

Designing educational resources of the 21st-century skills instructional models and socio-scientific issues integration

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Abstract: This research addresses the limited availability of reference books that comprehensively explain the syntax of the 21st-century learning and socio-scientific issues. It focuses on designing and developing educational resources that integrate the 21st-century skills instructional models with socio-scientific issues, utilizing the 4D (Define, Design, Develop, Disseminate) development model by Thiagarajan (1974). Conducted from March to September 2024 at an Islamic public university in Medan, Sumatera Utara, the subjects were Biology Education students currently enrolled in or who had completed the Biology Learning Strategies course. Data collection involved questionnaires and documentation studies. Initial analysis indicated that students struggled to understand the steps and processes of instructional models supporting the 21st-century skills and socio-scientific issues. To address these challenges, a comprehensive instructional book was developed, emphasizing the 21st-century skills, learning syntax, and socio-scientific issue integration. The book received validation from experts, including a biology learning strategies expert (98.3%), a 21st-century skills expert (100%), and a socio-scientific issues expert (91.7%), all within the highly valid category. It was also deemed highly practical by users, namely students (94.3%) and lecturers (93.7%). The findings underscore the necessity of enhancing learning resources in the course, highlighting the significance of socio-scientific issues in fostering 21st-century skills. This study contributes to advancing learning strategies and offers valuable resources for educators and students preparing for the demands of the 21st-century.

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1. Introduction

In the rapidly evolving educational landscape of the 21st-century, the development of essential skills beyond traditional content knowledge has become crucial for preparing students for future challenges. These skills, often referred to as the 21st-century skills, encompass critical thinking, creativity, collaboration, and communication (P21, 2019). In the context of biology learning, Mutanen and Uitto (2020) further explained that these competencies are particularly significant, as they empower students not only to understand complex biological concepts but also to apply them in real-world contexts, fostering innovation and problem-solving abilities. The integration of the 21st-century skills into biology education is closely tied to pedagogical competence, as effective teaching practices must support the development of these skills (Voogt & Roblin, 2010). Teachers who possess strong pedagogical competence are able to design learning experiences that not only enhance students' understanding of biology but also cultivate the essential skills necessary for future success in the scientific community and beyond (Pedro et al., 2019). Thus, the relationship between 21st-century skills and pedagogical competence is vital, as it ensures that biology education remains relevant and responsive to the evolving demands of both the discipline and the broader society (Ardelia & Juanengsih, 2021; Saavedra & Opfer, 2012).

Pedagogical competence encompasses not only the ability to teach in the classroom but also the capability to design and implement innovative learning experiences that are

relevant to contemporary developments. The significance of developing the 21st-century skills for students is widely acknowledged in educational literature (Mardhiyah et al., 2021). Skills such as critical thinking, creativity, communication, and collaboration are essential for preparing students to tackle the complex challenges of the modern world. Consequently, pre-service biology teachers must be equipped to integrate these 21st-century skills into the learning process. One effective approach is to provide students with an understanding of instructional models (Arends, 2012; Bonk & Graham, 2006) that facilitate the effective development of these skills within the biology curriculum (Voogt & Roblin, 2010), particularly for future biology educators who will ultimately impact their learners (Yip, 2001).

Moreover, a pre-service biology teachers must also develop a comprehensive understanding of socio-scientific issues, which encompass the social, environmental, and ethical dimensions of science. This knowledge is essential for preparing the next generation to comprehend the implications of scientific advancements on society and the environment. By integrating socio-scientific topics into their teaching, biology education students can encourage discussions and debates that enhance critical thinking skills (Dusturi et al., 2024; Rahayu et al., 2020; Suwono et al., 2021; Wang et al., 2017), problem solving (Cofré et al., 2017), communication and collaboration (Mutasam et al., 2021).

Incorporating socio-scientific issues into the curriculum enriches learning experiences and equips students to tackle complex societal challenges (Zeidler, 2014). Topics such as climate change, genetic engineering, and bioethics enable students to evaluate diverse perspectives, make informed choices, and take responsible actions. This educational approach aligns with the development of the 21st-century skills, emphasizing critical thinking, problem-solving, effective communication, and creativity (Indriani & Jayanti, 2022; Pursitasari et al., 2022). Thus, it is crucial for biology teacher candidates to not only grasp socio-scientific issues but also to adopt effective pedagogical strategies to teach these concepts, fostering a well-informed and engaged student body prepared to confront the pressing challenges of modern society (Nida et al., 2020).

Despite this, in April 2024, field observations were carried out by distributing questionnaires to students who had completed the learning strategy course in the undergraduate biology education program at a state Islamic university in Medan. The results indicate that not all pre-service teachers possess adequate pedagogical skills. This finding aligns with research by Jayanti (2020), which analyzed the planning skills of biology teacher candidates and revealed a lack of proficiency in developing lesson plans. Generally, students still struggle to create learning activities that align with the syntax of instructional models. This issue is further substantiated by Jayanti and Adlini's (2023) study, which indicates that students continue to encounter difficulties in understanding the variations of instructional models.

Furthermore, the lack of learning materials relevant to socio-scientific issues is a significant challenge in biology education. Existing materials often fail to thoroughly address critical topics such as climate change, biotechnology, and public health, which are vital in today's global context (Zeidler & Nichols, 2009). Research by Zeidler and Nichols (2009) indicates that integrating socio-scientific issues into the curriculum can enhance students' scientific literacy and critical thinking skills. However, many current learning materials still emphasize traditional biological concepts without connecting them to broader social and scientific contexts (Jackson et al., 2023; Martínez-Agüero & Hernández, 2023; Yoon et al., 2023). As a result, there is a gap in students' understanding of the real-world applications of biology and the global challenges they face (Jackson et al., 2023).

Moreover, the limited knowledge of pre-service biology teachers regarding socio-scientific issues poses a significant challenge in higher education. Research by Chen & Xiao (2021), Faisal and Martin (2022), and Kara (2012) indicates that teacher candidates often lack an understanding of how to integrate socio-scientific issues into biology instruction. A study by Álvarez-García et al. (2015) and Taşdelen & Güven (2023) found

that pre-service teachers struggle to connect biological concepts with social and environmental contexts, which are crucial for addressing issues such as climate change and biotechnology. Furthermore, [Amos et al. \(2020\)](#), [Chen and Xiao \(2021\)](#) and [Kara \(2012\)](#) argue that teacher education programs frequently fail to provide adequate training on socio-scientific issues, leaving candidates feeling unprepared and lacking confidence in teaching these topics. This highlights the necessity for teacher education curricula to provide more extensive training on socio-scientific issues, ensuring that prospective teachers are better equipped to address these critical topics effectively ([Çam, 2023](#); [Chang & Park, 2020](#)).

This limitation in knowledge hinders their ability to prepare students for complex global challenges, highlighting the need for improvements in the curriculum and teacher training programs that emphasize the integration of socio-scientific issues. Additionally, the lack of specific literature on developing biology instructional materials based on 21st-century skills and socio-scientific issues serves as a compelling reason to conduct this research. By approaching this study holistically, it is anticipated that significant contributions can be made to the renewal of biology education curricula and the equipping of pre-service biology teachers with relevant skills and contextual knowledge. Furthermore, additional support and resources are crucial for helping teacher candidates effectively understand and teach socio-scientific issues ([Amos et al., 2020](#); [Chang & Park, 2020](#); [Hancock et al., 2019](#); [Laurillard, 2013](#); [Santoso et al., 2020](#); [Zeidler et al., 2019](#)).

Thus, this research focuses on the development of educational resources in the form of a book that comprehensively addresses instructional models supporting the 21st-century skills and the integration of socio-scientific issues. Additionally, it aims to evaluate the validity and practicality of the developed book. This study is expected to provide a foundation for the development of a more adaptive and relevant biology curriculum that empowers pre-service teachers to create motivating learning experiences, preparing students to navigate an ever-evolving world.

2. Materials and Methods

2.1 Types of research

This study is a research and development that encompasses three key elements: the development model, the development procedure, and product testing. The procedure utilized adheres to the 4D model proposed by [Thiagarajan \(1974\)](#), consisting of four primary stages ([Figure 1](#)), although it is limited to the Develop stage. The first stage, Define, consists of five sub-stages: initial analysis, learner analysis, concept analysis, task analysis, and goal specification. The initial analysis highlights challenges within the Biology Learning Strategies course, while the subsequent analyses evaluate students' understanding of the 21st-century skills and socio-scientific issues. The second stage, Design, entails planning the product design, integrating relevant content, and establishing assessment criteria for learning. The third stage, Develop, involves the creation of a book prototype, expert validation, practicality assessments, and subsequent revisions based on the feedback received. Finally, effectiveness testing is conducted on a small scale to evaluate the book's impact on enhancing students' pedagogical competencies.

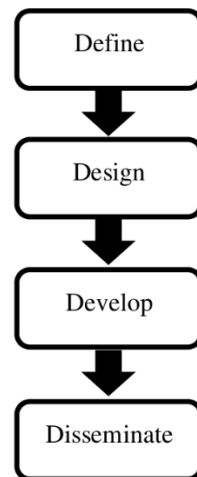


Figure 1. The 4D model (Thiagarajan et al., 1974)

2.2 Research Subjects and Objects

The participants for this study included 94 students enrolled in the Biology Education program at a state Islamic university in Medan, North Sumatra. These participants comprised 84 fourth-year students and 10 third-year students, all of whom were either currently taking or had previously completed the Biology Learning Strategies course. The fourth-year students, consisting of 10 males and 74 females, participated in the needs analysis. Meanwhile the third-year students, comprising 1 male and 9 females, were involved in the small-scale practicality and effectiveness testing.

2.3 Data Types and Sources

The data utilized in this research consists of both primary and secondary sources. Primary data includes the results of a needs analysis questionnaire, a knowledge assessment measuring biology teacher candidates' understanding of the 21st-century skills, socio-scientific issues, and their corresponding instructional models. Additionally, it encompasses expert validation outcomes and a practicality assessment. Secondary data is obtained from documentation studies, including analysis sheets of teaching materials and other relevant learning resources.

2.4 Data collection technique

The Needs Analysis in the Define stage employed several tools: 1) a literature review analysis sheet; 2) questionnaires to assess the needs of both students and lecturers; and 3) a knowledge assessment on the 21st-century skills and socio-scientific issues for biology pre-service teachers.

The validity test involved three experts, each in fields of biology teaching strategies, 21st-century skills, and socio-scientific issues. Experts were asked to assess the content of the book being developed, using validation sheets based on a Likert scale, along with a section for providing feedback and suggestions.

The practicality test evaluated the book's usefulness and user satisfaction (lecturers and students), measured through a questionnaire distributed to respondents. This instrument also used a Likert scale and an additional column for user suggestions and feedback.

2.5 Data Analysis Techniques

The collected data was subsequently analyzed using both quantitative (Formula 1) and descriptive methods. Then, the results of the data analysis of the validity and practicality of the module are interpreted using the criteria in Table 1.

$$\text{Percentage (\%)} = \frac{\text{score obtained}}{\text{score maximum}} \times 100\% \quad (1)$$

Table 1. Validation assessment result criteria (Riduwan & Akdon, 2010)

Percentage (%)	Criteria
80.0-100.00	Highly Valid/Highly Practical
60.00-79.00	Valid/Practical
50.00-59.99	Quite Valid/Quite Practical
00.00-49.99	Invalid/Not Practical

3. Results

3.1. Define phase

3.1.1 Front-End Analysis

The findings from the research and development of the book on teaching models centered around the 21st-century skills and socio-scientific issues are presented according to the stages of the 4D development model. During both the initial and final analysis phases of this model, an evaluation was performed on the Biology Learning Strategies course to identify issues associated with the teaching materials and resources utilized by instructors and students. The purpose of this evaluation was to pinpoint the shortcomings of existing reference books and to ascertain the need for additional resources that effectively support the 21st-century skills and socio-scientific issues. It was discovered that one of the main reference books employed by lecturers inadequately detailed the concepts of the 21st-century skills and instructional syntax.

During the study, seven reference books related to teaching models based on the 21st-century skills and socio-scientific issues were analyzed using Google Books and search engines. This analysis indicated that while numerous books addressed the 21st-century teaching models, most failed to explicitly link the characteristics of these skills to the instructional syntax of the models. Additionally, none of the analyzed texts offered learning scenarios or instructional videos, and only one book discussed the integration of socio-scientific issues into the educational framework.

Beyond the literature review, a needs analysis was carried out among students and lecturers to assess the challenges encountered in the Biology Learning Strategies course, as well as their requirements for supplementary learning resources. A questionnaire was administered to 84 students from the Biology Education Program at FITK UINSU who had completed the course.

The results indicated that the most difficult aspect for students was comprehending the instructional syntax of the teaching models. A significant number of students had trouble in understanding and applying the procedural steps associated with these models, suggesting a necessity for a stronger focus on teaching syntax. Scholars such as [Joyce et al. \(2015\)](#), [Marzano \(2017\)](#), [Shulman \(2005\)](#), and [Slavin \(2018\)](#) emphasize that a thorough understanding of instructional syntax is vital for developing structured and effective teaching strategies. Without this foundational comprehension, students are likely to struggle with creating innovative teaching approaches, ultimately impacting the educational quality of the course.

Furthermore, the examination of teaching materials utilized by lecturers highlighted ongoing limitations in the primary references concerning the 21st-century teaching models and socio-scientific issues. While most students regarded the available resources as somewhat beneficial, a notable proportion expressed that these references fell short of their expectations. Identified challenges included the absence of practical examples for implementing teaching models, limited access to online resources, and a lack of engaging content within the materials. Consequently, there is an urgent need for the development

of a more comprehensive, interactive, and relevant textbook to enhance student understanding and improve learning outcomes within this course.

3.1.2 Learner Analysis

The evaluation of students' knowledge regarding the 21st-century skills indicates that 84% of students are familiar with or have heard of these skills, primarily gaining their information from online sources and lectures. However, only 9% can accurately identify all the 21st-century skills, with creative thinking being the most recognized among them. Notably, 99% of students consider the development of these skills in biology education to be essential. These results highlight the pressing need to improve students' understanding of the full range of the 21st-century skills integrated within the curriculum, aligning with research that underscores the importance of preparing students for future challenges through such integration.

Additionally, 71% of students identified the scientific approach as the main method for cultivating the 21st-century skills, followed by student-centered methods. Project-Based Learning (PjBL) was selected by 86% of students as the teaching model that most effectively supports these skills. Nevertheless, students' familiarity with alternative teaching models, such as discovery learning and inquiry learning, remains insufficient. Previous research has demonstrated that instructional models like PBL and scientific approaches effectively promote critical thinking, collaboration, and innovation skills.

Furthermore, students' grasp of the instructional syntax related to the 21st-century skills-based teaching models also require further development. To address this, strategic initiatives such as offering comprehensive training and workshops on teaching models like project-based learning and problem-based learning can be implemented, alongside the integration of case studies and real-world examples into the curriculum to enhance the learning experience (Hattie, 2009; Kurt & Akoglu, 2023; Nurhasnah et al., 2022). Moreover, the application of project-based learning that fosters collaboration and addresses real-world problems has been shown to significantly improve students' understanding of these instructional models (Thomas, 2000).

The creation of interactive learning resources, including tutorial videos and simulations, can aid in clarifying the instructional syntax (Tarigan et al., 2021), supplemented by ongoing constructive feedback (Novak & Cañas, 2008). The development of textbooks that incorporate the 21st-century skills-based teaching models will be a vital step toward improving educational quality and equipping students to meet global challenges.

The assessment also reveals that students' awareness of socio-scientific issues is limited, with only 19% of courses covering this topic, which includes Biology Lesson Planning, Biology Assessment, and Biology Learning Strategies. However, when given adequate context and examples, students can provide relevant responses. This finding suggests that, despite their initial limited knowledge, students possess the potential to understand socio-scientific issues if they are supported by appropriate resources and guidance (Lee & Frame, 2018). Research further highlights the significance of embedding these issues within the curriculum to enhance scientific literacy (Husniyyah et al., 2023; Suwono et al., 2021) and enable students to connect biological concepts with broader social contexts (Amos et al., 2020; Çam, 2023; Chang & Park, 2020; Kara, 2012).

3.1.3 Concept Analysis

The subsequent phase of the development process involves a thorough concept analysis, focusing on the syllabus and learning outcomes (RPS/CPL) associated with the Biology Learning Strategies course as defined in the 2023 Curriculum for the Biology Education Program. This analytical phase is crucial as it aims to elucidate the cognitive learning outcomes that students are expected to achieve, particularly within the context

of the Biology Learning Strategies course. The competencies delineated for students include a comprehensive understanding of the principles underpinning teaching strategies and the capability to effectively plan instructional strategies that align with the Indonesian curriculum. Moreover, students are expected to implement biology teaching simulations tailored for Madrasahs and Schools, integrating various soft skills such as communication, collaboration, and critical thinking, which are essential for modern educational contexts.

The Merdeka Curriculum currently serves as the educational framework in Indonesia, specifically designed to confront the challenges posed by the 21st-century. This curriculum prioritizes the cultivation of vital the 21st-century skills, including critical thinking, creativity, collaboration, and communication. Considering this emphasis, the development of a supplementary learning resource, such as this book, is intended to facilitate students' understanding of teaching strategies and models that resonate with the needs of the 21st-century and address the evolving socio-scientific issues present in contemporary education.

Furthermore, the curriculum for the Biology Education Program, as articulated by the Directorate General of Islamic Education (Dirjen Pendis), encompasses knowledge-based learning outcomes (CPL) pertinent to pedagogical competencies. One such outcome, CP-KP14, underscores the necessity for students to adeptly select appropriate teaching approaches, models, instructional materials, and assessments specifically tailored for biology education. This requirement reflects a broader commitment to ensuring that future educators are equipped with the knowledge and skills to navigate the complexities of modern teaching environments.

The analysis of the syllabus for the Biology Learning Strategies course reveals several core topics integral to the course's structure. These topics include the theoretical underpinnings of learning within the context of biology education, various strategies, methods, techniques, and approaches to biology instruction, effective classroom management techniques, the design of instructional strategies in alignment with the materials taught in Madrasahs and Schools, and the practical application of biology teaching strategies in these educational settings.

In conclusion, the comprehensive concept analysis undertaken in this phase serves as a foundational basis for the development of the proposed supplementary learning resource. The insights gleaned from the examination of the syllabus and learning outcomes for the Biology Learning Strategies course illuminate the essential competencies that students must develop to thrive in contemporary educational settings. By identifying the critical elements of the Merdeka Curriculum, particularly its focus on 21st-century skills and pedagogical competencies, this analysis reinforces the need for instructional materials that are not only aligned with current educational standards but also responsive to the demands of modern biology education.

The integration of various teaching strategies, methods, and techniques, as highlighted in the syllabus, provides a framework for crafting a resource that effectively supports student learning and teaching practices. This book aims to address the gaps identified in the existing curriculum by offering practical applications, simulations, and examples that foster the necessary soft skills among students. By prioritizing these competencies, the resource will empower future educators to confidently implement innovative teaching strategies that engage students in meaningful ways.

Ultimately, the data derived from this analysis will guide the development of a book that is well-suited to the needs of both students and educators in the field of biology education. By ensuring that the content is relevant, comprehensive, and aligned with the principles of the Merdeka Curriculum, this initiative aspires to enhance the quality of biology instruction in Madrasahs and Schools, equipping educators with the tools they need to successfully navigate the complexities of teaching in the 21st-century.

3.1.4 Task Analysis

The task analysis is carried out in conjunction with the concept analysis based on the competencies specified in the Biology Learning Strategies course. This phase is designed to evaluate the essential skills that students are required to master within the course framework. Once students achieve an understanding of concepts related to teaching strategies and models, particularly those aligned with 21st-century learning frameworks and socio-scientific issues, they are expected to create learning scenarios that serve as practical applications of their acquired knowledge. Moreover, students should be capable of executing these scenarios through biology teaching simulations that are specifically tailored for Madrasahs and Schools.

In alignment with the curriculum established by the Directorate General of Islamic Education (*Dirjen Pendis*), the program outlines several learning outcomes (CPL) that encompass both general and specialized skills related to pedagogical competencies, the enhancement of 21st-century skills, and the engagement with socio-scientific issues. These include:

- **CP-KU10:** The ability to effectively utilize information literacy, media, and information and communication technology (ICT) to facilitate academic growth and professional skills development. This competency emphasizes the importance of being adept in navigating digital resources and utilizing them for educational and career advancement.
- **CP-KU12:** The capacity to work collaboratively in teams while demonstrating creativity, innovation, critical thinking, and problem-solving skills. This learning outcome highlights the necessity for students to engage in teamwork, fostering a collaborative environment where diverse ideas and solutions can emerge during academic projects and tasks in professional settings.
- **CP-KU3:** The ability to critically analyze the implications of scientific and technological advancements, with a focus on integrating humanitarian values. This competency encourages students to reflect on ethical considerations and professional standards while producing solutions, ideas, designs, or artistic critiques, thus ensuring that their contributions align with established norms and ethical practices in their respective fields.

The results of this task analysis will serve as a crucial foundation for the development of a book focused on teaching models centered around 21st-century skills and socio-scientific issues. By thoroughly evaluating the competencies necessary for students within the Biology Learning Strategies course, the analysis not only highlights the essential skills that future educators must master but also identifies the pedagogical approaches that are most effective in cultivating these skills. The focus on the 21st-century learning frameworks in this analysis will guide the development of the book's content, ensuring that it aligns with contemporary educational needs. The inclusion of practical applications, such as the creation of learning scenarios and biology teaching simulations tailored for Madrasahs and Schools, will provide students with relevant, hands-on experiences that reinforce their understanding of teaching strategies and models. This approach allows for the integration of theoretical knowledge with practical execution, preparing students for real-world teaching environments.

Additionally, the learning outcomes outlined in the curriculum, particularly CP-KU10, CP-KU12, and CP-KU3, will directly influence the structure and organization of the book. For example, CP-KU10 emphasizes the importance of information literacy and the use of technology in education; consequently, the book will incorporate sections that explore various digital tools and resources, equipping students with the skills to navigate and utilize technology effectively in their teaching practices. The collaborative and creative competencies highlighted in CP-KU12 will be reflected in the book's design,

featuring group activities, project-based learning opportunities, and strategies for fostering teamwork among students. This focus on collaboration is essential for developing skills that are not only relevant in educational settings but also critical in professional environments. Finally, the emphasis on ethical considerations and the integration of humanitarian values outlined in CP-KU3 will ensure that the book addresses the moral implications of teaching and learning within the realm of biology. By encouraging students to critically analyze scientific advancements and their societal impacts, the book will promote a holistic understanding of education that prepares future educators to navigate complex socio-scientific issues thoughtfully.

3.1.5 Goal Specification

This phase aims to articulate the objectives for the book's development in a focused and structured manner. Based on the analysis results, there is a need for a book that integrates the 21st-century skills-based learning models with socio-scientific issues. The book must clearly illustrate the connections between teaching models and the 21st-century skills, such as creative thinking, critical thinking, collaboration, and communication, accompanied by relevant implementation examples. With the publication of this book, it is anticipated that students' abilities to meet course competencies and address the challenges of the 21st-century will be enhanced.

The book being developed is designed to serve as a comprehensive resource for educators, explicitly incorporating the characteristics of the 21st-century skills alongside the integration of socio-scientific issues within the learning context, particularly in biology education. It clearly outlines the connections between the syntax of various teaching models and the essential indicators of the 21st-century skills, including creative thinking, critical thinking, collaboration, and communication. Additionally, the book features example scenarios and video barcodes that illustrate the practical implementation of these teaching models, enhancing the learning experience and providing educators with actionable insights for effective instruction.

3.2. Design phase

Drawing from the findings of the definition phase analysis, a book has been developed that center on learning models grounded in the 21st-century skills and socio-scientific issues. The objective of this book is to cultivate a comprehensive understanding of these learning models while simultaneously enhancing students' capacities to critically assess socio-scientific challenges. The 21st-century skills addressed in this work encompass the 4Cs: critical thinking, creativity, collaboration, and communication.

The book is organized into ten chapters, each addressing essential concepts of the 21st-century education, diverse learning models, socio-scientific issues, and their practical applications. The content includes in-depth discussions of the 21st-century education, as well as learning models such as discovery learning, inquiry-based learning, and problem-based learning, complemented by pertinent examples of implementation. Moreover, the book is designed with various visual aids, including diagrams and illustrations, to enhance students' understanding and engagement.

3.3 Develop phase

In this phase, a book centered on the 21st-century skills-based learning models and socio-scientific issues is developed, which includes the design of a prototype (Figure 2) and subsequent product testing for both validity and practicality. The content is organized according to a predetermined outline (Table 2) to provide students with an in-depth understanding, accompanied by relevant implementation examples (Figure 3).



Figure 2. Book cover

Table 2. Table of contents of the book

No. Chapter	Chapter	Subchapter
I	Concept of the 21 st -century education and learning	Characteristics of the 21 st -century Challenges of the 21 st -century The role of education in the 21 st -century The 21 st -century education and learning concept
II	The 21 st -century skills	Definition of the 21 st -century skills The 21 st -century skills framework
III	Development strategy of the 21 st -century skills	Integration of the 21 st -century skills in the curriculum Alternative learning approaches, techniques, and models Integration of character education Socio-scientific issues
IV	Assessment of the 21 st -century skills	Assessment of critical thinking skills Assessment of creative thinking skills Assessment of communication skills Assessment of collaboration skills
V	Discovery learning model	Definition Basic concepts Philosophical background Syntax of learning model The relationship between discovery learning and the 21 st -century skills The relationship between discovery learning and socio-scientific issues Learning media that supports the discovery learning model Examples of discovery learning model implementation
VI	Inquiry learning model	Definition Basic concepts Philosophical background Syntax of learning model

No. Chapter	Chapter	Subchapter
		The relationship between inquiry learning and the 21st century skills The relationship between inquiry learning and socio-scientific issues Learning media that supports the inquiry learning model Examples of inquiry learning model implementation
VII	Problem based learning model	Definition Basic concepts Philosophical background Syntax of learning model The relationship between problem-based learning and the 21 st -century skills The relationship between problem-based learning and socio-scientific issues Learning media that supports the problem-based learning model Examples of problem-based learning model implementation
VIII	Project based learning model	Definition Basic concepts Philosophical background Syntax of learning model The relationship between project-based learning and the 21 st -century skills The relationship between project-based learning and socio-scientific issues Learning media that supports the project-based learning model Examples of project-based learning model implementation
IX	Socio-scientific inquiry learning model	Definition Basic concepts Philosophical background Syntax of learning model The relationship between socio-scientific inquiry learning and the 21 st -century skills The relationship between socio-scientific inquiry learning and socio-scientific issues Learning media that supports the socio-scientific inquiry learning model Examples of socio-scientific inquiry learning model implementation
X	Interactive socio-scientific inquiry learning model	Definition Basic concepts Philosophical background Syntax of learning model The relationship between interactive socio-scientific inquiry learning and 21 st -century skills The relationship between interactive socio-scientific inquiry learning and socio-scientific issues Learning media that supports the interactive socio-scientific inquiry learning model Examples of interactive socio-scientific inquiry learning model implementation

Tabel 5.7 Contoh Implementasi Model *Discovery Learning* berkaitan dengan Isu-isu Sosiosaintifik

No	Tahapan <i>Discovery Learning</i>	Deskripsi Aktivitas	Contoh Implementasi
1	Stimulasi	Siswa dihadapkan pada suatu masalah atau fenomena yang memancing rasa ingin tahu mereka	<p>Topik: Pengaruh pembangunan infrastruktur terhadap kualitas ekosistem Sungai Deli</p> <p>Aktivitas:</p> <ul style="list-style-type: none"> Menampilkan video atau artikel tentang dampak pembangunan infrastruktur, seperti pembangunan jembatan dan jalan, terhadap kualitas ekosistem Sungai Deli di Medan serta menampilkan data lokal mengenai pencemaran sungai atau perubahan ekosistem. Ajak siswa berdiskusi tentang apa yang mereka ketahui mengenai pengaruh pembangunan infrastruktur terhadap ekosistem sungai. Buatlah pertanyaan seperti "Bagaimana pembangunan di sekitar Sungai Deli dapat mempengaruhi kualitas air dan kehidupan akuatik di sungai tersebut?"
2	Identifikasi Masalah	Siswa diminta untuk merumuskan masalah atau pertanyaan dari	<p>Aktivitas</p> <ul style="list-style-type: none"> Siswa diminta untuk merumuskan pertanyaan

(a)

Manfaat dari implementasi ini:

- Berpikir Kritis:** Siswa dilatih untuk menganalisis dampak lingkungan secara mendalam.
- Keterampilan Kolaborasi dan Komunikasi:** Proyek kelompok meningkatkan keterampilan komunikasi dan kerja sama.
- Berpikir Kreatif:** Menghasilkan solusi praktis dan inovatif untuk masalah lokal.
- Kesadaran terhadap Isu Sosiosaintifik:** Memahami bagaimana isu lingkungan dan sosial saling terkait dalam konteks lokal di Medan.

Silahkan pindai QR Code berikut untuk contoh lain dari pembelajaran *Discovery Learning*



(b)

Figure 3. The example of a learning model's implementation in the form of (a) table, and (b) QR codes

3.3.1 Expert Appraisal

The book's validity is assessed by three expert reviewers. The evaluation utilizes a validation instrument comprising a Likert scale ranging from 1 to 4, focusing on the suitability of the content, presentation, language, and contextual relevance. The results of the evaluation demonstrate that the book attained a validity score of 98.3% from experts in biology learning strategies (Table 3 and Table 4), 100% from specialists in the 21st-century skills (Table 5 and Table 6), and 91.7% from expert on socio-scientific issues (Table 7 and Table 8), with all categories categorized as highly valid.

Table 3. The results of validation by biology learning strategies expert

No.	Aspects	Number of items	Maximal score	Score obtained
1	Content	12	48	47
2	Presentation	6	24	24
3	Language	9	36	35
4	Contextual relevance	2	8	8
	Total	29	116	114
	Percentage			98.3%
	Category			Highly valid

Table 4. Comments from biology learning strategies expert

Suggestions	Before	After
Add information about the differences between inquiry learning and discovery learning.	The concepts of inquiry and discovery learning are explained separately, but they seem similar	The differences between the concepts of inquiry and discovery learning have been presented in tabular form based on seven aspects of difference.
In PBL, emphasize that the problems used are real issues surrounding the students	The problem described in PBL refers to an ill-structured problem	One of the characteristics of PBL is ill-structured problems, which is reinforced by focusing on issues that are present in the students' surroundings.

Suggestions	Before	After
In PjBL, emphasize that the product that should be produced in the project being conducted is a product that serves as a solution to existing problems, not just a product that does not solve any problems at all	Students engage in activities that require a process to complete complex projects, usually with results that can be applied in real-life contexts	Students are not only given problems to solve, but they are also expected to produce a product as part of the process in solving the existing problem, especially in real-life contexts.

Table 5. The results of validation by the 21st-century skills expert

No.	Aspects	Number of items	Maximal score	Score obtained
1	Content	2	8	8
2	Relevance of learning models to 21 st century skills	4	16	16
	Total	6	24	24
	Percentage			100%
	Category			Highly valid

Table 6. Comments from the 21st-century skills expert

Suggestions	Before	After
The relationship between learning models and the 21 st -century skills should be made in tabular form	Generally, the relationship between the syntax of learning models and the 21 st -century skills is explained in paragraph form	In table form, the relationship between the syntax of the learning model and the 21 st -century skills are explained in detail between each stage of the syntax and each indicator of the 4C aspects

Table 7. The results of validation by socio-scientific issues expert

No.	Aspects	Number of items	Maximal score	Score obtained
1	Content	2	8	7
2	Contextual assessment and socio-scientific issues	4	16	15
	Total	6	24	22
	Percentage			91.7%
	Category			Highly valid

Table 8. Comments from socio-scientific issues expert

Suggestions	Before	After
It would be better to add a description of the socioscientific issues that are relevant to the related learning model	There are only general socio-scientific issues are discussed in the book, not specific to any particular learning model	Specific examples of socio-scientific issues relevant to the discussed learning model are explained

3.3.2 Developmental Testing

After making the necessary revisions, the practicality of the book is examined through feedback collected from both students and lecturers. The evaluation outcomes indicate a practicality score of 94.3% from students and 93.7% from lecturers, with both ratings classified as highly practical (Table 9). This feedback is employed to refine the quality of the product, ensuring that the book is informative, engaging, and tailored to meet the needs of its users.

Table 9. The results of practicality test

Respondents	Percentage	Category
Students	94.3%	Highly practical
Lecturers	93.7 %	Highly practical

4. Discussion

The research and development outcomes for the book on teaching models incorporating the 21st-century skills and socio-scientific issues underscore the necessity for a thorough reassessment of the Biology Learning Strategies course. During both the initial and final analysis phases of the 4D development model, evaluations were conducted to pinpoint deficiencies in the teaching materials and resources utilized by both lecturers and students. This analysis revealed substantial limitations in the current reference books, many of which fail to adequately address the depth of the 21st-century skills, and the instructional syntax required (Joyce et al., 2015; Slavin, 2018).

Moreover, the study identified that many resources on 21st-century teaching models do not explicitly link the essential characteristics of these skills with the instructional syntax. Out of the seven books analyzed, only one discussed the integration of socio-scientific issues within the learning process, highlighting an urgent need for more comprehensive and inclusive educational materials (Chang & Park, 2020; Hancock et al., 2019; Sadler et al., 2011, 2016).

A needs assessment conducted with 84 students in the Biology Education Program at FITK UINSU further revealed that most students encountered difficulties understanding the instructional syntax of various teaching models, particularly in terms of their practical application. These insights highlight the importance of improving students' comprehension of teaching model syntax, enabling them to create more innovative and effective teaching strategies.

An evaluation of students' familiarity with the 21st-century skills revealed that while 84% had some knowledge of these skills, only 9% could accurately identify all the essential components. This finding emphasizes the necessity of embedding 21st-century skills more deeply within the curriculum to adequately equip students for future challenges (Sadler et al., 2021).

In the concept analysis phase, the course syllabus and learning outcomes (RPS and CPL) for the Biology Learning Strategies course were reviewed. The analysis showed that cognitive learning outcomes should include a comprehensive understanding of teaching strategies aligned with the Merdeka Curriculum, which places a strong emphasis on 21st-century skills. As part of the task analysis, students were expected to create learning scenarios based on their understanding of these modern teaching models. The results confirmed the need for the development of a textbook that more effectively integrates 21st-century skills and socio-scientific issues, aiming to enhance students' grasp of these concepts and their practical application in instructional settings.

The book, consisting of 10 chapters, is designed to cover a variety of teaching models, supplemented by diagrams and illustrations to aid comprehension. Expert validation assessments rated the book as highly valid, while feedback from both students and lecturers affirmed that it is highly practical for instructional use. It equips future teachers with innovative instructional models that integrate socio-scientific issues, fostering critical thinking, problem-solving, and decision-making skills essential for navigating complex, real-world challenges, all of which are key components of the 21st-century skills. Additionally, the book encourages collaboration, communication, and the use of technology, enabling pre-service teachers to create interactive learning environments while promoting global awareness, ethical reasoning, and the ability to connect scientific concepts with societal impact in their future classrooms.

5. Conclusion

The findings from the research and development process emphasize the critical need for an updated approach to the Biology Learning Strategies course, particularly through the integration of the 21st-century skills and socio-scientific issues. Existing educational materials fail to adequately connect instructional models with essential competencies like critical thinking, creativity, collaboration, and communication, while socio-scientific issues are underrepresented. Additionally, students struggle to comprehend instructional syntax, revealing a disconnect between theoretical concepts and practical application, which hinders effective teaching and learning, especially in preparing future educators. The proposed book addresses key gaps in biology education by integrating the 21st-century skills and socio-scientific issues, supported by practical resources like diagrams, illustrations, and examples for better accessibility. Validated as highly effective by experts—biology learning strategies (98.3%), the 21st-century skills (100%), and socio-scientific issues (91.7%)—and deemed highly practical by students (94.3%) and lecturers (93.7%), it bridges the gap between theory and practice, aligning teaching models with modern educational demands to equip students for a rapidly evolving world.

Based on the research findings, several recommendations are proposed: 1) students should be encouraged to practice developing learning scenarios and activities using various teaching models, particularly those designed to support the 21st-century skills and socio-scientific issues; 2) lecturers, especially those teaching biology learning strategies, should consider utilizing this book to enhance the integration of the 21st-century skills and socio-scientific issues, while also ensuring efficient use of instructional time; 3) future researchers should evaluate the strengths and areas for improvement in this book to further refine its quality and effectiveness; 4) due to time constraints, the book could not be implemented over the course of a full semester. Further research is needed to apply this book in the Biology Learning Strategies or Biology Lesson Planning courses to obtain more comprehensive and optimal outcomes.

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