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Development of Problem-Based E-Student Worksheets Integrated with Ethno-STEM on Global Warming Material to Enhance Chemical Literacy

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Abstract

This study aimed to develop a Problem-Based Learning (PBL) electronic Student Worksheet (e-LKPD) integrated with Ethno-STEM, focusing on global warming in the context of mangrove forests and water hyacinth plants, to enhance students' chemical literacy. The research subjects consisted of 36 students from class X A (experimental group) and 36 students from class X J (control group) at MAN 2 Semarang. The study employed a Research and Development (R&D) design following the 4D procedural model by Thiagarajan (1974), modified into three stages: Define, Design, and Development, as the Dissemination stage was not conducted. Data were collected through questionnaires, interviews, validation by content and media experts, and chemistry literacy tests. Quantitative analysis was performed using pretest-posttest comparisons and normalized gain (N-gain) calculations. The results indicate that the e-LKPD achieved high validity in both material and media aspects. Small-scale trials showed that the e-LKPD was highly engaging for students, while the N-gain test in the experimental class reached 0.8492, categorized as high. These findings suggest that the Ethno-STEM-integrated PBL e-LKPD is highly suitable as instructional material. It effectively improves chemical literacy by integrating knowledge, context, competence, and attitude, while also providing an interactive and culturally contextualized learning experience. This study demonstrates the potential of culturally integrated STEM-based teaching materials to enhance conceptual understanding, critical thinking, and student engagement in chemistry education.

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INTRODUCTION

Based on the results of the 2022 Program for International Student Assessment (PISA), it was found that Indonesia's science literacy has improved compared to the 2018 PISA results. Previously, Indonesia ranked last, 71st out of 77 countries, whereas in 2022, it rose to 67th out of 81 countries (Kemendikbudristek, 2023). In the era of globalization, equipping students with essential skills and competencies has become a fundamental responsibility of educators to prepare them to face contemporary problems and challenges. Education plays a crucial role in preparing high-quality human resources capable of competing in a rapidly changing world. Stehle and Peters-Burton (2019) identified that 21st-century learning and innovation skills include problem-solving and critical thinking, communication and collaboration, as well as creativity and innovation. Among these categories, science literacy (particularly chemistry literacy) is a key component. Chemistry literacy enables students to enhance their understanding of health, environmental issues, and contemporary challenges in an era dominated by advances in science and technology (Sari et al., 2022). Essential elements of chemistry literacy include scientific concepts, scientific processes, scientific attitudes, and scientific content knowledge (Devi, 2023).

In the context of globalization, chemistry education emphasizes 21st-century skills, including the development of chemistry literacy. This aims to enable students to think critically, solve real-life problems, and effectively navigate modern society (Viendrieana et al., 2021). However, students often demonstrate low interest in learning chemistry due to factors such as the method of material delivery, the teaching process employed by educators, the quality of information received, and overall learning outcomes (Mardatilla et al., 2023). Innovations in learning that incorporate local culture can enhance students' ability to apply scientific knowledge in daily life, thereby improving science literacy skills (Sudarmin, 2014). One such innovation is the integration of ethno-STEM (Science, Technology, Engineering, and Mathematics), which develops STEM-based learning rooted in local wisdom or ethnoscience. Ethno-STEM reconstructs local cultural knowledge into scientific knowledge encompassing basic science, technology, engineering, and mathematical computations (Reffiane et al., 2021). Ethnoscience refers to the body of knowledge held by a community or ethnic group, acquired using specific methods and procedures (Sudarmin, 2014). Learning through ethnoscience encourages students to explore and recognize the scientific potential within local culture, thereby strengthening their understanding of scientific concepts (Sumarni, 2018).

Ethno-STEM-based learning fosters students' cognitive abilities and critical thinking while promoting active participation in the learning process, which in turn enhances interest in science literacy (Zakiyah & Sudarmin, 2022). One effective instructional model for developing literacy and critical thinking skills is Problem-Based Learning (PBL), which presents students with problems or phenomena that generate questions and encourage group discussion to find solutions (Dewi, 2022; Haryani et al., 2017). The Merdeka Curriculum aims to cultivate 21st-century human resources equipped with critical thinking, creative thinking, communication, and collaboration skills (Nurhayati et al., 2021). A practical learning resource compatible with this curriculum is the electronic Student Worksheet (e-LKPD), which leverages technological developments to facilitate intensive learning through videos, images, virtual labs, animations, and other interactive features (Sonia, 2022). Ethno-STEM-based e-LKPDs can enhance students' critical thinking, dynamic reasoning, and conceptual understanding of science (Qomaria & Wulandari, 2022). Therefore, the development of e-LKPD integrated with Ethno-STEM and Problem-Based Learning is expected to improve chemistry literacy, broaden students' knowledge, foster critical thinking, and empower them to solve problems in learning, ultimately enhancing academic achievement.

METHODS

This study employed a research and development (R&D) method aimed at producing an Ethno-STEM-integrated electronic Student Worksheet (e-LKPD) and evaluating the effectiveness of the resulting product (Sugiyono, 2013). The development produced an Ethno-STEM-based e-LKPD on Global Warming for use in learning at MAN 2 Kota Semarang. The development model applied in this study was the 4-D model, which, according to Thiagarajan (1974), consists of four stages: Define, Design, Development, and Disseminate. The instruments used to assess students' chemistry literacy skills included a multiple-choice test based on three aspects of the chemistry literacy domain—knowledge, context, and competence—as well as a chemistry literacy response questionnaire based on the attitude domain (Viendrieana et al., 2021). Validation of the instructional material was conducted to assess the feasibility of the product, based on expert evaluation by lecturers and chemistry teachers. The validation process covered content, presentation, Problem-Based Learning (PBL) implementation, Ethno-STEM integration, and language quality. Following validation and subsequent revisions, a small-scale trial was conducted to identify potential shortcomings, weaknesses, obstacles, and challenges that may arise during the learning process. The next stage involved a large-scale trial to evaluate the effectiveness and practicality of the instructional material. The developed teaching material was in the form of an e-module and delivered through the web-based platform liveworksheets.com. The improvement in students' chemistry literacy following the implementation of the e-LKPD was evaluated using the N-gain test, based on pretest and posttest data.

RESULT AND DISCUSSION

This study was conducted with the aim of developing a Problem-Based Learning (PBL) e-Student Worksheet (e-LKPD) integrated with Ethno-STEM on the topic of global warming, specifically related to mangrove forests and water hyacinth plants, to enhance students' chemistry literacy. The research participants consisted of 36 students from class X A (experimental group) and 36 students from class X J (control group) at MAN 2 Kota Semarang. The research employed a Research and Development (R&D) method following the procedural 4-D model first introduced by Thiagarajan in 1974.

During the initial observation stage, unstructured interviews were conducted to gather teachers' perspectives on the developed LKPD. Questions addressed topics such as teaching materials, curriculum, learning activities related to local culture, assignments, potential obstacles, students' chemistry literacy, and other relevant information. The unstructured interview method was chosen to allow flexibility in addressing issues that emerged during the interview process (Sugiyono, 2015). Two chemistry teachers from MAN 2 Kota Semarang served as informants for these interviews.

In addition, interviews were conducted with members of the local community regarding the preservation of mangrove forests and water hyacinth plants. The results of these interviews were reconstructed into scientific knowledge using a STEM-based approach, as presented in Table 1.

Table 1. Ethno-STEM Mapping: Indigenous Knowledge and Scientific Reconstruction on Global Warming

STEM Domain	Indigenous Knowledge	Scientific Reconstruction
Science	Areas around mangrove forests have cool or moderate temperatures.	Mangroves have the ability to absorb carbon dioxide and convert it into organic carbon stored in their roots, stems, leaves, and other parts. Estimating the carbon absorption potential of mangrove vegetation is an important indicator in mangrove ecosystem conservation efforts to mitigate global warming (Ketaren, 2023).
	Swamps or rivers with water hyacinth do not get hot during the day.	Water hyacinth plants are capable of absorbing carbon dioxide (CO_2) and methane (CH_4) from the air during photosynthesis. This absorption process helps reduce greenhouse gas concentrations in the atmosphere, which contribute to global warming (Karno et al., 2020).
Technology	Tools used for mangrove reforestation include mangrove seedlings, bamboo, large pipe segments, measuring rulers, ropes, and supports.	Bamboo is used as a support for mangrove seedlings to keep them upright and prevent them from being carried away by currents or waves. Holes in pipes can help increase oxygen levels in the soil, which is crucial for root growth. Rulers are important for measuring the growth of mangrove seedlings over time, especially in scientific research and monitoring projects to assess their success (Fitria & Dwiyanoto, 2021).
	Water hyacinth waste can be made into handicrafts such as bags.	Water hyacinth waste can be used as an alternative energy source, such as biogas, reducing reliance on fossil fuels. This helps lower Earth's temperature and prevents climate change, playing an important role in mitigating global warming (Luthfiyah et al., 2022).
Engineering	Dig planting holes with 50–100 cm spacing and insert supports as markers.	Adequate spacing allows each mangrove plant to receive sufficient sunlight for photosynthesis, enhancing their ability to absorb carbon dioxide from the air (Irsadi et al., 2022).
	Water hyacinth can be used as animal feed.	Excessive water hyacinth growth can negatively impact the environment by blocking sunlight from entering the water, reducing oxygen content, and disturbing aquatic ecosystems (Suhartono et al., 2023).
Mathematics	The mangrove forest area in Semarang city spans tens to hundreds of hectares.	The size of the mangrove area determines the amount of carbon dioxide absorption. In North Semarang, CO_2 absorption is 1,463.22 tons/ha in standing trees, 2,789.996 tons/ha in sediments, and 30.02 tons/ha/day in litter (Yaqin et al., 2022).
	The water hyacinth area in Semarang city spans approximately tens of hectares.	Water hyacinth can absorb around 1.8 to 3.2 kg of CO_2 per square meter per year. These data indicate that water hyacinth is an efficient plant for CO_2 absorption in aquatic environments (Karno et al., 2020).

The quality of the e-Student Worksheet (e-LKPD) can be assessed based on the evaluation criteria established by the National Education Standards Agency (BSNP) in 2017. The product evaluation was conducted

by expert validators, consisting of two university lecturers and one chemistry teacher. The assessment of e-LKPD quality was divided into two aspects: material quality and media quality. The material quality evaluation focused on content feasibility, presentation, Problem-Based Learning (PBL) implementation, Ethno-STEM integration, and language use.

The results of the material quality evaluation by the validators showed an average score of 85.3%, indicating that the product is highly feasible. This score was achieved because the e-LKPD met the required material assessment criteria. According to W. Safitri et al. (2022), an e-LKPD is considered valid if it satisfies the requirements for content, presentation, language, and alignment with PBL principles. The e-LKPD's applicability indicates that its format and structure have been properly implemented. However, some feedback from the validators included spelling errors, the need to expand the content on global warming processes, and the necessity to emphasize the "STEM" components. The e-LKPD was subsequently revised based on the validators' suggestions. In line with previous research by Fikrina et al. (2023), which reported a material feasibility score of 70.7%, the findings indicate that the content of the e-LKPD is highly suitable for use in teaching global warming topics. A detailed breakdown of the material quality evaluation questions is presented in Figure 1.

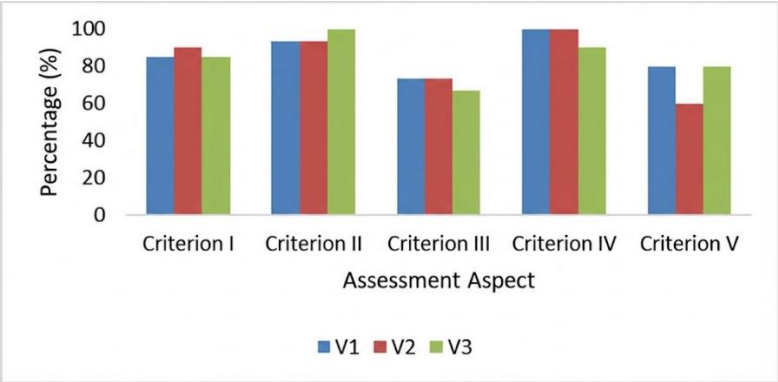


Figure 1. Expert Validation of e-LKPD Material Quality

The results of the media feasibility assessment of the e-Student Worksheet (e-LKPD) by the validators showed an average total score of 93.3%, indicating a "highly feasible" rating. The e-LKPD was considered feasible because it met the media quality criteria, including the quality of layout and images. However, the validators provided some suggestions, such as improving the layout of the cover images to make it neater and more visually appealing, as well as enhancing the use of images, videos, and animations to better clarify the global warming concepts. The e-LKPD was subsequently revised based on the validators' feedback. According to Palupi and Pujianto (2021), the feasibility of e-LKPD media can be assessed based on the quality of its visual appearance and images. These results indicate that the media content of the developed e-LKPD is highly suitable for use in teaching global warming topics. A detailed breakdown of the media feasibility validation questions is presented in Figure 2.

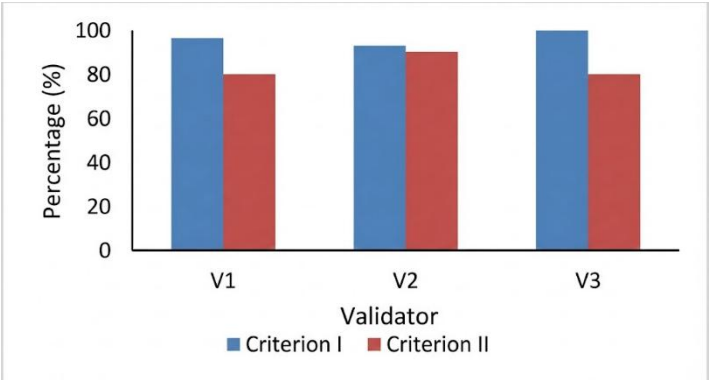
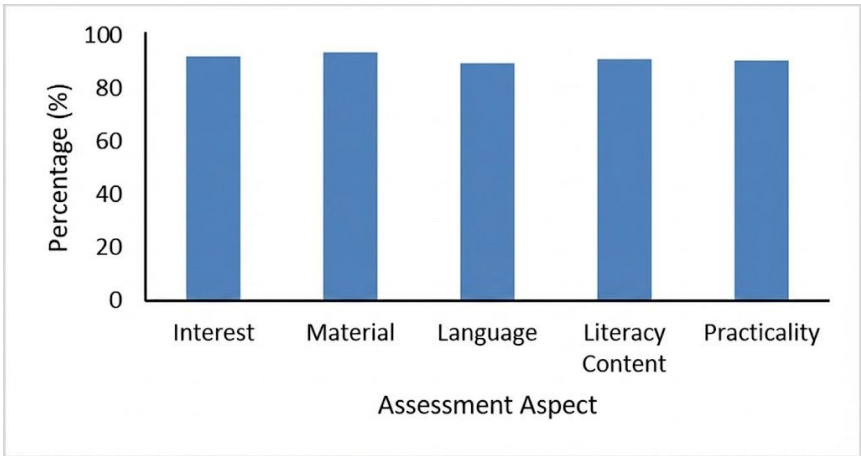


Figure 2. Expert Validation of e-LKPD Media Quality

The results of the evaluation by both content and media experts indicate that the e-Student Worksheet (e-LKPD) is highly suitable for use in learning, with an average material feasibility score of 85.3% and a media feasibility score of 93.3%. These findings are consistent with the e-LKPD feasibility study conducted by Fikrina et al. (2023), which reported an average score of 96.9%, categorizing the product as highly appropriate for use (see Figure 3). The student response questionnaire yielded an average score of 91.67%, indicating that the e-LKPD is highly engaging. This rating reflects the evaluation aspects, including interest, content, language, literacy integration, and practicality (Pancawardhani, 2022). Positive feedback from students included statements such as, "This e-LKPD encourages me to read more diligently." Moreover, the e-LKPD is easily accessible anytime and anywhere across various smartphones, laptops, and PCs via the liveworksheet.com platform, without requiring high-specification devices. These results align with the study by Wulan Junita (2022), which reported an average student response of 94% for the development of an ethnoscience-based e-LKPD.



.**Figure 3.** Student Response to e-LKPD on Global Warming.

The effectiveness of using the e-Student Worksheet (e-LKPD) can be assessed through the normalized gain (N-gain) and paired-sample t-test. Pretest and posttest data from the large-scale trial participants were used to calculate the normalized gain and conduct the paired-sample t-test. The results of the N-gain analysis are presented in Table 2.

Table 2. Normalized Gain (N-Gain) Results

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	25	.00	1.00	.8545	.24748
Valid N (listwise)	25				

Based on Table 2, the normalized gain (N-gain) obtained showed an average value of 0.8545, which falls into the high category. This indicates that the e-Student Worksheet (e-LKPD) effectively addressed several aspects of literacy, including knowledge, content, competence, and attitude (C. A. Dewi et al., 2022). These results were achieved because the chemistry literacy test items covered three literacy aspects—knowledge, context, and competence—yielding a percentage score of 83%, while the attitude aspect scored 81%. This finding aligns with Safitri (2021), who stated that an e-LKPD is considered effective for learning if the classically averaged mastery learning score is ≥ 80%.

CONCLUSION

This study concludes that the Problem-Based Learning (PBL) e-Student Worksheet (e-LKPD) integrated with Ethno-STEM, focusing on mangrove trees and water hyacinth within the global warming topic, is highly feasible, valid, and effective for chemistry learning. The developed e-LKPD can be accessed online through the liveworksheet platform, providing students with a user-friendly, engaging, and interactive learning experience. Its design is visually appealing and structured to maintain students' interest and motivation throughout the learning process. The e-LKPD has been validated by content and media experts, demonstrating high material quality (85.3%) and media quality (93.3%), while students' responses indicated high engagement and interest

(average score of 91.67%). Moreover, the effectiveness of the e-LKPD was confirmed through pretest and posttest assessments, with normalized gain (N-gain) scores averaging 0.8545, falling into the high category. These results indicate that the e-LKPD successfully enhances students' chemistry literacy across four key aspects: knowledge, context, competence, and attitude. Overall, this study highlights that integrating local cultural knowledge into STEM-based, problem-centered learning materials not only enriches students' conceptual understanding of chemistry but also promotes critical thinking, practical problem-solving skills, and positive learning attitudes. The findings suggest that such e-LKPDs have significant potential to support modern, technology-driven education and can be effectively applied in broader educational contexts to improve science literacy.

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