

## Exploring the implementation of the merdeka curriculum in biology education: A qualitative study at an Indonesian upper secondary school

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### ABSTRACT

This study aims to describe the implementation of the Merdeka Curriculum in Biology learning at SMA Negeri 1 Sibolga and to analyze its supporting and inhibiting factors. The study was conducted in the odd semester of the 2024-2025 academic year using a descriptive qualitative approach. Data collection techniques included observation, interviews, and documentation. The results show that the implementation of the Merdeka Curriculum in Biology was carried out gradually. Teachers showed strong enthusiasm and initiative in understanding and applying curriculum principles such as differentiated learning and project-based learning. The school supported this effort by providing a Biology laboratory, digital learning resources, and internal training. However, several challenges emerged, including unequal teacher understanding of the curriculum, difficulties in preparing teaching materials aligned with the learning outcome, and limited practical training. Learning evaluation was conducted regularly through formative assessments and classroom observations. Routine reflection served as a crucial means of improving instruction. The study concludes that the success of curriculum implementation is strongly influenced by teacher readiness, school support, and active student engagement. Strengthening teacher capacity and inter-teacher collaboration is recommended as a strategic step to optimize curriculum implementation.

**Keywords:** Implementation, merdeka curriculum, biology, SMA Negeri 1 Sibolga

### INTRODUCTION

The rapid development of science and technology is one of the main factors that encourage curriculum change (Ahmad et al., 2024; Muhamad et al., 2024; Wahidmurni et al., 2024). According to Huapaya et al., (2025) and Sebele-Mpofu (2024) an unchanging curriculum is no longer sufficient to answer the needs of students in facing various challenges and opportunities in the future. Therefore, curriculum renewal is a must for education to remain relevant, responsive and able to equip students with competencies that are in line with the times.

Changes in the education curriculum are also influenced by various social dynamics that develop in society, including advances in industry, technology, production patterns, as well as the direction of political policy and state governance (Sebele-Mpofu, 2024). In line with the growth of the industrial sector, the need for a highly skilled workforce with workplace-appropriate capabilities is becoming increasingly important. Therefore, the curriculum needs to be updated in order to produce graduates who are ready to compete and contribute to the growing industrial sector.

Curriculum change is a necessity in the education system in various countries around

the world. Each country periodically reviews and updates the curriculum to adapt to the development of science, technology, community needs, and the challenges of the times (Kelly, 2009). Indonesia is not exempt from this dynamic. Therefore, before discussing specifically the journey of the Indonesian national curriculum from 1947 to 2013, it is important to first understand that curriculum change is not a unique or stand-alone phenomenon. This concept is in line with Schleicher (2018) statement that developed and developing countries, such as the United States, Japan, and Finland, are also carrying out curriculum reforms as an effort to improve the quality of education and prepare students to face global demands. By understanding this context, the discussion regarding the evolution of the curriculum in Indonesia will be more focused and relevant within the framework of global educational thinking.

Since the implementation of the curriculum in 1947 until Curriculum 2013, the main focus of education has been on developing basic competencies, character and 21st century skills. However, there are still a number of shortcomings that need to be addressed, such as the lack of flexibility in the learning process, the lack of student participation in honing critical thinking skills, and the lack of optimal integration of technology in education (Anas et al., 2025; Ridwanulloh et al., 2024; Supratman et al., 2023). In addition, strengthening character in more depth and its application in everyday life is also still a challenge that needs to be overcome (Musyawir et al., 2024).

The evaluation of Curriculum 2013 revealed a number of weaknesses, such as overcrowded learning materials, lack of integration between education levels, high administrative burden for teachers, and limited flexibility in its application in the field. These conditions make it difficult to adapt the curriculum to the specific needs of regions, schools and students (Febriyenti et al., 2023). In response to these issues, the Merdeka

Curriculum was developed with a more flexible approach, allowing learning to be tailored to students' potential and interests. The Merdeka Curriculum has a role in Indonesian education that provides flexibility for schools and teachers to adapt learning to the needs and potential of students (Fajarudin, 2023; Minsih et al., 2023; Yoto et al., 2024). This explanation is in line with the results of research Chotimah et al., (2025) and Wijayanti et al., (2024), which reveal that the Merdeka Curriculum encourages an education system that is more inclusive, relevant, and responsive to the dynamics of the times.

Based on the results of initial observations at SMA Negeri 1 Sibolga, it shows that the implementation of the Merdeka Curriculum in Biology has started to run with a more student-centred learning approach. Teachers relate material to environmental conditions, such as biodiversity and local problems, and apply project-based learning to improve students' critical thinking skills and cooperation. However, some obstacles are still encountered, such as limited laboratory facilities and uneven teacher understanding of the Merdeka Curriculum, especially in planning assessments and preparing independent teaching modules. Even so, the enthusiasm of teachers and students is quite high, so that with the support of training and more adequate facilities, the implementation of this curriculum can run more optimally at SMA Negeri 1 Sibolga.

This research is important because the implementation of Merdeka Curriculum aims to improve the quality of education with a more meaningful learning experience, especially at SMA Negeri 1 Sibolga. However, empirical data on its application in the high school Biology subject is still minimal. Without understanding the practices and challenges in the field, curriculum development can be inappropriate. This research is expected to provide a comprehensive picture of learning planning, implementation and evaluation as well as supporting factors and constraints. The results

will be a scientific contribution as well as recommendations for schools, teachers, and policy makers to improve the effectiveness of Biology learning and the implementation of Merdeka Curriculum.

Although Merdeka Curriculum has been widely discussed in various literatures, most of the existing studies are still conceptual and normative, emphasising the philosophical foundation, curriculum structure, and general approaches used. However, there have not been many empirical studies that specifically evaluate how this curriculum is implemented in the context of Biology subjects at the senior high school level, especially in an out-of-centre area such as Sibolga City. In addition, previous studies tend to generalise the implementation challenges without looking at the specificities of science subjects that demand practical approaches, understanding of scientific concepts, and integration of technology. Thus, this research is present to fill this gap by conducting a field study directly at SMA Negeri 1 Sibolga, to explore the reality of the implementation of the Merdeka Curriculum in Biology learning. This research is different from previous studies because it emphasises the empirical experience of teachers and students, and examines in depth the supporting and inhibiting factors at the implementation level, not just examining the policy or curriculum in general.

This research, which focuses on the implementation of the Merdeka Curriculum in Biology lessons at SMA Negeri 1 Sibolga, is in line with various previous studies that highlight the dynamics of implementing this curriculum in various educational units. Previous research, such as that conducted by [Maya et al., \(2025\)](#) shows that the implementation of the Merdeka Curriculum provides flexibility for teachers in designing contextual and learner-centred learning, especially in science subjects. This is reinforced by the findings of [Rahmawati dan Nurwiyati & Yulianto \(2024\)](#) who stated that in Biology subjects, the Merdeka Curriculum opens

space for a project-based learning approach and exploration of the surrounding environment as a learning resource. Meanwhile, a study by [Prihatien et al., \(2023\)](#) found that the obstacles in implementing this curriculum are generally related to teacher readiness, availability of facilities, and understanding of the principles of learning differentiation. By examining the implementation of this curriculum specifically at SMA Negeri 1 Sibolga, this study aims to provide a contextual picture of the successes and real challenges faced by biology teachers, as well as enrich the empirical discourse on the implementation of Merdeka Curriculum in Biology subjects at the senior high school level.

To answer this problem, this study aims to (1) deeply analyse the implementation of Merdeka Curriculum in Biology subjects at SMA Negeri 1, (2) review aspects of learning planning, implementation, and evaluation as well as their impact on the teaching and learning process, and (3) identify factors that support and hinder curriculum implementation, in order to become the basis for future development recommendations.

## METHOD

This study uses a qualitative approach with a basic qualitative research design, as explained by [Ary et al., \(2010\)](#) which aims to gain an in-depth understanding of the implementation process of the Merdeka Curriculum, especially in Biology subjects at the high school level. This design was chosen because this study focuses on the meaning, perceptions, and experiences of education actors, not on quantitative aspects or generalization of results.

This research was conducted at SMA Negeri 1 Sibolga located in Sibolga City, North Sumatra. The research was conducted from February to April 2025. The subjects in this study included four biology teachers who taught grades X and XI as direct implementers of the Merdeka Curriculum, four students from each

grade X and XI as learning participants and one Vice Principal for Curriculum who has the responsibility for managing and supervising the implementation of the curriculum in schools. The four biology teachers consisted of one male and three females, with an age range of 33 to 50 years. They have teaching experience of between 7 and 18 years and all have participated in the Merdeka Curriculum training organized by the Ministry of Education, Culture, Research, and Technology. Meanwhile, the Vice Principal for Curriculum who participated in this study was 55 years old and had served in his position for five years, with the main responsibility for managing and supervising the implementation of the curriculum in schools. The selection of subjects was carried out purposively by considering their involvement and relevance to the implementation of the Merdeka Curriculum.

Data collection was conducted through in-depth interviews, observations, and documentation studies. Interviews were conducted with four biology teachers and the vice principal to explore their understanding, experiences, and practices in planning, implementing, and evaluating the Merdeka Curriculum learning. Interviews were conducted face-to-face, using Indonesian, with a duration of around 15 to 30 minutes per session. The questions were open-ended, covering aspects such as learning planning, implementation of differentiated learning, student involvement in learning, and supporting and inhibiting factors in the implementation of the Merdeka Curriculum. In addition, the interviews also explored information about the participants' backgrounds, including age, teaching experience, and curriculum training. Observations were conducted during three meetings for each grade X and XI (a total of six observations), with a duration of around 90 minutes per meeting. Observations were conducted directly by the researcher to see how the learning process took place, including the use of teaching modules, differentiated learning

strategies, student involvement in learning activities, and interactions between teachers and students. The researcher used a pre-prepared observation sheet to ensure that the data collected was systematic and focused on the indicators of the implementation of the Merdeka Curriculum. In addition to interviews and observations, this study also used documentation study techniques to review various learning documents such as teaching modules, teacher daily journals, and assessment instruments. The document review was conducted for two weeks in March 2025 by the researcher. The focus of this document analysis is to assess the suitability of the contents of the document with the principles of the Merdeka Curriculum in planning, implementing and evaluating learning.

The instruments used in this study include an interview guide with open-ended questions, a learning observation sheet, and a document analysis format. The interview guide was prepared to explore in depth the perceptions and experiences of teachers and schools regarding the implementation of the Merdeka Curriculum. The observation sheet was prepared based on indicators of differentiated learning and student involvement in active learning. Meanwhile, document analysis was carried out by assessing the completeness of the teaching module, the relationship between teacher daily journals and implementation in the classroom, and the quality of the assessment instruments used.

The data obtained were analyzed using the interactive model of [Miles et al., \(2014\)](#) which consists of three stages, namely data reduction, data presentation, and drawing conclusions. Data reduction is done by sorting relevant data according to the focus of the research, then the data is presented in narrative and table form to facilitate analysis, and finally conclusions are drawn based on the patterns found. To ensure the validity of the data, triangulation of sources and techniques is carried out, where information from interviews,

observations, and documentation is compared with each other. In addition, confirmation of the results (member check) is also carried out with informants to ensure that the data obtained is in accordance with the reality in the field.

## RESULTS AND DISCUSSION

### Planning

In implementing the Merdeka Curriculum, each subject faces different dynamics and challenges, including Biology. As one of the subjects that demands science-based learning, experimentation, and direct observation, Biology requires readiness from various aspects such as lesson planning, teacher training, and the availability of supporting facilities. SMA Negeri 1 Sibolga is one of the schools that has begun to gradually adopt the Merdeka Curriculum. This school carries out various strategies to ensure that the implementation of the curriculum is effective, especially in learning Biology.

The following presents the results of the analysis of the implementation of the Merdeka Curriculum in Biology subjects at SMA Negeri 1 Sibolga. This analysis refers to five main aspects, namely school readiness, teacher training, lesson planning, facilities and infrastructure, and socialization to students. The selection of these five aspects refers to the policy implementation model developed by [Edwards \(1980\)](#) which emphasizes the importance of communication, resources, disposition (attitude of implementers), and bureaucratic structure in implementing a policy. In addition, these aspects are also in line with the indicators of the success of the implementation of the Merdeka Curriculum as stated in the official document of [Kemendikbud \(2022\)](#) which highlights the importance of institutional readiness, resource support, and involvement of all school residents (Table 1).

Table 1. Merdeka Curriculum planning in biology subjects

No	Aspects	Curriculum Planning in Biology Subjects
1.	School Readiness Analysis	SMA Negeri 1 Sibolga implemented the Merdeka Curriculum in stages after considering the readiness of human resources and laboratory facilities. This school is more careful in making the transition, by first understanding the concept of Merdeka Curriculum, especially in the implementation of project-based learning and inquiry relevant to Biology subjects.  <i>"We did not immediately implement all aspects of the Merdeka Curriculum. We first see the readiness of teachers and facilities, especially the biology lab. So, we do it gradually."</i> (Interview with Vice Principal for Curriculum, S., March 12, 2025).
2.	Teacher Training and Development	SMA Negeri 1 Sibolga organised a comprehensive training for Biology teachers, including training on laboratory utilisation for scientific projects and the application of the scientific approach. Expert resource persons in biology and education are also invited to enrich teachers' understanding of learning strategies that emphasise exploration and direct observation.  <i>"We participated in training on the use of laboratories in project-based learning. There were also resource persons from outside the school who helped us understand the scientific approach."</i> (Interview with Biology Teacher, V.P.V.H., March 19, 2025).
3.	Lesson Planning	Lesson planning was carried out collaboratively by Biology teachers at SMA Negeri 1 Sibolga. They developed teaching modules based on environmental exploration and laboratory experiments, in accordance with the principles of Merdeka Curriculum. The preparation of lesson plans also involves integration with other subjects, such as Chemistry and Geography, to strengthen contextual learning.  <i>"We designed the lesson modules collaboratively. We develop the teaching modules together with other biology teachers. Sometimes we also collaborate with teachers of other</i>

No	Aspects	Curriculum Planning in Biology Subjects
		<i>subjects.</i> " (Interview with Biology Teacher, H.S., April 21, 2025).
4.	Provision of Facilities and Infrastructure	The school already has adequate Biology laboratory facilities, as well as equipment to conduct simple experiments. However, development is still ongoing to support project-based learning, such as the addition of digital microscopes, planting media, and technological devices supporting observation-based learning.  <i>"Basic equipment already exists, but we still need additions such as digital microscopes and tools for field observations so that Biology learning in our school can be maximised."</i> (Interview with Head of Biology Lab, D.W., March 12, 2025).
5.	Socialisation of Merdeka Curriculum to Students	SMA Negeri 1 Sibolga socialises the Merdeka Curriculum to students through orientation at the beginning of the school year and teacher explanations during the teaching and learning process. In the context of Biology, students are given an understanding of a new approach that emphasises direct observation, experimentation, and critical thinking skills through environmental and real-life based projects.  <i>"At the beginning of the new school year, when the school first started implementing the merdeka curriculum, we gave socialisation about the Merdeka Curriculum to the students we taught in their classes."</i> (Interview with Biology Teacher, Z.M., March 7, 2025).

### Implementation

The implementation of Merdeka Curriculum in Biology learning at SMA Negeri 1 Sibolga shows various strategic adjustments made by teachers in integrating the principles of the new curriculum into the learning process. This curriculum emphasises student-centred, project-based learning, and encourages differentiation and thorough assessment. Biology teachers are required to not only adjust the content of the material to the Learning Outcomes (CP), but also rearrange the approach, media, and evaluation strategies to suit the characteristics and needs of students.

In practice, Biology teachers utilise various resources, including teaching modules

from official platforms, and apply flexible and contextual methods. The use of diverse media and the application of differentiated learning are part of the efforts to improve learning effectiveness. In addition, assessments are conducted thoroughly to measure students' cognitive abilities, science process skills, and scientific attitudes. All of these aspects are sought to encourage students' active involvement in understanding Biology concepts in depth and application.

To provide a more systematic picture of how the implementation of Merdeka Curriculum is carried out in Biology subjects at SMA Negeri 1 Sibolga, the following analysis is presented based on five main aspects (Table 2).

Table 2. Implementation of Merdeka Curriculum in biology subjects

No	Aspects	SMA Negeri 1 Sibolga
1.	Implementation of Teaching Modules	Biology teachers use teaching modules from the Merdeka Mengajar platform and modify modules from other sources to suit student characteristics and local contexts. Teachers also regularly reflect and revise learning strategies based on previous learning results to improve student understanding.  <i>"We use the module from the Merdeka Mengajar platform as a reference, but we still adjust it to the conditions of the students and the school environment. If something is not quite right, we usually revise it after evaluating the learning outcomes."</i> (Interview with Biology Teacher, V.P.V.H., March 19, 2025)
2.	Implementation of Learning Methods	Although methods such as group discussions, demonstrations, and question and answer are still used, Merdeka Curriculum gives Biology teachers the

No	Aspects	SMA Negeri 1 Sibolga
		<p>freedom to apply more flexible and contextualised methods. Teachers also encourage students to engage in observations of the surrounding environment, simple experiments, and scientific projects.</p> <p><i>"The methods we apply are still the same as the last 2013 curriculum. However, during this merdeka curriculum, we involve students more in observations of the surrounding environment and simple science projects."</i> (Interview with Biology Teacher, Z.M., March 7, 2025).</p>
3.	Use of Learning Media	<p>Biology teachers utilise various media such as anatomical models, microscopes, animated videos of biological processes (e.g. photosynthesis or cellular respiration), and digital infographics. These media help students more easily understand complex concepts through visualisation.</p> <p><i>"There are various kinds of media that we use in learning Biology, such as anatomical models, animated videos, and microscopes that are very helpful. Students find it easier to understand processes that are abstract or we say invisible to the naked eye, such as the process of photosynthesis or respiration,"</i> (Interview with Head of Biology Lab, D.W., March 12, 2025)</p>
4.	Implementation of Differentiated Learning	<p>Teachers implement differentiated learning by providing various approaches according to students' learning styles. For example, kinesthetic students are invited to make organ models, visual students are given experimental videos, while verbal-logical students are given scientific articles or experimental report writing assignments.</p> <p><i>"Yes, we as teachers always try to adjust the approach to the students' learning styles. For example, kinesthetic children we invite to make models, visual ones we give videos like that. Anyway, we vary the learning"</i> (Interview with Biology Teacher, V.P.V.H, March 19, 2025)</p>
5.	Formative and summative assessment	<p>Biology teachers use formative assessment through oral questions, observation sheets, quizzes, and student journals during the learning process. Summative assessment is done through final exams, lab reports, and science projects. Assessment includes cognitive aspects, science process skills, as well as scientific attitudes such as curiosity and concern for the environment.</p> <p><i>"As usual, the assessments that we do are formative and summative. The formative is like quizzes, test questions, student journals too. Summative is at the end of the semester like the end-of-school exam."</i> (Interview with Biology Teacher, H.S., April 21, 2025).</p>

## Evaluation

Evaluation is an important part of the Merdeka Curriculum implementation process to ensure that learning runs in accordance with the predetermined objectives. In the context of the Biology subject at SMA Negeri 1 Sibolga, evaluation is carried out thoroughly, including teacher performance and reflection on the implementation of the curriculum as a whole. This evaluation not only aims to assess the final results, but also to monitor the progress of the process and provide constructive feedback for continuous improvement.

Evaluation of teacher performance is also conducted regularly, focusing on preparedness, creativity in teaching, and the ability to implement project-based approaches and differentiated learning. The reflection process provides a space for teachers to share the challenges they face and receive support from the school in the form of training or provision of supporting facilities. The details of the evaluation of the implementation of the Merdeka Curriculum in Biology learning at SMA Negeri 1 Sibolga can be seen in Table 3.

Table 3. Evaluation of Merdeka Curriculum in biology subjects

No	Evaluation Aspects	SMA Negeri 1 Sibolga
1.	Teacher and School Performance Evaluation	<ul style="list-style-type: none"> <li>• Biology teachers' performance is evaluated regularly through supervision and assessment of learning administration.</li> <li>• The evaluation focused on teachers' ability to design and implement project-based learning and scientific experiments.</li> <li>• Teachers feel helped by the evaluation that encourages them to continue to develop pedagogical competence and professionalism in teaching Biology.</li> </ul> <p><i>"We are routinely supervised and asked to show teaching tools such as teaching modules that we use, student assessment sheets and other tools. The focus is more on how we design merdeka curriculum-based learning in this biology course."</i> (Interview with Biology Teacher, Z.M., March 7, 2025).</p> <p><i>"This evaluation encourages us to keep learning and developing better ways of teaching."</i> (Interview with Biology Teacher, V.P.V.H., March 19, 2025)</p>
2.	Reflection and Continuous Improvement	<ul style="list-style-type: none"> <li>• Regular reflection meetings are held, both at the subject level and school level, to discuss the implementation of Merdeka Curriculum, especially in Biology learning.</li> <li>• Teachers conveyed the obstacles faced, such as limited practical tools or variations in students' understanding of abstract concepts.</li> <li>• The school provides solutions in the form of additional training, procurement of learning aids, and facilitation of collaboration between teachers for continuous improvement.</li> </ul> <p><i>"Every semester we usually have a reflection meeting. There we convey obstacles, such as the lack of practical tools or the difficulty of students understanding abstract concepts in learning Biology."</i> (Interview with Head of Biology Lab, D.W., March 12, 2025)</p> <p><i>"The school is quite concerned and responds to us Biology teachers. They organise additional training and help provide the necessary learning aids."</i> (Interview with Biology Teacher, H.S., April 21, 2025).</p>

### Supporting and inhibiting factors

The implementation of the Merdeka Curriculum in the Biology subject at SMA Negeri 1 Sibolga is influenced by various factors that can strengthen or hinder its success. Successful implementation depends not only on the readiness of individual teachers, but also on institutional support, infrastructure, and active participation from students.

Some supporting factors found in the field include the enthusiasm and initiative of Biology teachers in learning the new curriculum, the availability of supporting facilities such as laboratories and technological devices, as well as good cooperation between teachers and with external parties. Support from the school is also an important driver in

creating a conducive learning environment for the implementation of differentiated and project-based learning.

However, the implementation of the Merdeka Curriculum also faces a number of challenges. Common obstacles include the uneven understanding of teachers of the principles of the Merdeka Curriculum, difficulties in preparing appropriate teaching tools, limited applicable training, and low student involvement in learning that demands independence and active participation..

To provide a more structured picture of these factors, the following table summarises the supporting and inhibiting factors for the implementation of Merdeka Curriculum in Biology learning at SMA Negeri 1 Sibolga (Table 4).



Table 4. Supporting and inhibiting factors for the implementation of Merdeka Curriculum in biology subjects

No	Factors	Description at SMA Negeri 1 Sibolga (Biology Subject)
1.	Supporting Factors	<ul style="list-style-type: none"> <li>Teacher enthusiasm and readiness: Biology teachers show high enthusiasm in understanding and implementing Merdeka Curriculum through self-learning, training, and discussions with peers.</li> <li>Cooperation and collaboration between teachers: Collaboration between Biology teachers and other science teachers is active, especially in designing experiment-based learning and scientific projects.</li> <li>Readiness of infrastructure and learning resources: The school has provided an adequate Biology laboratory, technological devices such as projectors, as well as access to Merdeka Mengajar platform and digital learning resources.</li> <li>Collaboration with external parties: Teachers are members of the Biology MGMP and participate in forums or workshops held by the education office or other agencies to support curriculum development.</li> <li>School commitment in supporting curriculum implementation: The school provides support through the provision of lab equipment, internal training, and time flexibility for the development of Biology teaching tools.</li> </ul> <p><i>"We are enthusiastic because this curriculum gives room for innovation, so we do a lot of self-learning and discussions with colleagues."</i> (Interview with Biology Teacher, V.P.V.H., March 19, 2025).</p> <p><i>"We often collaborate with other teachers to make interdisciplinary science projects."</i> (Interview with Biology Teacher, Z.M., March 7, 2025).</p> <p><i>"The laboratory is quite adequate and we are also given access to the Merdeka Mengajar platform."</i> (Interview with Head of Biology Lab, D.W., March 12, 2025).</p> <p><i>"The school fully supports us, including providing special time for us to develop teaching tools."</i> (Interview with Biology Teacher, H.S., April 21, 2025).</p>
2.	Inhibiting Factors	<ul style="list-style-type: none"> <li>Uneven teacher understanding: Not all Biology teachers have the same level of understanding of Merdeka Curriculum principles, especially in terms of differentiated learning and scientific research-based projects.</li> <li>Difficulties in preparing teaching tools: Some teachers still have difficulty preparing teaching modules and lesson plans that are in accordance with CP and student needs in the context of Biology.</li> <li>Limited training for teachers: The available training is still predominantly online and does not provide enough space for hands-on practice, especially in the application of science experiments or lab work.</li> <li>Implementation of the Pancasila Student Profile Strengthening Project (P5): Integration between the P5 project and Biology materials remains a challenge, especially in linking P5 themes with scientific and environmental contexts.</li> <li>Technology literacy levels vary: Some teachers are still not optimally utilising digital platforms and interactive technologies that support Biology learning effectively.</li> <li>Low student participation: Some students are not used to active, exploratory and project-based learning approaches in Biology learning, so participation and learning initiatives still need to be improved.</li> </ul> <p><i>"We admit that not all teachers really understand about differentiated learning and research projects."</i> (Interview with Biology Teacher, Z.M., March 7, 2025).</p> <p><i>"Developing a module that suits the learning outcomes and students' needs is a challenge."</i> (Interview with Biology Teacher, V.P.V.H., March 19, 2025).</p> <p><i>"Training is mostly online and lacks hands-on practice, even though we need experimental simulations."</i> (Interview with Head of Biology Lab, D.W., March 12, 2025)</p>

No	Factors	Description at SMA Negeri 1 Sibolga (Biology Subject)
		<i>"Students are still not used to active learning, so their participation in projects is sometimes still low."</i> (Interview with Biology Teacher, H.S., April 21, 2025).



Figure 1. Biology learning activities in the laboratory of SMA Negeri 1 Sibolga  
(Source: Photo taken by Mhd. Rafi'i Ma'arif Tarigan)

The implementation of Merdeka Curriculum in Biology subject at SMA Negeri 1 Sibolga shows a serious and strategic effort from the school and teachers to adjust to the new approach in learning. As one of the subjects that relies heavily on the process of scientific exploration, experimentation, and direct observation, Biology demands comprehensive readiness in terms of planning, implementation, and evaluation.

Planning is an important early stage in the transition to the Merdeka Curriculum. SMA Negeri 1 Sibolga implemented this curriculum in stages by first ensuring the readiness of human resources and facilities. The school showed appropriate caution by not only understanding the concept of the new curriculum, but also preparing Biology teachers through intensive training. This training not only covers material mastery, but also strengthens skills in using the laboratory, developing project-based teaching modules, and integrating scientific and inquiry

approaches into learning. This exposure is in line with the results of research by [Adiba & Andriyati \(2025\)](#) and [Tarigan et al., \(2019\)](#) revealed that teachers are encouraged to develop modules collaboratively, which do not only focus on the content of the material and apply varied learning models.

Infrastructure such as laboratories and digital learning media have also been prepared although development is still ongoing, especially to support project-based learning and direct observation. On the other hand, students are gradually introduced to the new approach through orientation activities and direct interaction with teachers in the learning process, so that they understand the active role that must be assumed in exploration-based learning.

At the implementation stage, it was seen that Biology teachers did not only rely on teaching modules from official platforms such as Merdeka Mengajar, but also made modifications to suit the local context and characteristics of

students. The use of learning methods also becomes more flexible. Teachers not only use conventional methods such as discussions and demonstrations, but also provide space for students to make environmental observations, simple experiments, and scientific projects that demand active involvement. This concept is in line with the statement of [Sholeh & Prapanca \(2023\)](#) who revealed that the use of varied learning media, ranging from anatomical models, microscopes, to digital infographics and animated videos, enriches students' learning experience and helps them understand abstract concepts more concretely.

In addition, differentiated learning is implemented by providing approaches that are tailored to students' learning styles. This strategy reflects the application of the principles of constructivism, where learners are positioned as active subjects in the learning process. For example, teachers provide diverse activities such as modelling for students with kinesthetic tendencies, presenting videos for visual students, and compiling scientific reports for students with verbal-logical learning styles. This approach is in line with Gardner's theory of Multiple Intelligences, which emphasises the importance of understanding the diversity of learners' intelligences and learning preferences to create meaningful learning experiences.

Furthermore, the assessment process is conducted holistically by combining formative and summative assessments. Assessment not only emphasises cognitive aspects, but also includes science process skills and scientific attitudes such as curiosity, perseverance, and concern for the environment. This is in line with the findings in a study by [Schildkamp et al., \(2020\)](#) and [Boström & Palm \(2023\)](#) which showed that formative assessment conducted on an ongoing basis can significantly improve student learning achievement. In this context, evaluation is not only conducted at the end of learning, but also during the process to provide constructive feedback. This approach confirms the importance of the role of assessment as an

integral part of learning, not just a tool to measure the end result. When compared to previous research, this finding reinforces the results of a study conducted by [Maulana et al., \(2020\)](#) and [Pozas et al., \(2023\)](#) differentiated learning, which states that this strategy is effective in creating a learning environment that is inclusive and responsive to students' individual needs. Thus, the application of differentiated learning and continuous assessment in this finding is not only practically relevant, but also expands our understanding of how the implementation of modern pedagogical principles can improve the quality of learning in the classroom.

Evaluation is an important part of the curriculum implementation cycle. SMA Negeri 1 Sibolga regularly evaluates teacher performance as well as the effectiveness of Biology learning implementation. Biology teachers receive regular supervision and administrative assessments that focus on their ability to implement project-based learning and experimentation. In addition, reflection is part of the school culture, where teachers openly share challenges and obstacles faced, such as limited tools or students' varying levels of understanding. The school responds to this by providing additional training, learning aids, and opening spaces for discussion and collaboration between teachers to improve and refine learning strategies.

In terms of supporting factors, teacher enthusiasm and readiness are the main assets in the successful implementation of the Merdeka Curriculum. Biology teachers show high enthusiasm to continue learning and improving themselves, both through formal training, independent learning, and discussions with peers. This presentation is in line with the results of research by [Nisa et al., \(2023\)](#) which revealed that collaboration between science teachers also strengthens the design of integrative and applicable learning. The readiness of facilities such as laboratories, access to technological devices, and digital

platforms support more interactive and exploratory learning. Support from the school is also very significant, both in the form of providing tools, time to develop teaching tools, and facilitating internal training.

However, challenges are still found in this process. Not all teachers have an even understanding of the principles of Merdeka Curriculum, especially in the aspects of differentiated learning and research-based projects. The preparation of teaching tools is still a homework, especially in adjusting learning outcomes to the local context and student needs. In addition, the available training is still mostly online and theoretical, so teachers feel they lack hands-on experience in applying science practices. The implementation of the project to strengthen the Pancasila Learner Profile (P5) has also not been fully integrated with the Biology subject, especially in terms of the connection between the project theme and scientific aspects. Another important challenge is the low participation of students who are not used to active, exploratory and independent learning approaches.

Based on the results of interviews with SMA Negeri 1 Sibolga teachers who are implementing the Merdeka Curriculum in the Biology subject, it appears that the process of adopting this new curriculum is carried out gradually and carefully. This is in accordance with the statement of the Deputy Principal for Curriculum, S., who said that the readiness of teachers and facilities, especially the Biology laboratory, is a major consideration in determining the extent to which the Merdeka Curriculum is implemented. This phased approach shows an awareness of the importance of the readiness of the education ecosystem before implementing comprehensive curriculum changes, which is also supported by the findings of the Lukmariadi & Zubaidah (2024) study which states that curriculum changes require systemic readiness, not just administrative policies.

From the teachers' side, the spirit of collaboration and willingness to continue

learning were very prominent. Biology teachers such as V.P.V.H., H.S., and Z.M. actively participate in training, compile teaching modules collaboratively, and even collaborate across subjects in implementing science projects. This is in line with the main principles of Merdeka Curriculum, which encourages collaboration between teachers and the development of contextualised project-based learning. Research by Safitri et al., (2024) states that teachers who have collaboration and professional development opportunities are better able to integrate scientific approaches and differentiated learning in their classroom practices.

However, the interviews also revealed challenges in implementation. One of the main obstacles is the limited practical equipment and inadequate training provided, as stated by the Head of the Biology Laboratory, D.W. She stated that although basic equipment is available, some important tools such as digital microscopes and field observation equipment are still lacking. In addition, the majority of the training received is still done online and does not touch on direct practice, even though teachers really need experimental simulations to support laboratory activities. This is reinforced by the results of Raini (2021) which shows that the success of project-based and scientific learning is largely determined by the adequacy of infrastructure and hands-on practice-based training.

Other challenges revealed were related to teachers' understanding of differentiated learning and research projects. Some teachers admitted that not all colleagues fully understand the concept, and the development of teaching modules in accordance with student characteristics is still considered quite difficult. This statement illustrates that the adaptation process is still ongoing and continuous support is needed in the form of training and mentoring. This is in line with the findings of Zuariah et al., (2024) that one of the main challenges in implementing the Merdeka Curriculum is the uneven competence of teachers in developing

teaching tools that are adaptive and in accordance with student needs.

In terms of learning, Biology teachers have tried to apply contextual approaches, such as inviting students to make observations of the surrounding environment and simple science projects. Although the learning methods used are still largely similar to Curriculum 2013, there seems to be a real effort to make learning more active and experience-based. As revealed by Z.M. and V.P.V.H., students' involvement in projects is still not optimal, as they are not used to active learning. This is in line with the results of a study by Nisa et al., (2024) which states that the transition from teacher-centred to student-centred learning takes time and changes the learning culture among students.

## CONCLUSION

The implementation of Merdeka Curriculum in Biology learning at SMA Negeri 1 Sibolga shows that the success of implementation is strongly influenced by teacher readiness, school facility support, and active student involvement. Although teachers have tried to apply the principles of differentiated and project-based learning, there are still obstacles such as differences in understanding of the curriculum and limited practical training.

The implication of this finding is that schools need to formulate internal policies that support teacher capacity building through practical, contextualised and sustainable training. Teacher training institutions also need to develop more applicable competency improvement programmes, particularly in differentiated learning strategies and student needs-based projects. In addition, curriculum developers at the central and local levels need to provide more detailed and easy-to-understand technical guidelines to ensure uniformity of understanding in the field. It is also necessary to encourage collaboration between teachers as part of a learning community to share good practices in

implementing the Merdeka Curriculum. Future research is recommended to expand the focus on aspects of developing student potential and conducting a long-term evaluation of the impact of the Merdeka Curriculum on Biology learning outcomes. On the methodological side, future research should involve more varied and valid instruments to obtain more comprehensive and representative results

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