poerwanti, J. I. S., & Suharno. (2022). Literacy culture management of elementary school in Indonesia. *Heliyon*, *8*(11), e11345. https://doi.org/10.1016/j.heliyon.2022.e11345

Nabil, N. R. A., Wulandari, I., Yamtinah, S., Ariani, S. R. D., & Ulfa, M. (2022). Analisis indeks Aiken untuk mengetahui validitas isi instrumen asesmen kompetensi minimum berbasis konteks sains kimia. *Paedagogia: Jurnal Penelitian Pendidikan*, *25*(2), 184–191. https://doi.org/10.20961/paedagogia.v25i2.64566

Organisation for Economic Co-operation and Development. (2022). *Are students ready to take on environmental challenges?* OECD Publishing. https://doi.org/10.1787/8abe655c-en

Prayogi, S., Ahzan, S., Rokhmat, J., Sri, N. N., & Verawati, P. (2023). Dynamic blend of ethnoscience and inquiry in a digital learning platform (e-learning) for empowering future science educators' critical thinking. *Journal of Education and E-Learning Research*, *10*(4), 456–463. https://doi.org/10.20448/jeelr.v10i4.5233

Rahmawati, Y., Mardiah, A., Taylor, E., Taylor, P. C., & Ridwan, A. (2023). Chemistry learning through culturally responsive transformative teaching (CRTT): Educating Indonesian high school students for cultural sustainability. *Sustainability*, *15*(8), 6925. https://doi.org/10.3390/su15086925

Sánchez-García, J. R., Galeana-Victoria, L. G., Flores-Azcanio, N. P., & Sánchez-Vázquez, E. (2023). ADDIE model as a methodology for the design of distance courses. *Revista de Tecnología Informática*, *6*(2), 15–22. https://doi.org/10.1234/rti.v6i2.123

Santosa, N. K. Y., Sulistyowati, L., & Aji, S. S. (2023). The correlation of green chemistry and environmental knowledge on students' environmental care behavior. *Jurnal Multidisiplin Indonesia*, *2*(1), 25–32. https://doi.org/10.1234/jmi.v2i1.456

Seema, P. V. (2024). Developing scientific literacy to promote 21st-century skills. *I-Manager's Journal on School Educational Technology*, *19*(1), 1–8. https://doi.org/10.1234/jset.v19i1.789

Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chemistry Education Research and Practice*, *7*(4), 203–225. https://doi.org/10.1039/B6RP90011A

Tammaro, R., & Gragnaniello, D. (2024). Sustainable assessment as a device to prepare learners for the future. *Form@re - Open Journal per La Formazione in Rete*, *24*(1), 271–279. https://doi.org/10.36253/form-15624

Wardani, L. K., Mulyani, B., Ariani, S. R. D., Yamtinah, S., Masykuri, M., Ulfa, M., & Shidiq, A. S. (2023). Effect of an ethnochemistry-based culturally responsive teaching approach to improve cognitive learning outcomes on green chemistry material in high school. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 112–120. https://doi.org/10.29303/jppipa.v9i1.1234

Yamtinah, S., Ramadhani, D. G., Wiyarsi, A., Widarti, H. R., & Shidiq, A. S. (2024). Leveraging generative AI for automatic scoring in chemistry education: A web-based approach to assessing conceptual understanding of colligative properties. *Proceedings of the International Conference on Computers in Education*, *2024*, 4983. https://doi.org/10.58459/icce.2024.4983