

Planning a Problem Based Learning (PBL) Model in Biology Subjects in High School: A Case Study

Widya Arwita¹, Abraham Pranata Sitinjak², Naziha Amanda³, Rayuni Istiara⁴, Delsa Mahmudah⁵,
Sheila Desiska Nasution⁶, Sri Tama Rotua Sianturi⁷
^{1, 2, 3, 4, 5, 6, 7} Universitas Negeri Medan, Indonesia

Article Info

Article history:

Received October 12, 2025

Accepted November 29, 2025

Published December 27, 2025

Keywords:

Biology;

Case Study;

High School;

Learning Planning;

Problem Based Learning.

ABSTRACT

Biology learning in the 21st century demands a shift from conventional teacher-centered methods to student-centered approaches to improve critical thinking and problem-solving skills. The Problem-Based Learning (PBL) model is one relevant approach, but its implementation is highly dependent on the quality of teacher planning. This study intends to describe and analyze in depth the PBL model planning process in biology subjects at high school. This study uses a qualitative approach with a case study method. The research subjects are biology teachers and the school's internal MGMP team. Data collection was conducted through in-depth interviews, non-participatory observation during planning meetings, and document analysis in the form of lesson implementation plans. The results of the study indicate that the PBL planning process at High School 5 Medan goes through several crucial stages: (1) Identification of essential materials suitable for PBL; (2) Formulation of problems (scenarios) that are authentic, contextual, and relevant to the student's environment; (3) Design of systematic learning steps according to PBL syntax; and (4) Development of authentic assessment instruments that focus on process and product. The main challenges faced by teachers in planning are time allocation and alignment problems with the learning outcomes set by the curriculum. This case study concludes that thorough and collaborative planning is an essential key to the successful implementation of PBL and recommends the need for ongoing professional development support for teachers in designing innovative learning.

Copyright © 2025 ETDCI.
All rights reserved.

Corresponding Author:

Widya Arwita,
Universitas Negeri Medan, Indonesia
Email: widya.amrida@gmail.com

1. INTRODUCTION

Science education, particularly biology, plays a crucial role in preparing students for adequate scientific literacy, critical thinking, and problem-solving skills needed in the 21st century (Pinar et al., 2025; Suwono et al., 2023). However, biology instruction at the high school level is often dominated by lectures and memorization, leading to students' lack of active engagement and difficulty connecting biology concepts to real-

world situations (Byukusenge et al., 2023; Christopoulos et al., 2023; Ferry, 2024; Rozikin, A., & Sanjaya, 2025). Consequently, learning outcomes, particularly in higher-order thinking skills (HOTS) and problem-solving, tend to be low (Primahesa et al., 2023; Wikanta & Susilo, 2022).

One approach believed to be effective in addressing these challenges is Problem-Based Learning (PBL). PBL is a learning model that places authentic and meaningful problems as the primary focus of the learning process (Anggraeni et al., 2023; Muzaini et al., 2022; Smith et al., 2022). In PBL, students actively collaborate to analyze problems, identify learning needs, seek relevant resources, and present solutions (Hasbi & Fitri, 2022; Hussein, 2021; Satriani et al., 2021). This model inherently encourages the development of critical thinking skills, collaboration, and independent learning, which are particularly relevant for biology (Hung & Amida, 2020; Usman et al., 2024), a subject rich in contextual issues such as health, the environment, and technology.

The Problem-Based Learning (PBL) model is a student-centered learning model that focuses on presenting problems from everyday life at the beginning of the lesson (Peranginangin, 2025). The application of the problem-based learning model is based on the idea that learning is more effective when students are directly involved in solving real problems (Permata et al., 2022), so they are able to search, find, and apply ideas in analyzing and solving problems. The problem-based learning model is very suitable for application in biology because the combination of the two can increase student interest in learning (Ananda et al., 2023; Faradila et al., 2023).

A preliminary study conducted with five biology teachers at High School 5 Medan—three 11th-grade teachers and two 10th-grade teachers—found that they had different perspectives and experiences in implementing the PBL model. The first teacher stated that she does not use the PBL model and still relies on direct instruction. The second teacher revealed that she has implemented the PBL model in biology lessons but has not yet fully implemented the syntax due to time constraints. Meanwhile, the third teacher stated that she was able to implement the PBL model across all biology materials in 11th grade with careful planning, enabling students to be more actively involved in the learning process. Interviews with two grade 10 biology teachers revealed that the PBL model has been implemented in accordance with the Independent Curriculum, but its implementation has not been optimal.

Additionally, the main obstacle encountered is group formation, which requires time, direction, and guidance from the teacher. The teachers also stated that students still need assistance in implementing the PBL syntax, indicating that student independence, as linked to the Pancasila Student Profile, is still developing. Furthermore, in group discussions, students were still passive and the atmosphere was less conducive, particularly during the inquiry stage, which involves gathering information for problem-solving.

Although the effectiveness of PBL has been widely supported by research, its implementation in the classroom often faces obstacles, particularly in the planning and learning design stages. Biology teachers need clear and practical guidance on how to design authentic problem scenarios, integrate them with a comprehensive biology

curriculum, and systematically develop PBL steps tailored to the specific school context (Nursyada et al., 2025). The success of PBL implementation is largely determined by the quality of the planning (Evendi & Verawati, 2021; Meng et al., 2023; Yu et al., 2023).

While there is a wealth of research on the effectiveness of PBL in biology, this article offers significant novelty through several aspects: (1) Focus on the In-Depth Planning Process: Most studies focus on the outcomes or effectiveness of PBL implementation (e.g., improvements in learning outcomes or skills), but rarely comprehensively dissect and document the initial planning process undertaken by teachers. This article provides an in-depth look at teachers' pedagogical decision-making in designing PBL, from topic selection to the design of authentic problem scenarios. (2) Data-Rich Contextual Case Study: As a case study, this article presents rich, context-specific planning data from one school, including teachers' planning documents (teaching modules), developed problem scenarios, and in-depth interviews with teachers regarding the rationale behind each planning decision. This provides a practical model that can be replicated and adapted by other teachers. (3) Developing an Adaptive PBL Planning Model: The results of this case study are expected to produce a practical and adaptive PBL planning framework or model for biology, which bridges the gap between PBL theory and actual practice in high school classrooms, especially regarding the integration of complex biology material and contemporary issues.

Therefore, this study aims to explore and document in detail the PBL model planning process in biology at a specific high school (case study). The focus is on identifying key components, challenges, and strategies used by teachers in designing problem scenarios, determining time allocation, and developing assessment instruments that align with PBL objectives.

2. METHOD

This research uses a qualitative approach with a case study design. The case study design was chosen because it allows the researcher to conduct an in-depth and comprehensive exploration of a contemporary phenomenon (PBL planning) within a real-life context and specific constraints. The research was conducted at High School 5 Medan, North Sumatra. High School 5 Medan was chosen based on the consideration that the school has demonstrated a commitment to implementing innovative learning models or because it has a biology teacher who has/is planning PBL implementation and is willing to be a key participant (key informant). The following is the case study design presented in Figure 1.

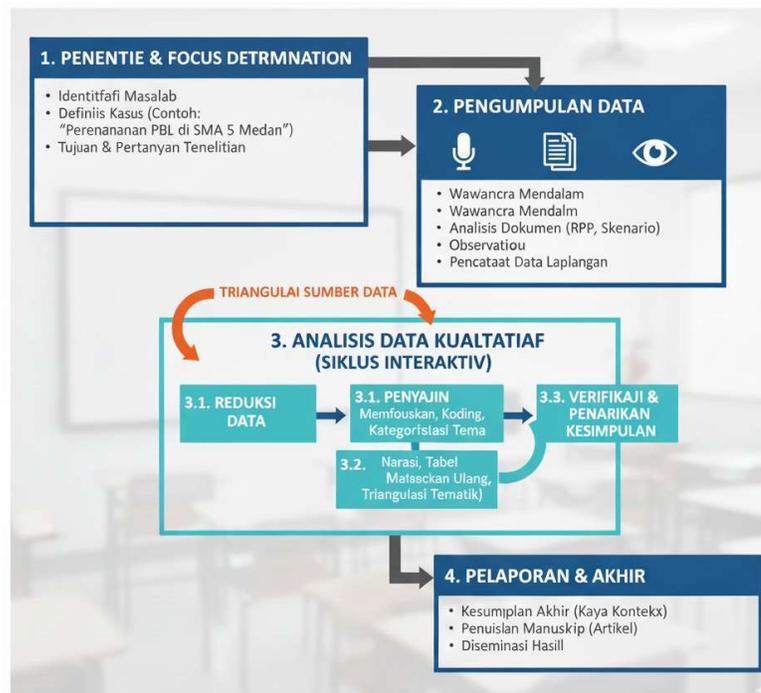


Figure 1. Research Flowchart

The key participants in this case study were (1) the biology teacher responsible for planning and implementing the PBL model in the biology class. This teacher was selected based on the criteria of having experience or currently planning lessons using the PBL model. (2) the Vice Principal for Curriculum: To obtain supporting data related to school policies regarding the implementation of innovative learning models. Data sources were obtained directly from participants through in-depth interviews. This data included teachers' perspectives, reasons, challenges, and strategies in planning PBL (e.g., selecting authentic problems and curriculum integration). Data were also obtained from official school and teacher documents and archives. Additionally, data was obtained from non-participant observations during the planning process or from initial implementation observations (to verify consistency between planning and practice).

The data collection techniques used were:

1. In-depth Interviews: Conducted with the biology teacher and the vice principal for curriculum using a semi-structured interview guide. The interviews aimed to elicit detailed information regarding why (rationality), how (process), and what (components) PBL planning was carried out.
2. Document Analysis: Analyze the lesson planning documents (teaching modules) to identify consistency between the planning and PBL principles and the applicable biology curriculum.
3. Observation: Non-participant observation is conducted during teacher planning meetings and/or at the beginning of PBL implementation to gain context and validate the collected planning data.

The collected data will be analyzed using qualitative data analysis techniques. The stages commonly used in case studies are

1. Data Collection: Collect all primary and secondary data (documents and interview transcripts).
2. Data Reduction: Select, focus, simplify, and transform raw data emerging from field notes and interview transcripts. The focus is on the PBL planning aspects.
3. Data Display: Present the reduced data in narrative form, tables, or thematic matrices to facilitate drawing conclusions.
4. Conclusion Drawing/Verification: Draw conclusions based on the findings and verify the findings through triangulation.

To ensure the validity (trustworthiness) of the data, this study will use the data source triangulation technique. Triangulation is carried out by comparing and checking information obtained from different sources, namely, comparing the results of teacher interviews (teachers' views on planning) with the planning documents (teaching modules) they created and comparing teachers' views with school policies (from the deputy head of curriculum, if interviewed). Triangulation aims to increase the credibility and internal validity of research findings.

3. RESULTS AND DISCUSSION

Results

This study's results are presented according to three aspects: the evaluation of teaching module documents, the evaluation of student worksheet materials, and the evaluation of assessment documents. The aforementioned features were employed to evaluate the planning of the PBL model concerning environmental change and preservation for grade 10, as well as the human nervous system for grade 11 at High School 5 Medan.

Assessment of Teaching Module Documents

The evaluation of the revised teaching module documents by biology instructors for grades 10 and 11 at High School 5 Medan reveals that both modules employ the PBL model for the subjects of environmental change and preservation, as well as the nervous system. The evaluation of the teaching modules offers a preliminary insight into instructor preparedness for classroom instruction. The findings of the evaluation of the teaching module papers are displayed in Table 1.

Table 1. Results of Assessment of Teaching Module Documents

Aspect	Indicator	Evaluation	
		Teacher Teaching Module X-11	Teacher Teaching Module XI-11
General Information	Module Identity	Good	Good
	Beginning Competencies	Good	Good
	Pancasila Student Profile	Good	Good
	Facilities and Infrastructure	Good	Good
Core Components	Target Students	Good	Good
	Learning Model	Good	Good
	Learning Objectives	Good	Good

Aspect	Indicator	Evaluation	
		Teacher Teaching Module X-11	Teacher Teaching Module XI-11
Attachment	Meaningful Understanding	Good	Good
	Leading Questions	Good	Good
	Learning Activities	Good	Good
	Introductory Activities	Good	Good
	Main Activities (Problem Orientation)	Good	Good
	Main Activities (Organizing Students)	Good	Good
	Main Activities (Guiding Investigations)	Good	Good
	Main Activities (Developing & Presenting Results)	Good	Good
	Main Activities (Analyzing & Evaluating Problems)	Good	Good
	Closing Activities	Good	Good
	Assessment	Good	Good
	Enrichment and Remedial Learning	Good	Good
	Teacher and Student Reflections	Good	Not Good
	Student Worksheets	Not Good	Not Good
Reading Materials	Good	Good	
Glossary	Good	Good	
Bibliography	Good	Good	

The results of the teaching module assessment presented in Table 1, along with the teaching module documents on environmental change and preservation for grade 10 and the nervous system for grade 11, compiled by the biology instructors for grades 10 and 11 at High School 5 Medan, are well-organized. In conclusion, both teaching modules are well-structured and exhibit a sufficient comprehension of the concepts of designing instructional materials. Both modules conform to the essential elements of a teaching module and satisfy most of the criteria for organizing learning through the PBL approach. Nonetheless, there exists potential for enhancement, especially with the comprehensiveness and quality of the appendices, notably in the formulation of the Student Worksheet and learning reflections, which require additional refinement to facilitate the attainment of overarching learning objectives.

Student Worksheet Document Assessment

This study evaluated the quality of student worksheet papers created by biology teachers for grades 10 and 11, focusing on the content of the documents. The evaluation concentrated on the thoroughness of critical elements, adherence to educational objectives, and compliance with the PBL model's syntax. The studied data comprised two Student Worksheet documents, each created by a teacher. The analysis findings are displayed in Table 2.

Table 2. Student Worksheet Document Assessment Results

Aspect	Indicator	Student Worksheet for Grade 10 Teachers	Student Worksheet for Grade 11 Teachers
Student Worksheet Title and Identity	Format Compliance or Completeness of Identity	Good	Good
Student Worksheet	Learning Objectives	Good	Good
Instructions and Guidelines	Instructions and Guidelines	Good	Good
Core Activities	PBL Syntax Compliance	Not Good	Not Good
	Problem Compliance with Student Worksheets	Good	Good
	Content and Material in Student Worksheets	Good	Good
	Initial Problems in Student Worksheets	Good	Good
Student Activities	Discussion and Collaboration Activities in Student Worksheets	Good	Good
	Problem Solving and Solutions in Student Worksheets	Good	Good
Assessment	Assessment Completeness	Good	Good

The examination of the student worksheets for grade 10 and 11 biology instructors at High School 5 Medan, as illustrated in Table 2, indicates that both student worksheets were effectively constructed and predominantly satisfied the criteria for facilitating the PBL model. Moreover, both student worksheets were classified as "good" in nearly all evaluation criteria. The learning objectives in both student worksheets were aligned with those in the instructional modules. This signifies a strong alignment between the planning of the teaching modules and the student worksheets as a framework for classroom execution. The issues outlined in both student worksheets were intended to stimulate active thinking, discussion, and collaboration among students. The issues identified were also connected to the topic matter and its contextual surroundings.

Document Assessment

This study evaluated assessment documents to determine the quality of exams created by biology teachers for grades 10 and 11, focusing on their content. The studied data comprised two assessment documents and was restricted to the evaluations articulated in the instructional modules developed by the two educators. The analysis findings are displayed in Table 3.

Table 3. Assessment Document Assessment Results

Aspect	Indicator	Class X Teacher	Class XI Teacher
Penerapan pola pikir bertumbuh	Clarity of supporting assessments	Good	Good

Aspect	Indicator	Class X Teacher	Class XI Teacher
Terpadu	Quality of knowledge, skills, and attitude assessment	Good	Good
	Quality of attitude assessment	Good	Good
	Quality of knowledge assessment	Good	Good
	Quality of skill assessment	Good	Good
Flexibility in determining assessment timing	Formative Assessment	Good	Good
Flexibility in using assessment techniques	Assessment Techniques	Good	Good
Flexibility in processing assessment results	Assessment	Good	Good

The examination of assessment papers, illustrated in Table 3, inside the biology teaching modules for grades 10 and 11 at High School 5 Medan, reveals that educators have created extensive assessment instruments to facilitate the execution of PBL-based learning. Both encompass many assessment methodologies that evaluate knowledge, abilities, and attitudes, while fostering the cultivation of a growth mindset among pupils.

Both teacher-designed exams can be classified as "good" across nearly all evaluation criteria. The educators have effectively crafted attitude evaluations. Teachers have developed thorough and detailed skills assessment rubrics, incorporating distinct evaluations for group discussions and presentations, as well as criteria for meeting learning objectives. Evaluations in the knowledge domain employ multiple-choice questions and are aligned with the intended learning objectives. The preliminary conclusion indicates that the assessment documents created by the grade 10 and 11 biology instructors at High School 5 Medan generally adhere to the principles of effective assessment: they are integrated, equitable, diverse, conducive to student learning advancement, and reflect robust planning direction.

Interview Results

In-depth interviews with biology teachers revealed several key findings related to the rationale, process, and challenges of PBL planning.

Rationale and Selection of PBL Topics

Both biology teachers agreed that PBL was chosen as an effort to improve critical thinking skills and the relevance of the material to students' real lives.

Teacher A: "We feel that the 11th grade biology material on the excretory system is simply memorized. With PBL, we can raise issues of kidney failure in society or the dangers of smoking. This makes students see biology as alive."

Teacher B: "Here (at State Senior High School 5 Medan), we apply PBL primarily to topics that pose strong controversies or social issues, such as environmental pollution or endemic diseases. The goal is for students to learn not only the theory but also the solutions."

The topics most frequently planned to use PBL are those related to ecology (environmental pollution), human organ systems (diseases), and biotechnology.

Authentic Problem Scenario Design Process

- The planning process carried out by teachers begins with identifying a problem that must meet the criteria of authenticity, relevance, and open-endedness (ill-structured).
- Problem Source Identification: Teacher A tends to use local news or case studies that have gone viral on social media, while Teacher B prefers data from the nearest community health center or environmental issues around Medan City.
- Curriculum Adaptation: The biggest challenge is the limited time available in class. Both teachers acknowledged that they had to select key sub-topics that could be covered by the problem scenario, with the remainder assigned as independent assignments.
- Problem Statement: Teachers create problems in the form of narratives or trigger videos that do not provide direct clues to the answer but instead force students to identify knowledge gaps they must explore (a key principle of PBL).

Teacher A: "I have to create a compelling problem statement, for example, about stunting cases in a particular village. Students should be confused: is this a nutritional, social, or biological issue? That confusion will drive them to investigate."

Assessment Planning

The assessment aspects planned by both teachers emphasize process and product assessment.

- Process Assessment: Conducted through observation sheets during group collaboration sessions, focusing on communication skills, collaboration, and independent learning.
- Product Assessment: In the form of the final product of problem-solving (e.g., a scientific report, campaign poster, or solution presentation). Teachers ensure that the assessment instrument (rubric) is clearly linked to the learning objectives and problem-solving criteria.

Observation Results

Observations were conducted on the lesson planning documents (teaching modules) designed by Teachers A and B, as well as brief observations of the classrooms used.

Planning Documentation (Teaching Modules)

Analysis of the planning documents found consistency between PBL theory and the implementation of its steps.

Table 4. Observation Results

Planning Components	Findings in the Teaching Module
Phase 1: Problem Orientation	There is a clear attachment of Authentic Problem Scenarios (in the form of long narrative texts or news video links).
Phase 2: Organizing Students	It includes heterogeneous group divisions and the teacher's role as a facilitator (coaching).
Phase 3: Guiding Inquiry	The teacher lists recommended primary and secondary learning resources (textbooks, journals, websites).
Phase 4: Developing & presenting	It includes detailed instructions on the final product format (e.g., creating a digital infographic or a mini-solution proposal).
Time Allocation	The time allocation is dominated by Phases 3 and 4 (approximately 70% of the total time) to allow space for in-depth investigation and solution development.

Learning Environment (Context of High School 5 Medan)

- Infrastructure Support: The school provides an adequate biology laboratory and Wi-Fi access to support students' data and resource search phases. This availability is explicitly integrated into the teacher's planning steps (e.g., online searching or data collection sessions in the lab).
- Resource Availability: The planning documents indicate that the teacher utilizes local resources (such as access to the school's online journal subscription) as references for students to ensure the data used in problem-solving is valid and scientific.
- Classroom Arrangement: The planning document mentions the use of group seating arrangements (U-groups or clusters) during PBL sessions, differing from the traditional classroom arrangement during conventional learning. This facilitates interaction and collaboration, as required by the PBL model.

Triangulation of Findings

We found high consistency through triangulation (comparison) between teacher interviews and document analysis of teaching modules. For example, teachers' focus on "improving collaboration skills" (Interview) was reflected in their use of "collaboration assessment rubrics" and "cluster seating arrangements" (Document/Classroom Observations). This confirms that the PBL planning conducted at High School 5 Medan was systematic and detailed.

Discussion

This discussion section will analyze research findings regarding the planning of the PBL model at High School 5 Medan and relate them to the theoretical principles of Problem-Based Learning (PBL) and the context of biology learning. Lesson planning is a crucial initial step in implementing the problem-based learning model. At this stage, teachers are responsible for designing a comprehensive and systematic lesson plan. Aspects of lesson planning include teaching modules, worksheets, and assessments developed by the teacher prior to the lesson.

Assessment of Teaching Module Documents

An examination of two biology teaching modules for grades 10 and 11 at High School 5 Medan revealed that both completely integrate the PBL model framework, featuring problems pertinent to students' everyday experiences. The chosen biology material for the PBL model planning was considered suitable for fostering critical thinking and problem-solving abilities in students. The two observed teaching modules were well-organized and fulfilled the majority of the specified assessment criteria.

[Rochim et al. \(2024\)](#) elucidated that structured lesson planning enables teachers to instruct more effectively, while students obtain enhanced support in their learning endeavors. The elements of the two biology teaching modules for grades 10 and 11 at High School 5 Medan were found to be sufficiently aligned with the standards for teaching module components in the independent curriculum. This aligns with the assertion by [Salsabilla et al. \(2023\)](#) that teaching modules typically comprise general information, core components, and appendices.

Assessment of Student Worksheet Documents

An examination of two Biology Student Worksheet documents for grades 10 and 11 at High School 5 Medan revealed that both utilized student worksheets to apply the problem-based learning model on subjects including environmental change and preservation, as well as the human nervous system. In the implementation of the Independent Curriculum, which emphasizes learning outcomes, the planning of the Teaching Module acts as the principal reference for creating teaching materials, such as the Student Worksheets. A proficient student worksheet must be meticulously crafted to ensure coherence with the teaching module planning. This alignment is evidenced by research findings indicating that the learning objectives in the student worksheets for grade 10 biology teachers are consistently articulated with those in the teaching modules. This illustrates the congruence between the planning of the teaching module and the student worksheets as a framework for classroom execution. According to [Istiqomah \(2021\)](#), alignment between the objectives of the Student Worksheet and the learning objectives guarantees that the activities within the Student Worksheet facilitate the attainment of competencies outlined in the teaching module.

The analysis indicates that the activities in the Student Worksheet generally embody the principles of problem-based learning. The Student Worksheet for teachers of grades 10 and 11 in student activities fails to conform to the principles of problem-based learning syntax. While the syntax is not explicitly articulated, the activities nonetheless encompass it, including group segmentation and information dissemination. This finding corresponds with [Syamsi and Fitrihidajati \(2021\)](#), who asserted that student worksheets in problem-based learning modules must explicitly delineate the syntax stages to facilitate concentrated learning and conform to the problem-based model.

Assessment Document Assessment

An examination of two evaluation documents for grade 10 and 11 biology instructors at High School 5 Medan revealed that both assessments were constructed in alignment

with the criteria outlined in the independent curriculum. Assessment is essential in the learning process as a means of evaluating student competency attainment (Krstikj et al., 2022). Consequently, the development of assessments must be executed meticulously and methodically to ensure that the outcomes accurately reflect student capabilities. The assessment was crafted with careful consideration of and compliance with universally applicable assessment principles.

This study's findings reveal that in the biology teaching modules for grades 10 and 11 at High School 5 Medan, educators have created extensive assessment instruments to facilitate the execution of problem-based learning. Both encompass diverse assessment modalities addressing knowledge, skills, and attitudes, while fostering the cultivation of a growth mindset in students. This aligns with Hadiansah (2022), who delineated the components of an assessment as (1) application of a growth mindset, (2) integration, (3) flexibility in determining assessments, (4) flexibility in employing assessment techniques, and (5) flexibility in processing assessment results.

Rationale for PBL Planning to Improve 21st-Century Skills

Interview findings indicate that Teachers A and B's decision to adopt PBL was based on a strong desire to overcome rote learning in biology and to improve students' critical thinking skills. This rationale aligns closely with the primary goal of PBL, which is rooted in constructivist theory (Hung et al., 2019; Schmidt et al., 2019).

- Contextual Connections: The use of local issues such as stunting cases or environmental pollution in Medan as sources of problems (as revealed by Teachers A and B) demonstrates that the teachers have successfully integrated the principle of authenticity into PBL planning. This authenticity is particularly important in biology, as it enables students to see the relevance of science to real-life social and environmental problems.
- Scientific Literacy: Planning topics involving social controversies demonstrates that teachers aim to develop students' scientific literacy, the ability to use scientific knowledge to understand and make decisions regarding social issues (OECD, 2018).

Challenges and Strategies in Designing Authentic Problem Scenarios

Interviews and document analysis showed that the main goal of planning was to come up with ill-structured problem scenarios. Ill-structured scenarios force students to define their problems, which is a critical initial step in the PBL cycle (Jaelani et al., 2023; Riis et al., 2017; Shipton, 2023).

- Curriculum Time Management: Both teachers faced classic PBL challenges, namely curriculum density and limited time allocation. Their strategy of focusing PBL on only key subtopics and making the remaining material independent assignments was a practical solution to balance curriculum demands without sacrificing the quality of PBL's in-depth inquiry.

- The Role of Video Triggers: The use of video triggers and narratives from local news in planning demonstrates the use of digital media to create "cognitive dissonance," effectively motivating students to engage in independent inquiry.

Integration of School Infrastructure in Planning

Observations indicate a strong correlation between teacher planning and infrastructure support at High School 5 Medan. Teacher planning explicitly includes the use of Wi-Fi access and a biology laboratory. PBL as Independent Learning: The availability and planning of these resources support the Guiding Independent Inquiry phase (Phase 3 of PBL), in which students need to seek diverse data and information sources. This feature demonstrates that planning should not only focus on classroom activities but also on learning resources outside the classroom.

Consistency of Process and Product Assessment

The teacher's assessment planning shows that they understand the requirements for PBL assessments, which include both the process (collaboration and self-directed learning) and the product (solution).

- Formative Assessment (Process): The emphasis on observation rubrics during group work (as reflected in the lesson plan) supports the teacher's role as a facilitator who monitors the development of students' non-cognitive skills, which are often overlooked in traditional assessments.
- Summative Assessment (Product): The use of digital infographics or mini-proposals as the final product reflects the teacher's efforts to integrate digital skills and scientific communication (solution presentation skills) into the biology curriculum, in line with the demands of 21st-century skills.

This case study provides theoretical and practical contributions by providing a feasible PBL planning model in the context of High School 5 Medan. This documented planning can serve as a practical guide (best practice) for other biology teachers, particularly in adapting authentic local problems into effective PBL scenarios. Overall, the PBL planning process at High School 5 Medan demonstrated systematic and detailed implementation, which successfully bridged the gap between PBL theory and real practice in biology subjects.

4. CONCLUSION

Teachers have planned their lessons using the problem-based learning model well, as demonstrated by the development of learning materials such as teaching modules, student worksheets, and assessments that have been adapted to its characteristics. However, the structured PBL syntax within the students' worksheets is still lacking. Additionally, the interview results show that PBL planning was driven by the need to improve students' critical thinking, problem-solving, and real-life biology skills. Teachers consciously chose PBL to shift away from rote-based learning. The planning process at High School 5 Medan was systematic, focusing on three main aspects: (1) selecting an authentic, local, ill-structured problem (e.g., stunting or local pollution), (2)

adapting the time allocation of the dense biology curriculum by prioritizing the investigation and solution presentation phases, and (3) explicitly integrating school resources (the biology lab and digital access) into the PBL steps. Assessment planning was consistent with PBL principles, emphasizing process assessment (collaboration and independent learning) through observation sheets and final product assessment (infographics/solution proposals). Overall, the PBL planning carried out by biology teachers at High School 5 Medan can be an adaptive planning model, successfully bridging PBL theory with practical challenges in the field by utilizing local issues and optimizing school infrastructure.

As a suggestion, teachers are advised to continue to strengthen the consistency between planning and implementation, especially in maintaining the authentic and unstructured nature of PBL problems so that students are truly involved in the process of identifying and defining problems. Schools and biology teachers are advised to create a database of PBL problem scenarios based on contemporary and local issues in Medan City so that it is easier for other teachers to plan PBL implementation on different biology topics. Further training is needed for teachers on the development and use of comprehensive assessment rubrics that are able to measure all dimensions of PBL, including metacognition and students' self-directed learning. In addition, further research is recommended to continue this case study by focusing on the implementation process (classroom observation) and the real impact of PBL planning on student learning outcomes, especially on the dimensions of higher-order thinking skills (HOTS) and scientific literacy.

REFERENCES

- Ananda, Y., Rahmatan, H., & Huda, I. (2023). Application of the video-assisted problem based learning model to increase student learning motivation in virus material. *Jurnal Penelitian Pendidikan IPA*, 9(8), 6230-6237. <https://doi.org/10.29303/jppipa.v9i8.4766>
- Anggraeni, D. M., Prahani, B. K., Suprpto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, 49, 101334. <https://doi.org/10.1016/j.tsc.2023.101334>
- Byukusenge, C., Nsanganwimana, F., & Paulo Tarmo, A. (2023). Difficult topics in the revised biology curriculum for advanced level secondary schools in Rwanda: teachers' perceptions of causes and remedies. *Journal of Biological Education*, 57(5), 1112-1128. <https://doi.org/10.1080/00219266.2021.2012225>
- Christopoulos, A., Pellas, N., Bin Qushem, U., & Laakso, M. J. (2023). Comparing the effectiveness of video and stereoscopic 360° virtual reality-supported instruction in high school biology courses. *British Journal of Educational Technology*, 54(4), 987-1005. <https://doi.org/10.1111/bjet.13306>
- Evendi, E., & Verawati, N. N. S. P. (2021). Evaluation of student learning outcomes in problem-based learning: study of its implementation and reflection of successful factors. *Jurnal Penelitian Pendidikan IPA*, 7(SpecialIssue), 69-76. <https://doi.org/10.29303/jppipa.v7iSpecialIssue.1099>

- Faradila, A., Prafitasari, A. N., & Farida, A. (2023). Integrated Paired Literacy Model Problem-Based Learning to Improve Biology Learning Outcomes. *Bioeduca: Journal of Biology Education*, 5(2), 133-142. <https://doi.org/10.21580/bioeduca.v5i2.17310>
- Ferry, D. (2024). Analisis kesulitan belajar siswa pada mata pelajaran biologi di SMA. *Biosfer: Jurnal Biologi dan Pendidikan Biologi*, 9(2), 172-181. <https://doi.org/10.23969/biosfer.v9i2.18613>
- Hadiansah, D. (2022). *Kurikulum Merdeka dan Paradigma Pembelajaran Baru*. Bandung: Yrama Widya.
- Hasbi, M., & Fitri, F. (2023). Pre-Service Teachers with Courses in Problem-Based Learning in Mathematics. *ETDC: Indonesian Journal of Research and Educational Review*, 2(2), 51-60. <https://doi.org/10.51574/ijrer.v2i2.588>
- Hung, W., Moallem, M., & Dabbagh, N. (2019). Social foundations of problem-based learning. *The Wiley handbook of problem-based learning*, 51-79. <https://doi.org/10.1002/9781119173243.ch3>
- Hung, W., & Amida, A. (2020). Problem-based learning in college science. In *Active learning in college science: The case for evidence-based practice* (pp. 325-339). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-33600-4_21
- Hussein, B. (2021). Addressing collaboration challenges in project-based learning: The student's perspective. *Education Sciences*, 11(8), 434. <https://doi.org/10.3390/educsci11080434>
- Istiqomah, E. (2021). Analisis lembar kerja peserta didik (LKPD) sebagai bahan ajar biologi. *Alveoli: Jurnal Pendidikan Biologi*, 2(1), 1-15.
- Jaelani, A. K., Hasbi, M., & Baharullah, B. (2023). A critical thinking profile of mathematics education students in solving ill-structured problem based on mathematical ability. *JTAM (Jurnal Teori dan Aplikasi Matematika)*, 7(2), 545-559. <https://doi.org/10.31764/jtam.v7i2.13378>
- Krstikj, A., Sosa Godina, J., García Bañuelos, L., González Peña, O. I., Quintero Milián, H. N., Urbina Coronado, P. D., & Vanoye García, A. Y. (2022). Analysis of competency assessment of educational innovation in upper secondary school and higher education: a mapping review. *Sustainability*, 14(13), 8089. <https://doi.org/10.3390/su14138089>
- Meng, N., Dong, Y., Roehrs, D., & Luan, L. (2023). Tackle implementation challenges in project-based learning: a survey study of PBL e-learning platforms. *Educational technology research and development*, 71(3), 1179-1207. <https://doi.org/10.1007/s11423-023-10202-7>
- Muzaini, M., Hasbi, M., Ernawati, E., & Kristiawati, K. (2022). The empowerment of problem-based learning models to improve students' quantitative reasoning. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 12(1), 11-24. <http://dx.doi.org/10.30998/formatif.v12i1.8502>
- Nursyada, A. P., Fadilah, S. N., Auranazwa, K., Wangi, R. R. P. L., Hidayat, N. P., Ramadhani, N., & Usman, U. (2025). Kurikulum Berbasis Sosio-Saintifik dalam Pembelajaran Biologi. *Innovative: Journal Of Social Science Research*, 5(3), 6303-6321. <https://doi.org/10.31004/innovative.v5i3.19734>
- Peranginangin, A. P. (2025). The application of problem-based learning model to improve students' mathematical problem-solving skills in junior high school. *Jurnal Info Sains: Informatika dan Sains*, 15(01), 140-150. <https://ejournal.seaninstitute.or.id/index.php/InfoSains/article/view/7057>

- Permata, S. A. I., Sunarno, W., & Harlita, H. (2022). The effect of the problem based learning and double loop problem solving learning models on problem solving ability in term of creative thinking on environmental pollution material. *Jurnal Penelitian Pendidikan IPA*, 8(6), 2647-2653. <https://doi.org/10.29303/jppipa.v8i6.1996>
- Pinar, F. I. L., Panergayo, A. A. E., Sagcal, R. R., Acut, D. P., Roleda, L. S., & Prudente, M. S. (2025). Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: a meta-analysis. *Disciplinary and Interdisciplinary Science Education Research*, 7(1), 18. <https://doi.org/10.1186/s43031-025-00137-9>
- Primahesa, A., Sajidan, S., & Ramli, M. (2023). Improving higher order thinking skills in high school biology: A systematic review. *Biosfer: Jurnal Pendidikan Biologi*, 16(1), 206-219. <https://doi.org/10.21009/biosferjpb.26724>
- Riis, J. O., Achenbach, M., Israelsen, P., Kyvsgaard Hansen, P., Johansen, J., & Deuse, J. (2017). Dealing with complex and ill-structured problems: Results of a Plan-Do-Check-Act experiment in a business engineering semester. *European Journal of Engineering Education*, 42(4), 396-412. <https://doi.org/10.1080/03043797.2016.1189881>
- Rochim, A. A., Baharung, S., & Isnaini, I. (2024). Perencanaan Pembelajaran Biologi Berbasis Project Based Learning pada Kurikulum Merdeka di SMAN 1 Bungku Tengah. *Jurnal Pendidikan Tambusai*, 8(2).
- Rozikin, A., & Sanjaya, E. (2025). Penerapan Pendekatan Saintifik dalam Pembelajaran Biologi untuk Meningkatkan Minat Belajar Siswa SMA 8 Surabaya. *Journal of Science and Mathematics Education*, 1(2), 55-62. <https://doi.org/10.70716/josme.v1i2.177>
- Salsabilla, I. I., Jannah, E., & Juanda, J. (2023). Analisis modul ajar berbasis kurikulum merdeka. *Jurnal Literasi Dan Pembelajaran Indonesia*, 3(1), 33-41. <https://jurnal.fkip.samawa-university.ac.id/JLPI/article/view/384>
- Satriani, S., Hasbi, M., Amiruddin., & Fahirah, A. (2021). Problem-Based Learning as a Facilitator Of Students' reading Comprehension. *SOKO GURU: Jurnal Ilmu Pendidikan*, 1(3), 27-34. <https://doi.org/10.55606/sokoguru.v1i3.140>
- Schmidt, H. G., Rotgans, J. I., & Yew, E. H. (2019). Cognitive constructivist foundations of problem-based learning. *The Wiley Handbook of problem-based learning*, 25-50. <https://doi.org/10.1002/9781119173243.ch2>
- Shipton, B. (2023). Problem-Based Learning. In *Signature Pedagogies in Police Education: Teaching Recruits to Think, Perform and Act with Integrity* (pp. 53-67). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-42387-1_5
- Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., ... & Smith, T. (2022). Principles of problem-based learning (PBL) in STEM education: Using expert wisdom and research to frame educational practice. *Education Sciences*, 12(10), 728. <https://doi.org/10.3390/educsci12100728>
- Suwono, H., Rofi'Ah, N. L., Saefi, M., & Fachrunnisa, R. (2023). Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking. *Journal of Biological Education*, 57(5), 944-959. <https://doi.org/10.1080/00219266.2021.2006270>
- Syamsi, A. N., & Fitrihidajati, H. (2021). Validitas lembar kegiatan peserta didik (LKPD) berbasis problem based learning (PBL) pada materi perubahan lingkungan untuk melatih keterampilan berpikir kritis siswa kelas X SMA. *Berkala Ilmiah Pendidikan Biologi (BioEdu)*, 10(2), 397-402. <https://doi.org/10.26740/bioedu.v10n2.p397-402>

- Usman, N. F., Mustaqimah, N., & Latjompoh, M. (2024). Needs Analysis for The Development of Biology E-Modules Based on Project-Oriented Problem-Based Learning (POPBL) to Improve Students' Critical Thinking, Creativity, and Collaboration Skillss. *Jurnal Penelitian Pendidikan IPA*, 10(12), 10859-10867. <https://doi.org/10.29303/jppipa.v10i12.9395>
- Wikanta, W., & Susilo, H. (2022). Higher order thinking skills achievement for biology education students in case-based biochemistry learning. *International Journal of Instruction*, 15(4), 835-854. <https://e-iji.net/ats/index.php/pub/article/view/290>
- Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. In *Frontiers in Education* (Vol. 8, p. 1139987). Frontiers Media SA. <https://doi.org/10.3389/feduc.2023.1139987>