

A STEM-based e-Book for Scientific Literacy and Sustainability-oriented Learning on Human Digestive System Concepts

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Abstract

The ability to comprehend and apply scientific concepts to contemporary issues is essential for the long-term growth of society. Scientific literacy enables students to understand how their bodies digest food, what it means to eat a balanced diet, and how their food choices affect the environment. The goal of this study was to create and test a STEM-based e-Book about the human digestive system that would help eighth-grade students become more scientifically literate while also teaching them about sustainability. The study utilized a Research and Development (R&D) methodology based on the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Experts in media, learning design, materials, and language confirmed that the product was valid. They showed that the e-Book would perform well in the classroom. Thirty-eight-grade students at a private junior high school in Medan were involved in the implementation. A pretest measured how well something worked. We used pretest and post-test assessments to evaluate the effectiveness. The results showed a significant improvement in students' scientific literacy. Most of the students scored above the minimum mastery level, with an average N-Gain in the high range (0.75). Feedback from students and teachers indicated that the e-Book was helpful for both classroom and independent learning. The results suggest that integrating STEM principles and sustainability topics into digital learning resources can significantly improve scientific literacy and promote health awareness grounded in sustainability among junior high school students.

Keywords: Scientific literacy, STEM-based e-Book, Sustainability awareness, Digestive system, Junior high school students

INTRODUCTION

To be effective, every part of society must also adapt to the changes brought by the Industrial Revolution as technology continues to evolve. Technology has changed how we conduct daily tasks, moving from old-fashioned approaches to using technology to complete them (Barreiro, 2022; Xu et al., 2018). Technology has become a requirement for improving people's ability to perform their jobs better and, thereby, the quality of life. Changes in technology use, such as smartphones, social media, and the internet, have had a significant impact on how teachers teach (Shatte & Teague, 2020; Ramaila & Molwele, 2022). Today's

students can access materials and resources from all across the globe, so the manner in which teachers educate will need to adapt to the changes brought on by technology as well.

The advancement of science and technology is benefitting society but it's also hurting it (Tegegn 2024). Science advances and technological advancements improve effectiveness but also cause environmental problems, such as energy emergencies, pollution, and unsustainable resource use (Goel et al., 2024). The problems we face because of this require students to receive quality science education, which will assist students to understand concepts and be aware of sustainability issues while making responsible choices. Students need to be scientifically literate so that they can apply scientific reasoning in solving real-life issues, and use that reasoning in evaluating social and environmental issues (OECD 2019)

The ability to read, analyze, and apply science to solve problems or make informed decisions is referred to as scientific literacy (Sari et al., 2019). Students will be exposed to knowledge, processes, and attitudes associated with scientific practices useful for evaluating events and addressing issues relevant to the present (Oberbauer et al.; Susongko et al., 2021). Susongko et al. (2022) discuss three major components of scientific literacy: 1) scientific reasoning; 2) scientific inquiry; 3) understanding the nature of science. In order to successfully lead into the future, all four dimensions are vital components in preparing students to solve more complex worldwide problems. Scientific Literacy is an important area for school age children, as evidenced by average- or above average-level of PISA Science Literacy score in Indonesia on the most recent PISA. It is therefore very important for high school teachers to have strategies in their classroom practices to close the gap in scientific literacy.

One of PISA's most frequently tested topics in the domain of science is the digestive system. According to previous studies, including Gul et al. (2024), many students struggle to explain how the digestive process works or relate that process to everyday experiences. The reason for students having difficulty explaining the process of digestion and relating it to daily experiences seems to be due to a general lack of interactive (hands-on) resources for learning about biology; thus the principles of biology cannot be applied to real-world situations, so they are of no significance in those situations.

Scientific literacy is impacted by a variety of external and internal factors, including students' preparedness to succeed in STEM-related activities, their ability to conduct scientific inquiry and their ability to carry out scientific investigations; the teacher's ability to deliver STEM instruction, the degree to which STEM instructional strategies are employed; and the degree to which ICT supports STEM instruction; and the extent to which students have access

to literacy-rich STEM environments within their school/campus and/or community. To address these issues, we need to develop new ways to teach and better use the digital learning tools we already have.

E-Books are becoming increasingly popular as digital learning tools because they are easy to use and can be used in many different ways (Ningsih et al., 2022; Santoso et al., 2018). Studies indicate that interactive e-Books can enhance students' engagement and advance scientific literacy (Ozturk, 2021; Sihombing & Hasruddin, 2024a). In addition, STEM based learning strategies help learners explore, investigate, and solve problems in real life situations through hands-on experience (Fomunyam, 2020). The success of STEM education provided through different types of tools or technologies will primarily determine the overall success of STEM education (Margot & Kettler, 2019; Suherman et al., 2025). Due to flexibility across many different environments, e-Books are becoming increasingly popular as an alternative method for giving learners access to digitally available learning resources (Ningsih et al., 2022; Santoso et al., 2018). Many previous studies have shown that interactive e-Books enhance student engagement and encourage the development of scientific literacy (Ozturk, 2021; Sihombing & Hasruddin, 2024a). At the higher education level, e-Books are valued for their portability as well as their digital features; however, how students utilize e-Books will influence the degree to which they gain academic benefits from using e-Books (Casselden & Pears, 2020).

STEM-based learning methods are also well-known for helping students ask questions, solve problems in the real world, and think at a higher level (Fomunyam, 2020; Margot & Kettler, 2019). For STEM to work well, the materials used to teach must be carefully planned so that they connect science ideas to technology, engineering, and math (Bybee, 2013; Funa, 2026). Nevertheless, many STEM implementations remain classroom-centred or project-based without being embedded into interactive digital platforms that facilitate independent and sustained learning (Avci et al., 2025).

Moreover, although scientific literacy has been emphasised as a key educational outcome in the 21st century (Örnek & Alaam, 2025; Osborne & Allchin, 2024), limited research has developed interactive e-Books that explicitly align STEM integration with scientific literacy competencies such as explaining phenomena scientifically, interpreting data, and evaluating evidence-based claims within sustainability-related contexts (Bybee, 2018). Empirical evidence demonstrating measurable learning gains from such integrated digital designs also remains limited.

Unlike previous studies that focused primarily on the development phase of STEM-based teaching materials, this research emphasizes the evaluation of the effectiveness of a STEM-based e-Book in improving students' scientific literacy and integrating sustainability awareness within the human digestive system topic. Specifically, the study investigates whether the implementation of the STEM-based e-Book can produce measurable improvement in students' scientific literacy while also supporting sustainability-oriented thinking in science learning. Following the background, the research questions were formed as follows:

1. How do the design features and instructional components of the STEM-based e-Book support scientific literacy development and sustainability-related learning for students studying the human digestive system?
2. How practical is the STEM-based e-Book when implemented in classroom learning based on teacher and student responses?
3. How well do students perform in terms of their scientific literacy because of the use of the STEM-based e-Book, as indicated by their pre-test–post-test scores and learning gains?
4. How are students' awareness and experience of sustainability reflected in the STEM-based e-Book?

METHOD

Research Setting and Participants

This study was conducted at a private junior high school based in Medan, North Sumatra, Indonesia. Participants of this study included ninth-grade students and two science teachers. Participants were selected based on the relevance of the human digestive system to the eighth-grade curriculum and the need to improve students' scientific literacy.

Research Design

This investigation employed a Research and Development (R&D) methodology to create a STEM-focused e-Book. The e-Book's overall layout emphasised providing valid, usable ways to develop students' scientific literacy and to assist in their understanding of sustainability concepts. This was accomplished through the use of the ADDIE (Branch, 2009) model as the method for developing the instructional product. The ADDIE model's five steps include a methodical and systematic approach to developing instructional products as well as providing a means for continuously improving instructional products.

Development Procedure

Analysis

The analysis phase aimed to identify deficiencies of students' scientific literacy of their knowledge of the human digestive system. Teacher interviews and first impressions of the classes showed that the students had difficulty using scientific reasoning, connecting biological concepts to real-world, and sustainability-related situations such as nutrition and the environment. In addition, a needs assessment was performed to determine the feasibility of introducing digital learning tools into the curriculum.

Design

During the design phase of the STEM e-book, there were numerous opportunities for conducting systematic research to compile an appropriate list of educational objectives and then create a viable foundation for creating an educational resource. Educational objectives for developing scientific literacy which includes: (1) to explain science phenomena; (2) to define and interpret types of data; and (3) to apply scientific information to real-world issues. Examples of sustainable living examples were incorporated in the content of the e-book, which provided a base for teaching students about these types of issues. Many forms of entertaining features were added to attract students to read and use the e-book (e.g., animations, video, and links to external websites) while there was including assessments for evaluating student learning with formative quizzes and formative in-class assessments.

Development

The e-Book was created using a range of digital tools such as Microsoft PowerPoint, Canva, Flip PDF Corporate, and APK Builder. The product combined parts of Science, Technology, Engineering, and Mathematics with the topic of the digestive system. Experts in material content, learning design, media, and language checked the work. The goal of the validation process was to make sure that the content was correct, the instructions were clear, the technical quality was high, and the language was clear. Before putting the changes into practice in the classroom, they were developed based on expert feedback.

Implementation

After revision, the e-Book was implemented in classroom learning activities. The implementation stage included one-to-one, small-group, and field trials. Students used the e-Book during instruction on the human digestive system. During this phase, data were collected to measure practicality through student and teacher response questionnaires and to assess effectiveness through pretest and post-test assessments of scientific literacy.

Data Collection

Data were collected using interviews, questionnaires, and scientific literacy tests.

- Interviews were conducted during the analysis phase to identify instructional needs. Questionnaires were used for expert validation and to gather student and teacher responses regarding practicality and engagement.
- Scientific literacy tests in the form of pretests and post-tests were administered before and after the implementation of the e-Book to measure students' learning improvement.

Data Analysis

Quantitative and qualitative data analyses were conducted to determine validity, practicality, and effectiveness. Validity was analyzed descriptively based on expert evaluation scores. Practicality was determined from student and teacher response questionnaires collected during one-to-one, small-group, and field trials. Effectiveness was evaluated by comparing pretest and post-test results of students' scientific literacy. An evaluation of improvement was also conducted using normalized gain categories. When evaluating the extent of learning improvement exhibited by students in their use of the e-Book, an e-Book would be considered "effective" if a majority of students achieved scores above the minimum mastery criteria and showed significant improvement in their scientific literacy.

RESULTS AND DISCUSSION

Overview of STEM-Based e-Book and Sustainability Awareness

The STEM-based e-Book on the human digestive system was developed to address the low scientific literacy among ninth-grade students while integrating sustainability awareness into the learning process. The e-Book features interactive elements such as hyperlinks, animations, videos, quizzes, and evaluation questions that help students learn about science, technology, engineering, and math. Students can learn a lot about the digestive system while also improving their scientific reasoning, problem-solving, and critical thinking skills thanks to these features. The e-Book can be read online or offline and therefore has a wide range of uses in different learning environments. The portability, longevity, and absence of paper of the e-Book support sustainable practices, using less paper than traditional learning resources and encouraging more environmentally friendly use of learning resources (Stehle & Burton, 2019; Prasetyo et al., 2021).

Additionally, because an easy-to-read e-Book can assist individuals in acquiring 21st-century skills such as critical thinking, collaboration, communication, and creativity, students will be able to better grasp and comprehend concepts, engage in informative dialogue, and inquire at

a deeper level when the content is presented in an organized manner (Redhana, 2024; Sonia & Yuliani, 2023; Sviri & Arlinayanti, 2024).

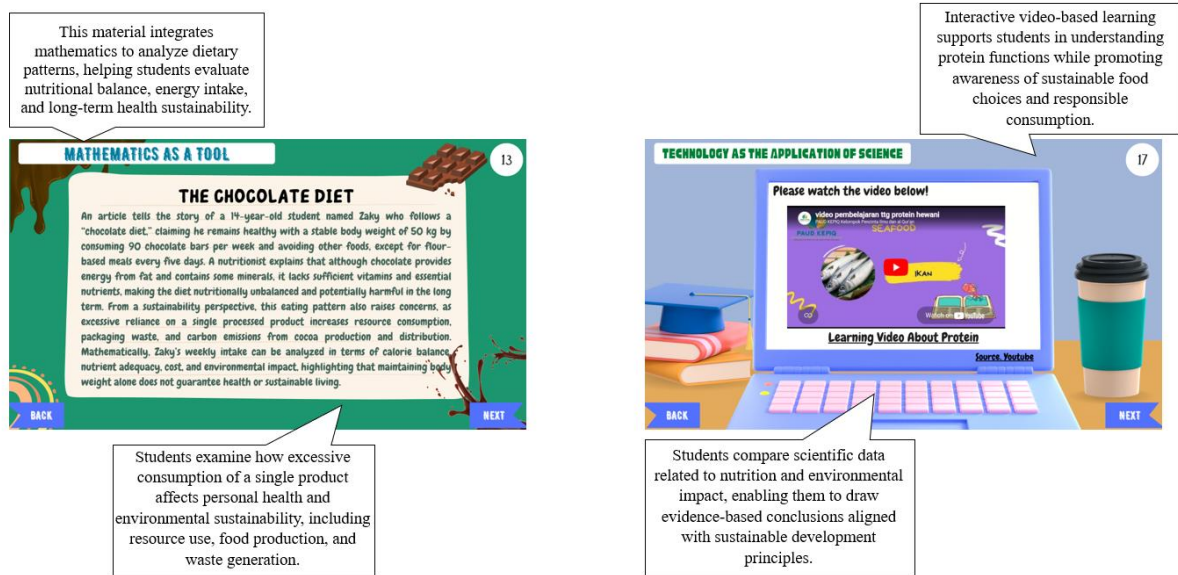


Figure 1. e-Book Features: Using Math to Look at Sustainability

As illustrated through the “Chocolate Diet” case using e-Books with a STEM-based approach, Figure 1 reflects each section that incorporates mathematics and ways to utilize them to understand real world sustainability situations. The activity encourages students to use quantitative reasoning to determine how many calories they consume, how balanced their diet is, and what the long-term effects on their health will be. Students learn to read scientific evidence, identify cause-and-effect relationships, and estimate how long consumption patterns will persist by working on this contextual problem (Meriç & Yılmaz, 2025; Rahmaniati et al., 2026). Combining math with health and environmental issues also helps raise awareness of sustainability, especially regarding responsible consumption and long-term health.

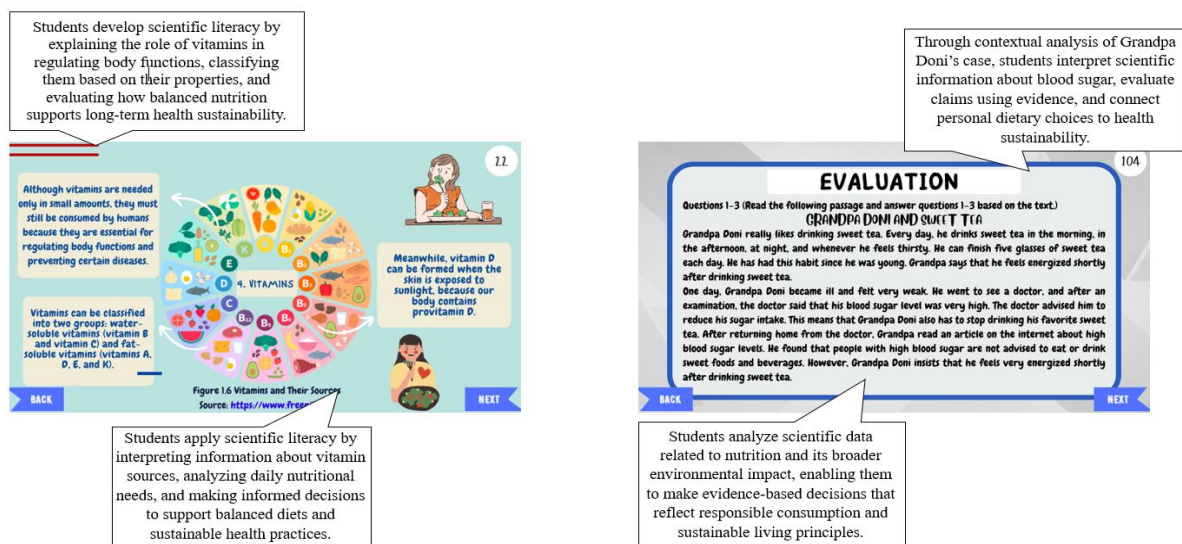


Figure 2. e-Book Features: Learning About Scientific Literacy and Sustainable Health

Figure 2 shows e-Book features that help people learn about science by discussing vitamins and examining their eating habits. Students are taught to group vitamins, discuss what they do in the body, and understand scientific information about blood sugar and nutrition. They are also encouraged to relate scientific ideas to everyday situations, such as how much food they eat each day and how it might affect their health. This contextual approach helps students understand both the theory and its application in real life (Avram et al., 2024; Schaafsma et al., 2025).

Through the evaluation component, learners will become more skilled at developing analytical skills related to evaluating evidence, challenging the validity of claims (e.g./how one might feel ‘energized’ after consuming a sugar-based food/drink), and making wise, well-researched decisions. Reflective questions and problem-based learning tasks provide learners with opportunities to understand how to interpret scientific data (and statistical analyses), use multiple sources of information, and create scientifically supported arguments using data (Eroğlu, Mesch). The e-Book was created to assist individuals in making informed decisions about their health and well-being over time and to connect academic material to broader concepts of sustainability.

Students’ Scientific Literacy Improvement

Pre- and posttests were administered to assess the extent to which an e-Book improved students’ scientific literacy. Initial pretest results showed that students did not know much about human digestion or how to reason logically about science. These findings support previous research that indicated a lack of scientific literacy among middle school aged students.

Furthermore, after employing the mathematics taught through the use of the eBooks, post-testing indicated that student scores were significantly higher in areas of scientific literacy and many students achieved scores greater than the minimum mastery proficiency level, demonstrating a strong understanding of the content.

Table 1. Results of the Pretest and Post-test for Students’ Scientific Literacy

Assessment	N	Minimum	Maximum	Mean (M)	SD
Pretest	30	55	78	67.05	4.50
Post-test	30	70	92	77.20	5.12

The results of the evaluation demonstrate that the use of an e-Book based on STEM produces a high level of not only efficacy (N-Gain Value 0.75) but also indicates a great increase in science literacy of students. Therefore, this demonstrates that the e-Book had an impact on students’ science literacy. By using the N-Gain score as a method of determining the amount of relative improvement towards maximum potential from the start of the study to

the end of the study, this reflects that students gained a substantial amount of knowledge and understanding (Azalia et al., 2020; Firdausy & Prasetyo, 2020).

The results indicated consistency with other research supporting the notion that interactive STEM resources improve student engagement, foster independent learning, and create opportunities for problem-solving skills, all of which lead to the development of science literacy (Azalia et al, 2020). Additionally, it was noted by Deehan et al., 2025) and Sarac (2018) that teaching STEM concepts within the same instructional unit promotes overall student knowledge and skill development as they support comprehension and active involvement in the teaching/learning experience.

In addition, the e-Book's focus on the application of knowledge and the ability to learn independently through interaction with materials allows for individualised learning. The ability to learn independently from others helps improve each student's ability to manage their own learning without having to rely on others for help (Qizi & Kobiljanovna, 2021). Therefore, the inclusion of STEM-related content, the different means of interaction, and the high levels of accessibility creates an authentic and empowering learning experience.

In addition, the analysis of previous data illustrates that the introduction of interactive features, real-world examples of sustainability, and the provision of digital learning materials, have all positively affected students' overall N-Gain scores.

Students' Engagement and Practicality of the e-Book

Multiple sources were used in the evaluation of the e-Book's usability and student engagement, including: individual content assessments, small group trials, large group trials, and teacher feedback. From individual assessments, students reported that the e-Book's ease of use, interactivity, and enjoyment made the experience highly positive. The technical quality of the e-Book received high marks due to the clarity of its instructions and its functionality on both computers and mobile devices. Students also found the use of the scientific method – which includes observing, inquiring, gathering information, using images, and communicating – to be a very positive aspect of the e-Book in facilitating their ability to engage in independent, active learning.

Additionally, during small-group trial sessions, students identified the visual and auditory components of the e-Book (i.e., figures, animations, videos) as clear and appealing. Teachers verified that the e-Book promoted effective classroom implementation by enabling different instructional approaches. In addition, results from field trials reaffirmed that the e-Book provided students with the option to access it online or offline, enabling them to study at

their own pace, return to the content as needed, and enhance their mastery of the statute materials and engagement in their learning activities.

Table 2 Field Trial Assessment of e-Book Practicality

Aspect	Max Score	Score	Mean (M)
Implementation Ability	360	305	84.7
Continuity	360	317	88.0
Compatibility with Environment	240	214	89.1
Acceptance and Attractiveness	480	427	88.9

According to the data, students saw tremendous utility and versatility in using e-Books, providing a unique blend of opportunities for learning in formal and informal settings. The notion of ‘continuity’ represents sustainability in education because the digital format of learning materials permits them to be reused and accessed without incurring additional costs to the environment. This will promote responsible behaviours in the education setting (Casselden, 2020; Güntem & Kılıç, 2025). Additionally, the beneficial aspects of using digital resources in education—i.e., enhancing student abilities and assisting teachers in their preparation—aid in enhancing the learning experience, and assist in being environmentally sustainable. By reducing their use of paper and other physical resources (Olipp et al., 2024; Ramírez-Correa et al., 2025), digital educational resources support more responsible educational practices, as well as establish a long-term level of ecological awareness.

The usefulness of interactive educational resources will also increase the likelihood of their integration into your classroom. Brugliera (2024) and Kaplar et al. (2022) found that interactive educational resources were particularly useful because they enabled teachers and students to access them anytime, anywhere. The STEM-based e-Book that was developed provides an excellent example of how versatile e-Books can be, as it can be accessed on multiple devices—PCs, laptops, and smartphones—enhancing its usability. The ability to have access to your educational materials on your mobile phone creates a unique opportunity for students to review and strengthen their understanding of educational materials on an ongoing basis, without time and space limitations (Hsieh, 2025; Sophonhiranrak, 2021), which increases the likelihood that students will continue to learn outside of the formal classroom environment.

Integration of Sustainability Awareness

While specific scores for sustainability awareness were not provided, the e-Book incorporated many principles of sustainable living in a learning context. Through the use of real-life examples, case studies, and exercises that required students to reflect on their actions as humans and how they affect the earth/environment, especially with respect to

nutrition/food waste/digestive health, students developed an understanding of how their individual actions can affect the environment (Jooyandeh & others, 2026). By choosing to use real-world examples of the digestive system rather than testing on the textbook definition, the authors of the e-Book helped develop students' scientific knowledge and raise their awareness of the relationships between their own health and the environment (Jooyandeh et al. 2026).

The e-Book contains sustainability content that promotes waste management, healthy eating, and food choice awareness. It makes direct connections between the digestive system and day-to-day actions that impact both the environment and oneself. The connections foster positive development of responsible sustainable living behaviours among students (Díaz-Pichardo et al. 2026; Gardner et al. 2023). In addition, this provides the necessary components for meeting objectives associated with STEM education through enabling opportunities for critical thinking, problem-solving and for the development of a sense of social responsibility (Chrysochou et al. 2025). After using the e-Book, teachers indicated that their students engaged in many more conversations relating dietary practices to health as well as to the environment. The lack of paper also provides a way to model environmentally responsible behaviours, which relates to the larger goal of creating a generation of youth that has an awareness of sustainability and will act as stewards of sustainability (Sihombing et al. 2024c). These findings indicate that digital STEM related educational resources can promote sustainability awareness and help enhance the scientific literacy of students (Prasetyo et al. 2021; Sihombing et al. 2024b; Stehle & Burton 2019).

CONCLUSION

According to this research, the use of STEM-based e-Book to teach the human digestive system is an appropriate and effective way to support student learning in science. The application of sustainable methods into the curriculum will help enhance students' overall comprehension of science by providing a tangible example of how sustainability relates to what they are learning. Through a systematic, validated process of developing the E-book as a resource for formal secondary educational settings, we have established the E-book as academically, instructionally, and functionally appropriate resources within that educational context.

Data demonstrates students' development of competence in scientific literacy. This growth supports students' evaluations of the validity of scientific data, concepts and critical thinking skills when faced with real-world problems. The research indicates that STEM combinations with interactive digital design create challenging yet attainable learning

environments for students. Creation of significant knowledge occurs in an interactive learning space rather than just memorizing and repeating facts.

Research also supports the notion that incorporating sustainability concepts into the science curriculum doesn't diminish the integrity of the core content. For example, the e-Book includes an examination of the human digestive system in developing healthy eating habits, food systems and the environment. Here, the e-Book combines biological knowledge with the ability to make informed decisions to solve real-world issues. Thus, scientific literacy will be determined by a student's understanding of the scientific principles studied, and their ability to make an informed decision and behave responsibly regarding social and environmental issues.

The study confirms that the materials and methods used for the digital learning of STEM can improve higher order thinking skills, as well as creativity and ability to generate sustainable solutions. The goal of this study was not only to create a single instruction-based digital resource but also to corroborate the concept that purposeful STEM resource design has the potential to be a springboard for advancing student scientific literacy and education in sustainability. Through our results, we show that sustainability can be embedded in all content areas of science through the creation of connections and relevance throughout all disciplines.

This study demonstrates that by using resources based on digital STEM methods students can transform traditional, text/book-driven methods of instruction into hands-on inquiry-type experiences. A range of multimedia interactive elements, the ability to solve real-world contextual problems, and an understanding of the structured scientific way of thinking increase students' interest and support the development of higher-order thinking skills. This finding implies that new ways to teach science should focus on the design principles that link technology to educational goals.

An example of this could be the integration of sustainable health consumption within the larger context of the digestive system. Rather than treating science as a discrete discipline, it can now be shown that science can promote broader societal goals, such as sustainable development and the development of 21st-century skills. By linking biological processes to consumption and the environmental impact of these behaviours, students become not only science students but also future citizens able to make reasonable and responsible decisions based on the knowledge gained throughout their schooling. In addition, the study shows that the use of sustainable digital materials, both in an educational and ecological sense, will promote environmentally responsible instructional practices. Reusing digital learning materials instead of producing paper-based copies aligns the institution's efficiency with its

environmental awareness. Therefore, it may be possible to align educational innovation and environmental sustainability.

Future research could explore the long-term effects of STEM-based digital interventions on measurable sustainability awareness and behavior change, as well as their scalability across different scientific fields and educational levels. Such studies would help clarify the role of integrated STEM teaching in developing scientifically literate and sustainability-conscious learners.

Availability of data and material

The datasets generated and/or analyzed during the current study are available from the first author upon reasonable request.

Funding

National Taiwan Normal University

Ethics approval

The study was approved by the Institutional Review Boards (IRB) of Universitas Negeri Medan on 2 April 2026.

Patient consent statement

Informed consent was obtained from all individual participants included in the study.

Permission to reproduce material from other sources

No material from other sources was used in this manuscript.

Clinical trial registration

This study is not a clinical trial and does not require registration.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used QuillBot in order to improve the language and readability. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Credit authorship contribution statement

Rizky Agassy Sihombing, Noviansyah Kusmahardhika, Shiang-Yao Liu, Chun-Yen Chang, Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no competing financial or non-financial interests in relation to this study.

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