

DEVELOPMENT OF AN E-ENCYCLOPEDIA BASED ON SOCIO-SCIENTIFIC ISSUES ON BIOLOGICAL TECHNOLOGY INNOVATIONS AS A SUPPLEMENTARY LEARNING RESOURCE TO IMPROVE THE SCIENTIFIC LITERACY

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ABSTRAK

Rendahnya tingkat literasi ilmiah siswa masih menjadi tantangan dalam pembelajaran biologi, khususnya pada topik inovasi teknologi biologi yang kompleks dan berkaitan erat dengan berbagai isu sosial. Penelitian ini bertujuan untuk mengembangkan e-ensiklopedia berbasis Isu Sosial-Ilmiah (ISM) tentang inovasi teknologi biologi sebagai sumber belajar tambahan untuk meningkatkan literasi ilmiah siswa. Penelitian ini menggunakan metode Penelitian dan Pengembangan (R&D) dengan model pengembangan 4-D yang terdiri dari tahapan Mendefinisikan, Merancang, Mengembangkan, dan Menyebarluaskan. Partisipan penelitian adalah 36 siswa kelas 10 SMA Negeri 10 Medan. Instrumen penelitian meliputi lembar validasi materi, media, dan desain pembelajaran, kuesioner tanggapan guru dan siswa, serta tes literasi ilmiah. Hasil penelitian menunjukkan bahwa e-ensiklopedia yang dikembangkan mencapai skor validasi rata-rata 92,92%, yang dikategorikan sangat baik. Tes kepraktisan menghasilkan skor rata-rata 86,5%, yang menunjukkan kategori sangat praktis. Keefektifan produk tersebut ditunjukkan oleh peningkatan hasil belajar dan literasi ilmiah siswa, dengan rata-rata skor pretest meningkat dari 55,9 menjadi 87,4 pada posttest dan skor N-gain sebesar 0,71, yang dikategorikan tinggi. Oleh karena itu, e-ensiklopedia berbasis SSI tentang inovasi teknologi biologi dianggap valid, praktis, dan efektif sebagai sumber belajar tambahan untuk meningkatkan literasi ilmiah siswa.

Kata kunci: e-ensiklopedia, Isu Sosial-Ilmiah (SSI), inovasi teknologi biologi, literasi ilmiah, sumber belajar tambahan..

ABSTRACT

The low level of students' scientific literacy remains a challenge in biology learning, particularly in biological technology innovation topics, which are complex and closely related to various social issues. This study aimed to develop a Socio-Scientific Issues (SSI)-based e-encyclopedia on biological technology innovation as a supplementary learning resource to improve students' scientific literacy. The research employed a Research and Development (R&D) method using the 4-D development model consisting of Define, Design, Develop, and Disseminate stages. The participants were 36 tenth-grade students of class X-2 at SMA Negeri 10 Medan. Research instruments included material, media, and instructional design validation sheets, teacher and student response questionnaires, and scientific literacy tests. The results showed that the developed e-encyclopedia achieved an average validation score of 92.92%, categorized as very good. The practicality test yielded an average score of 86.5%, indicating a very practical category. The effectiveness of the product was demonstrated by an increase in students' learning outcomes and scientific literacy, with the average pretest score improving from 55.9 to 87.4 on the posttest and an N-gain score of 0.71, categorized as high. Therefore, the SSI-based e-encyclopedia on biological technology innovation is considered valid, practical, and effective as a supplementary learning resource to improve students' scientific literacy.

Keywords: e-encyclopedia, Socio-Scientific Issues (SSI), biological technology innovation, scientific literacy, supplementary learning resource..

I. INTRODUCTION

1. Background

Technology and knowledge are developing quickly in the twenty-first century. Learning in this century is meant to meet the needs of modern approaches and problems to focus on preparing students to live and contribute effectively in a society that is continually changing, driven by technical innovations, globalization and social complexity (Ledoh et al., 2025). Science education focused on 21st-century skills is supposed to give students the capacity for critical thought, creative problem-solving, and the development of effective social and communication skills all of which are crucial in the workplace (Yunita & Mandasari, 2025). The Merdeka Curriculum was created in response to these advancements in order to use student-centered learning to help students become more adaptive and self-sufficient. Teachers have also been impacted by the Merdeka Learning Curriculum's implementation. In terms of instructional strategies, the curriculum mandates that teachers comprehend the traits of their students in order to manage a wider range of learners and to offer more adaptability and variety in their methods. In the meantime, the Merdeka Learning Curriculum's adoption provides students with additional possibilities for non-monotonous learning experiences, resulting in a different learning environment that lessens classroom learning fatigue (Armadani et al., 2023). The Programme for International Student Assessment's (PISA) poor findings indicate that Indonesia's performance over the course of its 15-year participation in PISA has continuously stayed at a low level, served as the impetus for the creation of the Merdeka Curriculum. As a result, compared to other participating nations, Indonesia's educational system is thought to be of extremely low quality. Internal pressures brought on by widespread media coverage of Indonesia's PISA results and criticism of the country's curriculum, which was seen as having failed, contributed to this predicament. As a result, the Indonesian Ministry of Education and Culture determined that curriculum modifications were necessary to better align with PISA (Pratiwi et al., 2019). According to Arlis et al. (2020), scientific literacy is the ability of students to recognize scientific concepts, understand and explain them, and communicate scientific knowledge. This ability also includes the application of science in everyday life, whether in the classroom, madrasa, or the surrounding living environment, in order to solve various daily problems related to the material that has been learned. Students are expected to develop positive attitudes as well as good awareness of themselves and their interactions with the environment through scientific literacy. The learning crisis in Indonesia is reflected in the low achievement of the PISA. Based on PISA 2022 data, Indonesia's average science score was 383 points, which was lower than the OECD average of 485 points. Indonesia ranked 68th out of 81 countries in reading ability, as well as 61th and 60th in mathematics and science, respectively (Hewi & Shaleh, 2020). Low reading abilities, non-contextual learning, a lack of enthusiasm in reading, and the predominance of traditional methods are all contributing causes to students' inadequate scientific literacy (Yusmar & Fadilah, 2023). Factors contributing to low scientific literacy skills include the selection of learning resources. According to Aqil (as cited in Suparya et al., 2022), textbooks are used by 90% of all science teachers and occupy 90% of instructional time allocation. Scientific literacy knowledge and its application that rely solely on textbooks or textual materials have not fully engaged students, resulting in monotonous learning experiences and limited understanding of subject matter within real-life contexts. Teachers need to develop their own learning resources in accordance with curriculum demands by applying a scientific approach, implementing innovative learning models, methods, strategies, or techniques, and integrating local wisdom. The use of such teaching materials make students' understanding can be enhanced by connecting learning content with the realities of their daily lives (Suparya et al., 2022). According to Ma (2021), a good

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textbook should be able to bridge theory and practice, giving students the chance to comprehend concepts while applying them in real life. This illustrates the significance of proper material construction in textbooks. This indicates that a range of learning strategies are included in the content, including conversations, case studies, text analysis, and project-based activities that are relevant to daily life. In the digital age, students can comprehend and analyze information critically and sensibly with the aid of textbooks that incorporate digital literacy (Huda, 2024)..Digital encyclopedias represent a significant and effective innovation in science learning at the elementary school level, as they not only enhance students' knowledge and understanding but also foster a higher awareness of scientific literacy (Aviariski et al., 2024). This is supported by research findings indicating that digital books have a positive and significant effect on scientific literacy skills (Putri et al., 2022). According to the results of interviews conducted at SMA Negeri 10 Medan, students show greater interest and understanding when biology learning is linked to Socio-Scientific Issues (SSI) that are relevant to real-life situations. There has been no media explicitly available that offers SSI-based content in a methodical and compelling style. The biology instructor at the school claims that biotechnology content might be included in SSI-based learning materials because the subjects are pertinent to both scientific advancements and contemporary social challenges. Based on the review of existing studies, no research has been found that applies a Socio-Scientific Issues (SSI) based encyclopedia as a supplementary learning resource to improve students' scientific literacy. Therefore, this study aims to **“Development of An E-encyclopedia Based on Socio-Scientific Issues on Biological Technology Innovations as A Supplementary Learning Resource to Improve The Scientific Literacy”**

2. Problem Formulation

The formulation of the problem in this study is how the research entitled Development of an E-encyclopedia Based on Socio-Scientific Issues on Biological Technology Innovations as a Supplementary Learning Resource to Improve the Scientific Literacy can be carried out according to procedures and on time.

3. Research purpose

The aim of this research is to obtain research results with the title Development of an E-encyclopedia Based on Socio-Scientific Issues on Biological Technology Innovations as a Supplementary Learning Resource to Improve the Scientific Literacy

4. Research Benefits

Based on the issues raised, this study is expected to have the following benefits:

1. For educators, as a source of additional teaching materials that can be used to supplement and provide information on biotechnology.
2. For students, as an additional learning resource to supplement learning from textbooks available in biology, especially biotechnology material, thereby becoming a means of improving students' science literacy.
3. For schools, it can be used as an input for learning resources in the form of an efficient e-encyclopedia that can improve students' science literacy.
4. For researchers, the results of this research are expected to provide researchers with experience in developing an e-encyclopedia and to serve as a reference for utilizing it as a teaching medium when they become educators in the future.

II. RESEARCH METHOD

Times and Location Research

Location

The location of this research was conducted at SMA Negeri 10 Medan, located at Jl. Tilak No. 108, Medan City, North Sumatra.

Times

This research was conducted from October 2025 to May 2026

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Subject and Object Research

Subject

The subjects of this research are 36 students of Class X–2 at SMA Negeri 10 Medan. The selection of subjects for the effectiveness test was conducted using cluster random sampling. This was done because all Grade X classes were considered to have students with above-average, average, and below-average abilities within each class, without distinguishing between superior and non-superior classes.

Object

The object of this research is an SSI-based digital biology encyclopedia (e-encyclopedia) on biotechnology material, used as a supplementary learning resource in Biology learning.

Type of Research

This research is a development study aimed at developing supplementary learning resources in the form of a digital encyclopedia (e-encyclopedia). Therefore, this study is categorized as Research and Development (R&D). The e-encyclopedia refers to the development model by Thiagarajan, commonly known as the 4-D model. The 4-D model consists of four stages: define, design, development, and disseminate.

Operational Definitions

Operational definitions are explanations used to guide the thought process in identifying the core of the problem precisely. Therefore, to avoid errors in interpretation, boundaries for the following terms are required:

1. An encyclopedia is an additional learning resource in the form of a digital encyclopedia containing biological technology innovation materials, systematically presented to support students' understanding and enhance scientific literacy.
2. Scientific literacy is the ability to engage with science-related issues as a reflection of citizenship, measured through students' mastery of content knowledge and scientific competencies, including explaining scientific phenomena, interpreting data and evidence scientifically, and applying scientific concepts in everyday situations.
3. Socio-Scientific Issues (SSI) refer to real-world social issues that are closely related to scientific concepts and are used in learning activities to help students apply scientific knowledge, develop reasoning skills, and connect science with societal contexts.
4. Biological Technology Innovation refers to technological discoveries based on biological principles. One form of such innovation is known as biotechnology.

III. RESULT AND DISCUSSION

Berdasarkan hasil penelitian dengan jumlah sampel 20 orang, didapatkan ada pengaruh *Art Therapy* terhadap tingkat stres pada mahasiswa Sarjana Keperawatan tingkat I Sekolah Tinggi Ilmu Kesehatan Santa Elisabeth Medan tahun 2025. Tingkat stres mahasiswa Sarjana Keperawatan tingkat I sebelum dilakukan *Art Therapy*, sebanyak 10 responden (50%) dalam kateg

Research Results

Based on research object on e-encyclopedia of biological technology innovation was conducted using the Research and Development (R&D) approach, referring to the 4-D development model. The 4-D model consists of four stages: Define, Design, Develop, and Disseminate, as proposed by Thiagarajan et al. (1974). The results of the development research conducted by the researcher are presented as follows.

Define Stages

The define stage is the initial phase that must be carried out before designing the product. This stage aims to identify and determine the needs of the teaching and learning process at

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SMA Negeri 10 Medan, as well as to gather various information related to the e-encyclopedia product to be developed. Several steps are involved in the define stage, namely:

Front End Analysis

At this stage, classroom observations and interviews were conducted with the tenth-grade biology teacher at SMA Negeri 10 Medan. The findings revealed several issues related to the current learning conditions. From the curriculum perspective, the school has implemented the Merdeka Curriculum. However, its implementation in the learning process has not yet been optimal. In classroom instruction, teachers primarily rely on teaching materials such as textbooks and Student Worksheets (LKPD) provided by the school. These learning resources have not fully supported the development of 21st-century skills. Furthermore, although teachers are aware of the importance of 21st-century skills, their integration into classroom activities remains limited. Regarding the learning approach, most teachers are familiar with the concept of Socio-Scientific Issues (SSI); however, it has not yet been incorporated into the teaching and learning process.

Learner Analysis

Based on the identified problems, it was found that the students of Class X possessed heterogeneous abilities. Some students were able to understand the learning materials well, while others still experienced difficulties in comprehending the content. In addition, students tended to be less active during the learning process and remained dependent on the teacher's explanations. Their interest in learning appeared to be higher when instructional activities incorporated visual and contextual media. From the perspective of scientific literacy, students still encountered difficulties in understanding information presented in scientific texts, analyzing problems, and drawing conclusions.

Concept Analysis

Based on the problems identified through the analysis of the Biological Technology Innovation material used at SMA Negeri 10 Medan, it was found that the content covers basic concepts, various types of biological technological innovations, and their applications in everyday life. The results of the content mapping indicated that several subtopics, such as the utilization of microorganisms, tissue culture, cloning, and genetic engineering, are directly related to Socio-Scientific Issues (SSI).

Task Analysis

The teacher analyzed the essential tasks that students must master in order to achieve the intended learning outcomes. In this learning process, students were assigned evaluation tests that were aligned with the learning objectives established by the teacher, ensuring that the expected learning outcomes could be attained. Task analysis was conducted to identify and clarify whether the problems encountered by students required a solution in the form of an e-encyclopedia based on Socio-Scientific Issues (SSI). Based on interviews with the subject teacher, it was found that problem-solving practices across schools were generally similar, involving the assignment of homework, the preparation of papers, the writing of laboratory reports, and the creation of PowerPoint presentations.

Formulating of Learning Objectives

The learning objectives were formulated based on the learning outcomes specified for Phase E. The specification of learning objectives was intended to develop clear and measurable objectives based on the results of the analysis of Biological Technology Innovation concepts. These objectives subsequently served as the foundation for designing the e-encyclopedia as a learning resource. Based on the results of the analysis conducted in the previous stage, the following learning objectives were formulated:

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1. Students are able to explain the concept of Biological Technology Innovation, distinguish between conventional biotechnology and modern biotechnology, and explain the role of microorganisms in biotechnology.
2. Students are able to explain the principles and stages of plant tissue culture, as well as the processes of embryo cloning and nuclear transfer cloning in animals.
3. Students are able to analyze the stages of genetic engineering, explain its applications, and evaluate the potential negative impacts of biotechnology implementation.

Design Stages

This stage was carried out with the aim of designing an e-encyclopedia on Biological Technology Innovation that could be used as an additional learning resource. Several steps were undertaken in this stage, namely:.

IV. CONCLUSION

Based on the results of the research and discussion previously described, the conclusions obtained are as follows:

1. The feasibility of the e-encyclopedia based on Socio-Scientific Issues (SSI) for biological technology innovation material, according to subject matter experts, is categorized as highly feasible with an average percentage score of 93.75%
2. The feasibility of the e-encyclopedia based on Socio-Scientific Issues (SSI) for biological technology innovation material, according to subject media experts, is categorized as highly feasible with an average percentage score of 87,5%
3. The feasibility of the e-encyclopedia based on Socio-Scientific Issues (SSI) for biological technology innovation material, according to subject instructional design experts, is categorized as highly feasible with an average percentage score of 97,5%
4. The practical response toward the e-encyclopedia based on Socio-Scientific Issues (SSI) for biological technology innovation material, according to the biology teacher is categorized as highly practical with a teacher's score of 87.5% and response from students is categorized as highly practical with a teacher's score of 86,5%
5. The effectiveness of the e-encyclopedia based on Socio-Scientific Issues (SSI) for biological technology innovation material in improving students' scientific literacy is categorized as highly effective with an average N-gain score of 0.71.

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