



Ethno-STEM-Based E-Book on Colligative Properties of Solutions to Improve Students' Chemical Literacy and Sustainability Awareness

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Abstract: This project aims to develop and test Ethno-STEM-based e-books to enhance students' chemical literacy and sustainability awareness regarding the colligative properties of solutions. The e-book's development integrates coordination science with local knowledge, enabling students to understand chemical concepts in a relevant and applicable manner. The research strategy employed is R&D using the ADDIE model. The e-book was approved by media and content specialists and tested on students to assess its effectiveness in improving chemical education and sustainability awareness. The level of feasibility based on media expert judgment is 89% in the "Valid" category, and media experts are 95% in the "Valid" category. Also, the CVR value is 0.86 and the CVI is 0.93, both of which are in the valid range. E-Books improve students' chemical literacy and sustainability awareness, with N-Gain indices of 0.745 in the "high" category and 0.541 in the "moderate" category—long-term impacts and applications to other disciplines are to be studied to support ESD programs.

Keywords: chemical literacy; colligative properties of solutions; ethno-STEM; sustainability awareness

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INTRODUCTION

The learning process is part of the education system that has undergone significant changes due to the industrial revolution. 21st-century learning requires complex stimuli. This is influenced by the high demands for competencies that students must have. This complexity consists of affective, cognitive, and psychomotor competencies (Akimov et al., 2023; González-Pérez & Ramírez-Montoya, 2022; Supena et al., 2021). Student-centered learning and the demand for meaningful learning through performance are evidence of changes in the learning system in the 21st century (Handa & Talisayon, 2023; Mardhiyah et al., 2021). The complexity of competency demands in the 21st century can be addressed through context-based learning. This learning is a strategy to increase interest and motivation and to train thinking. This is because the scientific concepts presented are derived from experiences or daily life activities recognized by students (Prins et al., 2018; Pursitasari et al., 2019). Context-based learning in natural science subjects provides a picture of real problems, and students are required to propose ideas for overcoming them.

Science is divided into three main areas: chemistry, physics, and biology. Chemistry is considered one of the most difficult subjects because it is influenced by several factors, namely the scientific language, which is relatively complex and difficult to understand, and the complexity of studying chemistry itself (Childs & Sheehan, 2009; Woldeamanuel et al., 2014). These obstacles are the initial factors in realizing 4C-oriented learning (Critical Thinking, Creative Thinking, Communication, and Collaboration). Project-based learning is among the anticipated strategies for overcoming these obstacles (Rati et al., 2023). Project-based learning will provide more complex outcomes when combined with STEM. STEM-based learning is believed to build 21st-century skills and prepare future generations to face globalization (Permanasari et al., 2021). The interdisciplinarity of STEM is an attractive approach for providing complex cognitive and psychomotor skills to students. Local wisdom, as part of tradition, is rooted in community culture (Ridjal, 2019). Culture-based learning can be used as an alternative to controlling the pace of time, so that students can understand the local wisdom of their environment and grasp the scientific concepts contained therein (Botero, 2015). Ethno-based learning, referred to as local wisdom by Khotimah et al. (2022) and Sudarmin et al. (2018), can improve learning outcomes and foster affective improvements for students and provide challenges for them to explore scientific facts from phenomena in the local wisdom they have.

Learning that links culture and science is known as ethnosience-based learning (Sudarmin, 2016). Meanwhile, the combination of ethnosience and STEM is known as Ethno-STEM (Sudarmin et al., 2018). The implementation of Ethno-STEM in chemistry learning can train critical thinking (Izzania et al., 2024) and increase

innovation and creativity (Sudarmin et al., 2020). Learning supported by Ethno-STEM-based teaching materials can also develop 21st-century skills (Zakiyah & Sudarmin, 2022). Another skill required in the 21st century is scientific literacy (Anggraeni et al., 2022), with students' ability to interpret problems and apply scientific concepts to solve them. PISA reported that scientific literacy was still quite low, with a score of 383. Literacy in science learning, one of which is chemical literacy (Alvina et al., 2024; Yulianti et al., 2019). In its function, chemical literacy is very important in preparing students to be skilled at solving problems and to enhance competitiveness (Annisa & Laksono, 2021; Kohen et al., 2020). The low scientific literacy score proves that literacy in the context of chemistry is also low. Thus, project-based learning, supported by Ethno-STEM, is the best solution for providing stimulus to increase interest and motivation in learning chemistry. However, teachers rarely use Ethno-STEM-based e-books in their teaching.

Good chemical literacy will support sustainability awareness, the fourth goal of the SDGs, which focuses on education for sustainable development (ESD). Sustainability awareness aims to protect and respect the surrounding environment by prioritizing impacts on social, economic, and environmental aspects (Ridwan et al., 2021; Rini & Nuroso, 2022). Another opinion holds that sustainability awareness is a conscious effort to protect the environment and local wisdom (Hanushek & Woessmann, 2012; Zidny & Eilks, 2022). Therefore, chemical literacy and sustainability awareness need to be incorporated into chemistry education to prepare students to face the era of modernization. Concerns about the development of the times will shift local culture and alter the natural environment due to increasing human needs. Therefore, in 2017, Education for Sustainable Development established an instrument to emphasize the role of education in supporting sustainable development. Sustainable development-based learning has a positive effect on a small category and a negative effect on lower-class education (Olsson et al., 2016). Students' thinking skills influence how they process data and interpret the problem to be solved. A preliminary study of students' sustainability awareness, focusing on maintaining local wisdom. The conclusion is that many students are not skilled at processing regional specialties such as salted fish, brown sugar, mandai, and pickles.

Students' chemical literacy was found to be lacking in terms of content, context, and competence (Harianto et al., 2025). The factors causing this include students' limited ability to interpret the material taught in terms of content, lack of knowledge or understanding of the material's implications for real life, and limited demands for performance-based learning in terms of competence. This finding is one of the bases for improving the learning process by using teaching materials to enhance chemical literacy and sustainability awareness. Ethno-STEM-based books can enhance students' chemical literacy by providing meaning to problems, thereby increasing students' interest and motivation to learn (Rosyada et al., 2025). STEM-based teaching materials with an ethno-science approach can foster creativity and improve critical thinking skills (Nurhayati et al., 2021). By integrating local culture into learning materials on colligative properties of solutions, namely local food processing from Seruyan Regency, Central Kalimantan Province, it is hoped that this will improve chemical literacy and student sustainability awareness. The research problem is to develop and test the feasibility of an Ethno-STEM-based e-book on the colligative properties of solutions to improve students' chemical literacy and sustainability awareness. This research aims to produce and test the feasibility of an Ethno-STEM-based e-book on colligative properties of solutions to improve students' chemical literacy and sustainability awareness.

METHODS

This study employs the ADDIE (Branch, 2009). model in a research and development design to create an ETNO-STEM-based e-book on colligative properties, aimed at enhancing chemical literacy and sustainability awareness. Product implementation uses a one-group pre-test and post-test design due to the research location having only one project class. This design involves experimental research without assessing the group's stability and clarity before treatment. It uses a one-group pretest-posttest design, with measurements taken before and after treatment. This study included chemistry teachers, high school students, and academic experts in Seruyan Regency, with 19 12th-grade students selected through purposive sampling. Participants provided valuable feedback during product testing, and various instruments were used to collect comprehensive data. The e-book's suitability was tested for content validity using the CVI and CVR methods. This test involved 20 chemistry teachers as expert validators to assess the suitability of the developed e-book's content.

After the ADDIE stage is completed, an analysis is carried out to determine its effectiveness in improving students' chemical literacy and sustainability awareness. Chemical literacy and sustainability awareness are known using validated instruments. The chemical literacy indicator was modified from the research of Kohen et al. (2020), while the sustainability awareness indicator is from the research of Sari et al. (2024). The increase in chemical literacy is known by comparing the N-Gain score from the students' pre-test and post-test scores. Students' chemical literacy is analyzed for each aspect, and the average for each is categorized by its N-Gain score. The average N-Gain score is then reduced and categorized according to Table 1. Students' sustainability awareness is measured through a Likert-scale questionnaire. A score of 4 is categorized as strongly agree, a score of 3 is categorized as agree, a score of 2 is categorized as disagree, and a score of 1 is categorized as strongly disagree. The data obtained were then reduced and categorized according to Table 1.

Table 1. Criteria for Improving Students' Chemical Literacy
Level of Student Sustainability Awareness

N-Gain Score	Criteria	Score	Category
$g \geq 0,7$	High	1,00 – 2,33	Low Awareness
$0,7 > g > 0,3$	Medium	2,34 – 3,66	Medium Awareness
$g \leq 0,3$	Low	3,67 – 5,00	High Awareness

(Hake, 1999)

(Hassan et al., 2010).

RESULT AND DISCUSSION

At this stage, the researcher conducted a problem analysis of the needs for developing chemistry teaching materials at stage F (12th grade). Based on student interviews, 46.67% of students liked e-books, 25.0% liked student worksheets, 16.67% liked handbooks, and the rest liked e-modules (11.66%). Analysis of learning resources used in chemistry learning shows that most students used the internet (60.0%), printed books (23.3%), and e-books (16.7%). The results of observations in chemistry learning show: 1) some students are still not focused on the teaching materials, because the teacher does not provide reference books/guides; 2) when learning using the internet; 3) students tend to be passive; 4) students are not actively involved in learning and tend to chat; and 5) Teachers are still the main source of learning. Media analysis is also conducted to determine the type of media to be developed and how to deliver it to students. In developing this teaching material, researchers use e-books compatible with Android- and iOS-based smartphones. Teaching materials in the form of e-books are equipped with images, text, sound, chemical literacy-based practice questions, Ethno-STEM projects, and complementary videos. The e-book will then be converted into a flipbook to increase students' interest and motivation in studying chemistry.

At this stage, a design is developed in line with the panelists' (teachers and students) needs and recommendations. The characteristics that are typical of the e-book developed in this study are: 1) conceptual approach with local Seruyan culture; 2) Ethno-STEM-based projects; 3) examples of questions and evaluation questions based on culture; 4) there is a diagnosis of sustainability awareness for readers. The e-book developed consists of four chapters: 1) the potential of ethnochemistry in learning chemistry; 2) the potential of the STEM approach in learning chemistry; 3) Learning chemistry based on Ethno-STEM; 4) Colligative properties of solutions based on Ethno-STEM. The Ethno-STEM-based e-book on colligative properties of solutions was validated by four experts: 2 media and 2 material validators. Assessment results from material experts and media experts are in Table 2.

Table 2. Validation from Material and Media Experts

Expert	Score	Percentage	Criteria
Material Expert 1	44	89%	Valid
Material Expert 2	45		
Media Expert 1	46		
Media Expert 2	48	95%	Valid
Media Expert 3	48		

The feasibility of the developed teaching materials was validated with chemistry teachers. This validation was carried out by 20 teachers, who provided assessments of the Ethno-STEM-based e-book teaching materials on the validation sheet. The assessment was to determine the (CVR) and (CVI). The teacher's validation results are presented in Table 3.

Table 3. E-Book Validation by Teachers

Aspect	Index CVR	Index CVI	Criteria
Content suitability	1,00	1,00	Valid
Language eligibility	0,70	0,85	Valid
Feasibility of Ethno-STEM learning strategies	0,80	0,90	Valid
Feasibility of component completeness	1,00	1,00	Valid
Display eligibility	0,80	0,90	Valid
Mean	0,86	0,93	Valid

This limited trial was conducted on 15 grade 12 students from another high schools/F phase. The sample selection in this limited trial was carried out randomly by the science teacher (Chemistry) at the school, with the condition that it was collected from students who were categorized as high, medium, and low. At this limited trial stage, it began by introducing the E-Book on Colligative Properties of Solutions Based on Ethno-STEM to students before being used in chemistry learning. Furthermore, a general description of the use of the teaching materials was provided. The activity continued by allowing students to study and read the teaching materials

distributed to each student's cellphone via a link or barcode. After that, students studied the provided teaching materials and then responded to the student response questionnaire for the E-Book on colligative properties of solutions based on Ethno-STEM.

This stage involved a trial at SMA Negeri 1 Danau Seluluk with 19 students, spanning 6 meetings of 2 x 45 minutes each. Researchers utilized this stage to assess students' chemical literacy and sustainability awareness. This is the final phase of the ADDIE model for research and development. During the evaluation stage, student responses to the use of E-Books in learning were analyzed. Data was collected through questionnaires distributed to 19 students who used the E-Book on colligative properties of solutions based on Ethno-STEM. Table 4 shows the results of the student response recapitulation.

Table 4. Recapitulation of student response

Aspect	Total score	Percentage	Criteria
Material Aspect	90	94,7%	Very valid
Display Aspect	92	96,8%	Very valid
Learning Objectives Aspects	94	98,9%	Very valid
Mean		96,8%	Very valid

Based on the analysis results in Table 5, the teaching materials needed by students and teachers are in the form of e-books (electronic books). Pursitasari et al. (2019) stated that textbooks are teaching and learning resources that have been the main source for teachers and students in obtaining information. Educational institutions have provided innovation in these learning resources in the form of electronic books or BSE (Electronic School Books). However, Putra et al. (2022) noted that BSE digitizes printed books only into PDF format, with the presentation of learning content limited to written/text elements and images. This study developed electronic books on the colligative properties of solutions using Ethno-STEM, a recent research approach in Indonesia (Primadianningsih & Sumarni, 2023). Ethno-STEM helps students learn through contextual problems, focusing on local product processing in Seruyan Regency. Table 5 presents ethno-STEM content on colligative properties of solutions.

Table 5. Correlation of Ethno-STEM Content with Colligative Properties of Solutions

Ethno-STEM Studies	Colligative Properties of Solutions
Making Brown Sugar	Boiling Point Elevation
Making Candied Rattan Fruit	Vapor Pressure Drop
Fertilizing Oil Palm with Urea	Freezing Point Depression
Making Salted Fish	Osmotic Pressure

Harianto et al. (2025) recommend developing teaching materials in the form of books that combine ethnos (culture) and STEM to provide innovative learning tools and train students to think critically, creatively, communicate, and collaborate in line with the demands of the 21st-century industrial revolution. This statement is supported by Sumarni and Kadarwati (2020), who found that Ethno-STEM, based on project-based learning, can improve students' critical and creative thinking skills. Sudarmin et al. (2019) added that project-based learning integrated with Ethno-STEM can develop students' entrepreneurial character. Based on this statement, the development of an e-book on the colligative properties of solutions using Ethno-STEM is expected to foster 21st-century capabilities and enhance students' entrepreneurial character. The development of this e-book was carried out to improve students' chemical literacy and sustainability awareness. This e-book has the following characteristics: 1) material is connected to ethnos (cultural) content; 2) examples of questions and evaluation questions based on ethnos (cultural); 3) STEM Projects with ethnos (cultural) content. The ethnos (cultural) content that is the main characteristic of this e-book is to provide guidelines for students and teachers in learning using an ethnos approach or local wisdom. Harianto et al. (2025) emphasized that learning grounded in ethnochemistry cannot improve students' chemical literacy unless it is supported by appropriate learning resources.

The impact of e-books on students' progress in their chemical education and sustainability awareness was assessed by analyzing pre- and post-test results. The investigation carried out was the typicality test, theory test, and N-Gain test. The following are the outcomes of each examination. The Shapiro-Wilk normality test was used as the prerequisite test, since the sample size was less than 50. The outcomes of the normality test showed a pre-test importance esteem of 0.109, whereas the post-test had a centrality esteem of 0.869. Based on the centrality values of the pre-test and post-test, it can be concluded that the information is regularly disseminated, as the importance esteem is > 0.05 . The outcomes of this normality test can be used as a reference for selecting a parametric test, specifically the subordinate t-test (Combined t-test). Hypothesis testing was carried out using SPSS 23. The decision from this hypothesis test is that if the p-value is < 0.05 , then H_0 is rejected and H_1 is

accepted. Conversely, if the significance value > 0.05 , then H_1 is rejected and H_0 is accepted. The results of the paired-samples t-test showed that the significance value between students' pre-test and post-test scores was 0.000, indicating a sig value < 0.05 . So, it can be concluded that H_0 is rejected and H_1 is accepted. Based on this, the hypothesis test shows that there is a difference in students' average chemical literacy scores before and after using the Ethno-STEM-based e-book on colligative properties of solutions. Analysis of the increase in students' average chemical literacy score before and after using the E-book on colligative properties of solutions, based on Ethno-STEM, was further carried out using the N-Gain test for each chemical literacy indicator. The results of the N-Gain analysis on each indicator of students' chemical literacy are shown in [Table 6](#).

Table 6. Results of the N-Gain analysis of each indicator of chemical literacy

Students	Indicator	Question Number	N-Gain	Category
19 Students	Content	1, 2, 3, 4	0,715	High
	Context	5	0,792	High
	Competence	6, 7	0,739	High
	attitude of science	8, 9, 10	0,734	High
	Mean		0,745	High

Based on [Table 6](#), each indicator of chemical literacy, namely content, context, competence, and science attitude, has an average N-Gain with the "High" category. In addition, based on the average N-Gain for each indicator, it can be concluded that the use of the Ethno-STEM-based solutions e-book on colligative properties is effective in improving students' chemical literacy. Thus, this e-book is expected to serve as a learning resource for students or teachers studying the colligative properties of solutions through the Ethno-STEM approach. The increase in students' chemical literacy was analyzed using the N-Gain score derived from their pre-test and post-test scores. The score was obtained before and after students used the e-book on the colligative properties of solutions. Based on the N-Gain score, all chemical literacy indicators are categorized as high. Meanwhile, the paired t-test showed a difference in the average chemical literacy score of students before and after using the Ethno-STEM-based e-book on colligative properties of solutions. [Kohen et al. \(2020\)](#) stated that chemical literacy includes the chemical knowledge and skills needed to understand chemistry-based social science issues.

The average difference between the pre-test and post-test scores was 45.34%, with pre-test scores averaging 39.29% and post-test scores averaging 84.63%. The results of interviews with students revealed that chemistry content presented in a culturally relevant way can make it easier for students to imagine abstract concepts. This is because the problems or materials provided are contextual. This aligns with [Pursitasari et al. \(2019\)](#), who highlight that contextual learning enhances meaningfulness and positively affects student outcomes. [Heliawati et al. \(2022\)](#) noted that culturally-based learning can enhance students' scientific explanation skills. The increase in chemical literacy resulting from Ethno-STEM-based learning resources aligns with the claim that chemistry books developed using Ethno-STEM improve students' chemical literacy and numeracy skills ([Laila et al., 2022](#); [Rosyada et al., 2025](#)). Students' efforts to interpret or understand chemistry (both its concepts and its implications in everyday life) are part of chemical literacy. If students have strong chemical literacy, they will be able to meet the demands of 21st-century thinking skills, namely critical thinking, creativity, collaboration, and effective communication ([Pratomo et al., 2020](#)). The topic of colligative properties of solutions was chosen because students often encounter it in context. Colligative properties of solutions are also among the materials with a high level of difficulty, due to the complexity of the discussion ([Auliyani et al., 2018](#)).

This e-book practicum requires students to conduct community-based cultural experiments, combining STEM (Science, Technology, Engineering, and Mathematics) to enhance their insights and skills. This aims to enable students to interpret cultural behavior through STEM projects that promote chemical literacy. A contextual learning approach has a positive impact on students' chemical literacy, regardless of gender ([Cigdemoglu & Geban, 2015](#)). Chemical literacy includes an understanding of the nature, norms, and methods of chemistry ([Shwartz et al., 2005](#)). Chemists work to develop products that constitute scientific knowledge by understanding chemical theories, concepts, and models. This subject covers widely applicable theories, including the relationship between chemistry and technology. Chemistry aims to explain nature, while chemical technology focuses on its transformation. The concepts and models of both fields are closely related and influence each other. Sustainability awareness is the awareness of the environment around students, or the awareness to protect and appreciate the environment and life around them. Sustainability awareness must be built early, as it is a key component supporting sustainable development. The questionnaire in this study consisted of three sections: Sustainability Practice Awareness, Behavioral and Attitude Awareness, and Emotional Awareness. The results of the pre- and post-sustainability awareness questionnaires of students were also calculated using N-Gain. The N-Gain values for each sustainability awareness category are shown in [Table 7](#).

Table 7. N-Gain Score per Sustainability Awareness Indicator

Indicator	Average Pre-Questionnaire	Average post-questionnaire	N-Gain	Category
Sustainability Practice Awareness	24,105	29,474	0,473	Currently
Behavioral and Attitude Awareness,	20,895	27,053	0,660	Currently
Emotional Awareness	25,368	30,158	0,491	Currently
Average N-Gain	23,456	28,895	0,541	Currently

Sustainability awareness is continuous awareness of the environment around students, or the awareness to protect and appreciate the environment and life around them. Sustainability awareness should be built early because it is a very important component in supporting sustainable development. Then, with active learning, students will learn more effectively and consistently when learning a concept related to real life. In active learning, the teacher serves only as a guide and prepares the learning environment, while students actively participate cognitively, emotionally, socially, and physically (Clarisa et al., 2020). Sustainability awareness refers to the main objective of Education for Sustainable Development (ESD). In line with the objectives of Education for Sustainable Development (ESD), an instrument is needed to measure students' sustainability awareness profile. The instrument developed is based on Kurnia et al. (2020). The sustainability awareness profile studied comprises 3 sub-dimensions: economy, society, and environment. Then these sub-dimensions are correlated with the sustainability dimensions of environmental, social, and economic.

The questionnaire in this study was developed from research conducted by Hassan et al. (2010), namely Sustainability Practice Awareness, Behavioral and Attitudinal Awareness, and Emotional Awareness. In contrast, the questionnaire used in this study was developed from that of Atmaca et al. (2019). In addition, across the three categories of sustainability awareness, students only have awareness of sustainability values at the emotional level, without practicing them in their daily lives, as indicated by the highest value in the sustainability practice awareness category: never doing so. The low level in the practice category has not supported sustainability education as a whole (Hassan et al., 2010). Based on findings in the field, the percentage of students who have awareness of education for sustainable development (ESD Awareness) is 63.3%, with the interpretation that it is rarely done. This finding is also in line with Hassan et al. (2010), who stated that students' sustainability awareness is at a moderate level, indicating that students practice sustainable behavior only occasionally. The findings of this study are in contrast to the research conducted by Sari et al. (2024), which stated that sustainability awareness in the category of awareness of sustainability practices showed the highest results compared to behavioral and emotional awareness. This occurs due to limitations of this study or differences in learning content. In addition, the research subjects differ: junior high and high school students. This can yield different responses, affecting differences in research results. The product's effectiveness will be evaluated based on feedback from 19 student respondents who participated in the study. Student feedback on the Ethno-STEM e-book indicated that the teaching materials met their needs in terms of content, design, and learning objectives. Teaching activities require appropriate materials (Harianto et al., 2025). Using teaching materials that do not align with the method can confuse students and decrease their motivation and interest in learning. Ethno-STEM can influence chemical literacy and the demands on abilities in the 21st century (Primadianningsih & Sumarni, 2023). Heliawati et al. (2022) noted that local knowledge-based learning positively impacts students' scientific literacy. Both statements are supported by Pursitasari et al. (2019), who found that the teaching and learning process and the teaching materials used in context-based learning can improve students' critical thinking, thereby impacting student literacy. These characteristics are the hallmarks of the teaching materials, which serve as the basis for students to respond positively to Ethno-STEM-based e-books.

CONCLUSION

Teaching materials in the form of Ethno-STEM-based e-books can improve students' chemical literacy and sustainability awareness regarding the colligative properties of solutions. This study concludes that Ethno-STEM-based e-books meet the criteria for teaching materials, including content suitability, language suitability, presentation suitability, design, and appearance. Other characteristics of this teaching material are a culture-based material approach, culture-based sample questions and evaluations, and Ethno-STEM-based practicums or scientific projects. The level of suitability based on the assessment of media experts is 89% in the "Valid" category, with 95% of media experts in the "Valid" category. In addition, the CVR is 0.86 and the CVI is 0.93, both within the valid range. E-books improve students' chemical literacy and sustainability awareness, with N-Gain indices of 0.744 in the "high" category and 0.541 in the "moderate" category. Students gave very good responses to the aspects of material, appearance, independence, and understanding. Based on the research findings, recommendations include developing Ethno-STEM-based e-books for different chemistry sub-topics or other subjects. Further research is needed to examine further the implementation of Ethno-STEM-based e-books in improving student literacy and numeracy.

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