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Profile of Biology Teachers' Skills in Senior High School in Designing Design Thinking-Based Teaching Materials to Improve Students' Critical Thinking, Numeracy, and Creative Thinking Abilities

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Abstract

This study aims to describe the profile of senior high school biology teachers' skills in designing teaching materials based on Design Thinking to enhance students' critical thinking, numeracy, and creative thinking skills. A descriptive method was employed using an assessment rubric for the product of teaching materials and rubric of Design Thinking-based teaching materials covering seven aspects. Data were collected through the evaluation of teaching materials designed by biology teachers, focusing on organic waste management. The results indicate that the overall quality of the teaching materials was categorized as "very good," with an average validator score of 3.55. Teachers' skills in applying the Design Thinking stages were also categorized as "very good," with an average score of 3.68 out of 4.00. The highest scores were obtained in the empathize and define stages (4.00), while the lowest score was found in the test stage (3.29). The integration of 21st-century skills was considered good, with a score of 3.33 for formulating learning objectives and 3.48 for developing critical thinking, numeracy, and creative thinking skills. Overall, teachers demonstrated good competence in designing Design Thinking-based teaching materials, although improvements are needed in prototype testing and the consistent integration of 21st-century skills. This study recommends further training and mentoring to enhance the quality of innovative teaching materials that align with the demands of 21st-century education.

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INTRODUCTION

Critical thinking, numeracy, and creativity are key competencies in 21st-century education, requiring the integration of deep-thinking skills and scientific application in learning (Sari et al., 2025). These skills have been identified as core abilities that individuals must possess to contribute productively to modern society (Hidayati et al., 2025). Design thinking in 21st-century learning enables students to become creative thinkers capable of facing the challenges of the ever-evolving world (Smiechowski et al., 2021). Nevertheless, the results of the international PISA study show a decline in the numeracy scores of Indonesian students, indicating the need for innovation in teaching methods that simultaneously stimulate critical and numerical thinking skills. In the context of biology learning, the use of systematically designed teaching materials has proven effective in improving student learning outcomes and engagement (Usman, 2024). Additionally, biology teachers in Kartasura demonstrated a high level of PCK (Pedagogical Content Knowledge) in preparing teaching materials, with scores above 80% indicating their readiness to design teaching materials based on the Merdeka curriculum.

The design thinking method has been recognized as effective as an active learning approach that fosters students' critical, creative, collaborative, and empathetic thinking abilities through an iterative process that encourages exploration and innovation (Aprianto, et al., 2023). This model offers a framework that allows students to become knowledge designers, not just information recipients, and encourages teachers to act as active facilitators and collaborators in the knowledge construction process (Lev Vygotsky's sociocultural perspective). The design thinking method is relevant for designing teaching materials because it emphasizes creative, collaborative, and learner-centered processes. At the empathize stage, teachers try to understand students' learning characteristics, needs, and problems through observation and context analysis, so that the teaching materials developed truly stem from the real experiences of the learners (Brown, 2009). The define stage allows teachers to formulate learning problems more directionally, for example, by defining the competencies that must be achieved and the obstacles students are experiencing. Next, the ideate stage encourages teachers to generate various alternative learning strategies and activities that can be incorporated into the teaching materials design. At the prototype stage, these ideas are realized in the form of a systematic teaching material design, containing objectives, materials, activities, and evaluations. Through these stages, teachers are helped to produce teaching materials that not only meet curriculum aspects but are also contextual, innovative, and responsive to 21st-century skills that need to be developed in students.

Based on this, it is important to understand the skill profile of high school biology teachers in designing Design Thinking-based teaching materials, as an effort to improve students' critical thinking, numeracy, and creative thinking abilities. This type of competency evaluation has not been extensively researched in the context of teaching material design using the Design Thinking approach, particularly at the high school level. While previous studies have focused on the general application of design thinking in instructional material development (Anwar et al., 2024), this research specifically examines teachers' skills in designing Biology teaching materials, identifying weaknesses in the testing phase, and integrating 21st-century skills. Therefore, this study offers a novel contribution in the form of a competency map for teachers implementing design thinking in teaching material design, which can serve as a basis for mentoring programs and further training.

RESEARCH METHOD

This research uses a descriptive method with a qualitative-quantitative approach, involving expert and teacher evaluations of a Biology teaching material based on design thinking. The research aims to describe the profile of high school biology teachers' skills in designing design thinking-based teaching materials and their relationship to efforts to improve students' critical thinking, numeracy, and creative thinking abilities. The population in this study consists of all Biology teachers who are members of the Biology Subject Teacher Association (MGMP) in Sukabumi City and District, while the research sample was selected purposively based on the teachers' active involvement in the development of teaching materials. This research was conducted in Sukabumi City and District over a specific period, as agreed upon by the MGMP and based on

the availability of respondents.

Data collection was carried out using a rubric that included: teaching material quality indicators covering content, language, appearance or presentation, graphics, and technical usability; and a teaching materials rubric for each stage of design thinking and 21st-century skills, encompassing seven aspects: empathize, define, ideate, prototype, test, write 21st-century skills as learning objectives, and develop 21st-century skills such as critical thinking, numeracy, and creative thinking. The analysis of the teaching materials prepared by the teacher is used to assess the extent to which design thinking principles are applied in the development of teaching materials. The scoring scale and feasibility indicators for the content of the teaching material can be seen in Table 1 (adapted from Riduwan, 2012) and Table 2 (Purwono, 2008).

Table 1. Product Assessment Rubric (Teaching Materials)

Score	Category	Description
4	Very Good	The aspects in the teaching material are fully achieved, clear, consistent, and in-depth.
3	Good	Most aspects of the teaching material are well-achieved.
2	Fair	Only a small portion of the aspects in the teaching material were achieved.
1	Poor	Not a single aspect of the teaching material was fulfilled.

The rating scale in Table 1 is used as a reference for interpreting the quality of the teaching materials designed by the teacher. Thus, each score obtained reflects the extent to which the indicators on the rubric have been met. A high score indicates that the teaching material has been designed according to the principles of content creation feasibility, while a low score signifies areas that need improvement, particularly in content depth. To provide a more comprehensive overview, this assessment was then broken down into specific indicators for each aspect of teaching material creation, as shown in Table 2.

Table 2. Product Assessment Indicators (Teaching Materials)

Aspect	Indicator
Content	Content alignment with the High School/Middle School CP
	Content alignment with learning objectives (numeracy and creative thinking skills)
	Avoiding conceptual errors or misconceptions
	Evaluate according to the learning objectives.
Language	Compliance with Indonesian language rules
	Accuracy of term usage
Appearance/Presentation	Consistent presentation in every section
	The presentation is easy to understand.
	Considering the ease of information processing
Graphic Design	The illustration is consistent with the concept.
	Illustrations create motivation
Technique	Practicality of use
	Device compatibility

Following the assessment of general aspects of teaching materials as presented in Table 2, further evaluation was directed toward identifying indicators that specifically reflect the integration of design thinking principles and the development of 21st-century skills. This stage aimed to capture how biology teachers incorporated the phases of design thinking: empathize, define, ideate, prototype, and test within their teaching materials, as well as how these materials fostered critical thinking, numeracy, and creative thinking among students. The detailed indicators used for this purpose are outlined in Table 3.

Table 3. Product Assessment Indicators Based on Design Thinking and Developing Critical Thinking, Numeracy, and Creative Thinking

Aspect	Indicator
Empathize	The teaching material presents contextual stimuli (articles/cases) relevant to students' lives, encouraging an understanding of user perspectives.
Define	The problem statement is presented clearly, focused, and aligned with students' learning needs.
Ideate	Variations in learning ideas/concepts emerge; activities encourage creativity and alternative solutions.
Prototype	The teaching materials produce a structured activity/project design; prototypes are presented concretely.
Test	There are steps for students to test the prototype; there is a mechanism for collecting feedback for improvement.
Writing 21st-century skills as learning objectives	Learning objectives include critical thinking, numeracy, and creative thinking skills; and the application of explicit strategies to stimulate these skills.
Developing 21st-century skills (critical thinking, numeracy, and creative thinking) in teaching materials.	Integrating activities and tasks that deeply and contextually stimulate and develop all three skills.

Table 3 provides a more detailed framework for assessing the extent to which the teaching materials designed by the teacher have implemented design thinking principles while integrating 21st-century skills. Through this indicator, the assessment focuses not only on the technical aspects of teaching material development but also on the depth of the thinking process facilitated by the teacher for the students.

Quantitative data obtained from questionnaires were analyzed descriptively using simple statistics such as frequency, percentage, mean, and mode to describe the distribution of teacher skill profiles. Meanwhile, qualitative data obtained from teaching materials were analyzed narratively to identify patterns of design thinking implementation and its relationship to efforts to improve students' critical thinking, numeracy, and creativity skills.

RESULTS AND DISCUSSION

The evaluation results for the three teaching materials designed by the high school biology teacher show that the overall average score falls into the very good category, with an average of 3.55. The first teaching material received the highest average score of 3.59, followed by the third teaching material with a score of 3.55, while the second teaching material was relatively lower with a score of 3.49. The differences in scores between teaching materials indicate that although the overall quality of the teacher's design is consistently good, there is variation, particularly in the integration of 21st-century skills and the testing phase of design thinking. When linked to the evaluation rubric, it is evident that the teacher demonstrates strength in the empathize and define stages, as indicated by the maximum score (4.00). This illustrates that teachers are quite skilled at presenting contextual stimuli, such as articles or cases on organic waste processing, enabling students to understand user perspectives and formulate problems clearly.

During the ideation and prototyping stages, teachers also demonstrated good performance, although the variety of ideation techniques and the depth of prototyping were still limited. Conversely, the lowest score was found at the test stage (3.29), indicating limitations in the teacher's ability to facilitate the prototype testing process by students and gather feedback for improvement. This is consistent with the findings on the integration of 21st-century skills, where the formulation of new learning objectives scored 3.33 (good category) and the development of critical thinking, numeracy, and creative thinking skills scored 3.48 (fairly good). Thus, although teachers are already capable of integrating 21st-century skills into teaching material designs, their implementation is not yet consistent and in-depth. This finding indicates that high school biology teachers already possess good competence in utilizing the design thinking approach, particularly in the aspects of empathy and problem formulation. However, the elements of prototype testing and strengthening the integration of 21st-century skills still require guidance. Therefore, it is recommended to provide advanced training focusing on testing strategies in project-based learning and explicit techniques for formulating and developing critical thinking, numeracy, and creative thinking skills. The direct application of project-based learning encourages students to think critically, creatively, and analytically in solving real-

world problems, making them more active, enthusiastic, and motivated in the learning process, and improving the higher-order thinking skills needed in the 21st century (Fazillah & Nisa, 2024).

The skill profile of high school biology teachers in designing Design Thinking-based teaching materials shows that teachers are already competent at the empathize and define stages. This aligns with the findings of Wulandari et al. (2024), who stated that valid and reliable assessment instruments in Biology learning are highly dependent on how well the questions and activities are designed to elicit analytical and interpretive aspects, as well as engage with real-world contexts that are close to students' experiences. Thus, the success of teachers in presenting contextual stimuli in the teaching material they create also contributes to achieving maximum scores in both of these stages. Nevertheless, this study indicates that the test stage is a weak point in the teacher-designed material, with the lowest average score. This condition is similar to the findings of Puspitasari and Rahayu (2023), who reported that although the implementation of problem-based learning with STEM integration successfully improved critical and creative thinking skills, the process still requires revision cycles and reinforcement thru user feedback to make the resulting product or prototype more mature and impactful. This means that teachers' skills in facilitating trials and gathering feedback still need to be strengthened.

In the aspect of 21st-century skills integration, particularly critical thinking, numeracy, and creative thinking, the teachers in this study demonstrated fairly good but not optimal abilities. This result aligns with the findings of Lestari & Hindun (2023), which revealed that high school students' 4C skills in Biology learning are still in the moderate to low category for critical and creative thinking, compared to communication and collaboration. This highlights the need for more explicit learning strategies to stimulate students' numeracy and creativity, rather than simply including them in the learning objectives. Further mentoring and training are important recommendations. This is supported by the study by Anwar et al. (2024), which compared inquiry and inquiry-creative models in the context of STEM learning. The results of this study showed that using a learning model that incorporates creative elements, such as ideation, prototyping, and testing, is more effective in improving prospective teachers' critical thinking skills compared to the conventional inquiry approach. In design thinking, a human-focused, prototype-driven, and innovative problem-solving strategy can be used to investigate unclear problems (Roterberg, 2020). Thus, high school teachers also need to be provided with training that emphasizes the practice of prototype testing and feedback-based reflection strategies from students.

Finally, the results of this study support the view that high school biology teachers are already at a strong level in responding to the demands of 21st-century learning, but there is still room for improvement to ensure that students' critical thinking, numeracy, and creative thinking skills develop optimally. This aligns with the results of a meta-analysis conducted by Nugraha et al. (2022), which showed that the guided discovery learning model with e-learning support has a significant effect on improving students' critical thinking skills. The implication of this research is the need for a combination of the Design Thinking approach with innovative and technology-based learning strategies to produce teaching materials that are not only "very good" in design, but also effective in improving students' 21st-century skills in learning practice.

CONCLUSION

The evaluation of three high school Biology teaching materials showed that the quality of the teacher's design was in the very good category with an average score of 3.55. The teacher demonstrated strength at the empathize and define stages with a maximum score, indicating the ability to present contextual stimuli and formulate problems clearly. However, limitations were evident in the test stage (score 3.29) and the integration of 21st-century skills, particularly critical thinking, numeracy, and creative thinking, which were still not optimal. These results confirm that high school biology teachers have strong competencies in utilizing the design thinking approach, but still require strengthening in facilitating prototype testing and explicitly applying 21st-century skills development strategies. Therefore, further mentoring and training focused on testing practices, feedback-based reflection, and the integration of innovative and technology-based learning models are needed. Thus, the developed teaching material is not only superior in design but

also capable of significantly improving students' 21st-century skills.

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