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# Implementing Biology Learning with a Differentiated Approach to Support Students 21st Century Skills Independent Curriculum

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**Abstract:** In the context of implementing the independent curriculum, a differentiated learning approach is an important strategy by giving freedom to teachers and learners. This research aims to analyze various learning models, media, and the impact of implementing biology learning with a differentiated approach to support 21st century skills. The method used is a systematic analysis that follows the PRISMA guidelines. The results showed that the implementation of biology learning based on a differentiated approach can support critical thinking, creativity, collaboration, and effective communication skills. The applied learning model includes PBL (Problem Based Learning), PjBL (Project Based Learning), and DL (Discovery Learning), each of which supports content, process, and product differentiation. The learning media used include teaching modules, puzzles, images, educational videos, canva, worksheets, presentation slides, audio, and posters. Thus, the application of appropriate learning models and media in Biology learning in accordance with the diversity and learning needs of students has a positive impact on the development of students' 21st century skills, such as problem analysis, exploration, solutions, and effective communication.

**Keywords:** 21st century skills; Biology; Differentiated

## Introduction

Biology learning is one of the lessons that discusses phenomena based on scientific facts, so it is not uncommon for students to consider Biology learning as complex and abstract learning. Biology content not only discusses scientific phenomena in daily life but also the relationship between living organisms and their environment (Sayan & Mertoğlu, 2020). In learning Biology content, a differentiated learning approach is needed to be able to accommodate the diverse characteristics and learning styles of students in the classroom. Through a differentiated approach, it is expected that teaching can be tailored to students' needs and interests, so that students can be engaged and motivated to learn.

The differentiation approach is a teaching strategy that aims to adjust the needs of learners' learning methods, considering that classes often consist of individuals with diverse backgrounds, thus creating a more meaningful and increasingly relevant learning experience in an educational context (Koimah et al., 2024). There are three strategies to implement differentiated learning where the teacher acts as a facilitator who creates a variety of teaching methods, namely content differentiation, process differentiation and product differentiation. However, the approach should not be separated from the aspects of learning readiness, interest, and student learning profile (Mahfudz, 2023). By implementing differentiated learning, it is expected that learning is interactive and

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can increase learner involvement and be more motivated to learn (Rohmah & Zulfitria, 2024).

Optimal learning focuses not only on the acquisition of knowledge, but also on the development of relevant skills, especially in the 21st century, which include life and career skills, learning and innovation skills, and information, media, and technology skills (Pare & Sihotang, 2023). In this context, the 4C skills, namely Critical Thinking, Communication, Creative Thinking, and Collaboration, are key to preparing students for an ever-changing world (Sugiharti & Gayatri, 2021). To support this, education policy needs to be oriented towards a student-centered approach, emphasizing active learning methods (Pertiwi et al., 2022).

Education policy transformation aims to harmonize the education system to achieve better changes (Muktamar et al., 2024). The Independent Curriculum provides freedom for students, teachers, and schools to innovate in education, encourages students' active participation in the learning process and creates an innovative and inclusive learning environment (Lembong et al., 2023). Different learning approaches, particularly in biology, are designed to meet the unique needs of each student, allowing them to explore the material according to their abilities and needs (Halimah et al., 2023).

However, to implement this learning strategy effectively, teachers need to have the latest ideas and innovations in using appropriate teaching methods and models, so that students are more motivated to engage in the entire learning process (Farid et al., 2022; Bendriyanti et al., 2022). The independent curriculum also emphasizes the importance of developing 6C skills which include critical thinking, Creativity, Collaboration, Communication, Character, and Citizenship (Candrikaningtyas et al., 2024). In this case, the context of the Pancasila Student Profile Strengthening Project, where an understanding of biology contributes not only to scientific knowledge but also to developing a sense of responsibility and concern for the environment (Lasaiba, 2023; Zulaiha et al., 2023). By integrating these skills into differentiated learning, students can be trained to become more collaborative, creative, and critical thinkers (Avandra & Desyandri, 2022).

Based on the explanation of the issues and potential solutions above, the purpose of this study was to conduct a systematic literature review to identify various learning models, media, and their impact in biology learning that can support 21st century skills. Analysis of the various learning models and media used identified best practices accepted by educators. This research is also expected to provide deeper insights into effective learning strategies to enhance students' 21st century skills. Thus, the findings of this study contribute to the development of more innovative and relevant learning in the current educational context.

## Method

The method used in this study was a Systematic Literature Review (SLR). This approach served as the methodology for collecting, identifying, and analyzing studies related to the implementation of Biology learning using a differentiated approach within the Independent Curriculum. The SLR method applied in this research was as follows (Habibi & Manurung, 2023; Dinter et al., 2021).

*Research Questions*

Q1: What models have been used for Biology learning with a differentiated approach in the implementation of the Independent Curriculum?

Q2: What learning media have been utilized in the application of Biology learning with a differentiated approach in the Independent Curriculum?

Q3: What impacts have resulted from the implementation of Biology learning using a differentiated approach in the Independent Curriculum?

These questions provided a deeper understanding of the application of the differentiated approach in Biology learning.

*Study Selection Criteria*

**Table 1.** Inclusion and exclusion criteria

| Criteria | Inclusion | Exclusion |
|---|---|---|
| Year of publication | 2020-2024 | < 2020 |
| Article type | Journal of original scientific research | Review articles, editorials, opinions, conference proceedings, thesis/ dissertation |
| Text availability | Full text available | Only the abstract or part of the text |
| Access | Open access | Paid/limited |
| Methodology | Clear research Methodology | Methodology is unclear or incomplete |
| Research subject | Focus on learning biology with a differentiated approach | Not related to biology learning or differentiated approach |
| Indexation & Reputation | Has a DOI | Does not has a DOI |

The second stage involved the literature search or identification of relevant journals and articles through academic databases such as Scopus, Google Scholar, Garuda, and ScienceDirect. A systematic search was

conducted using a combination of Boolean operators (AND, OR, NOT) with the following keywords: "biology learning" OR "biology education" AND ("differentiated approach" OR "differentiated teaching"); ("freedom curriculum" OR "independent curriculum") AND ("biology teaching" OR "biology learning"); ("21st century skills" OR "21st century competencies") AND "biology education." The study selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, as illustrated in the flow diagram (Figure 1). Only articles that met the inclusion criteria were selected for further analysis. Below is the table of inclusion and exclusion criteria.

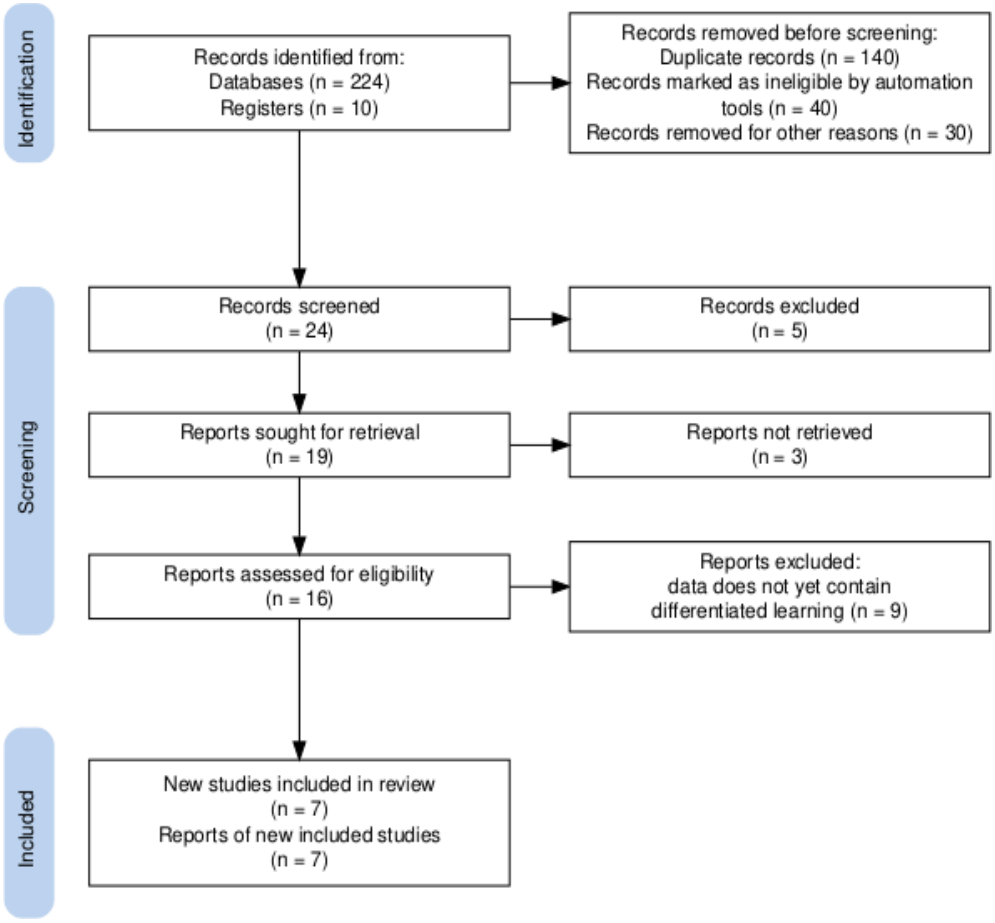


**Figure 1.** The flow of article selection used in SLR using the PRISMA model (source: https://estech.shinyapps.io/prisma_flowdiagram/

*Study Quality Assessment*

The third stage was quality assessment. In this research, study assessment using an instrument from the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. Yes (2 points), unclear (1 point), and No (0 points), and N/A (no points). Articles that scored at least 70% of the total maximum points were included in the review. The quality assessment process was conducted through double-blind review by two independent reviewers to ensure the objectivity of the assessment. If there are differences in assessment between reviewers, a discussion was held to reach an agreement. In the event that consensus was not reached, a third reviewer was involved as an arbiter to provide the final assessment.

*Data Extraction and Synthesis*

The data extraction process was carried out by creating an extraction form based on predetermined research questions. At this stage, the author determined the extraction elements used, as seen in Table 2. The extracted data was then implemented in MS Excel, enabling further data synthesis to identify patterns.

**Table 2.** Category and detail tables for data extraction and synthesis

| Category | Details |
|---|---|
| Research topic | The main focus of the research |
| Learning Models and Tools | Learning model and/or learning media used in differentiated learning |

The data synthesis was presented in the form of graphs to recap the frequency of each goal category to provide an overview of the research findings. Then the author has conducted an in-depth analysis of the information that has been collected with the aim of understanding the relationship between the various elements extracted, as well as evaluating the learning models and media related to the relevance and effectiveness used in the context of differentiated learning. After that, the author has organized the data in an orderly manner and visualized it through graphs to help identify significant patterns and make it easier for the author to compose a clear narrative about the research findings.

*Reporting and Using the Results*

The final stage in this research was the presentation of the findings obtained in the form of tables and graphs. This included the learning model with a differentiated approach, the media used in differentiated learning, and the impact of implementing biology learning with a differentiated approach. After that, the researcher drew conclusions that summarize the results of the analysis and provide answers to the research questions. In this process, the author also compared the results obtained with previous research and relevant theories, thus providing a broader context.

## Result and Discussion

**Table 3.** Identity and characteristics of the article

| Author | Year of publication | Research purposes |
|---|---|---|
| Thurrodliyah et al. | 2024 | Application of Differentiated Problem-Based Learning (PBL) Model to Improve Biology Learning Outcomes |
| Cahya et al. | 2023 | Analysis of Student Characteristics as Basifor Differentiated Learning to Enhance Student Collaboration |
| Rahmah et al. | 2023 | The effect of Applying differentiated teaching materials based on multiple intelligence on students' critical thinking skills |
| Novitasary | 2023 | Application of project-based learning to improve learners' communication skills |
| Karlina et al. | 2022 | Implementation of the Pancasila Learner Profile in the Independent Curriculum Changes in Biology Learning in Kuningan Regency High School |
| At'haya et al. | 2023 | Analysis of Pancasila Student Profile in the Learning Process of High School Biology in the Curriculum Merdeka Mandiri Belajar |
| Putri et al. | 2023 | Analysis of Students' 21st Century Skills in Biology Learning |

Based on the analysis presented in Figure 1, a total of 234 articles were obtained at the identification stage. Then, articles were selected using the quality assessment from JBI instruments, resulting to 7 articles. Table 3 and 4 shows the results of the analysis of the obtained articles.

**Table 4.** Research topic, learning models and tools

| Biology Topics | Learning Models and Tools | 21st Century Skills (4C) |
|---|---|---|
| Innovative conventional biology technology | PBL model; and modules with modern biotechnology material, Learner Worksheets (LKPD). | Critical thinking |
| Conventional biotechnology and the impact of biotechnology | PBL model; and teaching materials, learning videos, puzzle shopping, pictures, posters. | Collaboration (cooperation, communication to achieve common goals, positive interdependence, social coordination). |
| Ecosystem | Discovery learning model; and differentiated teaching module. | Critical thinking skills |
| Biodiversity | PjBL model; and canva, pictures, slide presentation, posters. | Communication skills |
| Biodiversity | Project-based learning model, problem-based learning model; and teaching module. | Critical thinking, creative |
| Biodiversity | Models of discovery learning, problem-based learning, project-based learning; and audio, video, presentation slides. | Critical reasoning, creativity, collaboration. |
| Biology Materials | 21st century learning model | Critical thinking, creativity, communication, collaboration. |

Q1: What models have been used for Biology learning with a differentiated approach in the implementation of the Independent Curriculum?

The differentiated learning approach used in developing 21st century skills must certainly encourage contextual learning and be experienced directly by students in the Biology learning process. This can create and have a meaningful essence obtained during the Biology learning process. Based on the results of the study, in the bar chart below there are learning models used in differentiated learning, especially Biology learning materials.

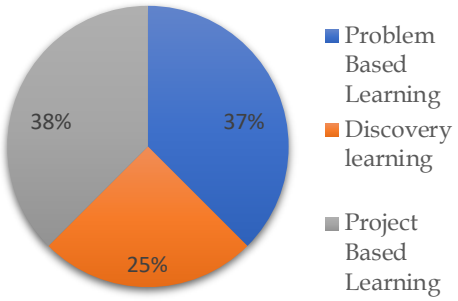


**Figure 2.** Model often used in differentiated learning

The Problem Based Learning (PBL) model emphasizes solving real problems that encourage learners to think critically and collaborate in investigations. The application of PBL in differentiated learning is effective in training students' critical thinking, collaboration, innovation, and communication skills (Nawati et al., 2023; Aprilianti & Siswandari, 2024). In the context of ecosystem material, the variety of cases in the LKPD can be adjusted to the level of learning readiness of students. Students with early stage learning readiness are given simpler problem-based LKPDs, while more prepared students are given more complex cases (Maulani et al., 2023). This suggests that PBL can be used to differentiate biology content as well as develop collaboration, independence, and critical thinking skills.

In process differentiation learning, students with early learning readiness receive more attention and guidance during group discussions compared to more prepared students, with the aim that they can construct knowledge according to their individual learning needs. Suhardi et al. (2023) revealed that differentiated learning integrated with PBL on metabolic system material showed attitudes of cooperation, independence, creativity, and critical reasoning. Research by Irma & Prafitasari (2023) also shows that the application of differentiated-based PBL models can increase the interest and activeness of students, so that learning outcomes are in accordance with the learning objectives of interaction materials in the ecosystem.

The PBL process consists of several phases. The first phase is problem orientation, where the teacher provides problems that are then analyzed by students. The second phase organizes students by forming groups according to the learning styles obtained from the initial diagnostic test. The third phase is group investigation guidance, where students are free to conduct learning activities according to their preferred learning styles, such as using videos for visual learning styles, articles for auditory, or direct observation for kinesthetic. The fourth phase is the presentation and development of work, where students present the results of group discussions. The fifth phase involves analyzing and evaluating the problem-solving process, where researchers and students summarize the results, reflect, and evaluate student learning outcomes.

Minasari & Susanti (2023) shows that content and process differentiated learning can respond to the diversity of learning styles of students. Students with visual learning styles are presented with infographics about circulatory system disorders (hypertension), while students with auditory learning styles receive recordings, students with audio-visual learning styles are presented with videos, and students with reading and writing learning styles are given material through blogs. Students with kinesthetic learning style were given the opportunity to practice using tensimeter. The results show that differentiated Biology-based learning has a positive effect on students' attitudes in learning.

In addition, research by Shafira et al. (2023) on the application of PBL based on product differentiated learning shows that students with visual learning styles can choose the final product in the form of posters, illustrated stories, or comics to explain the results of ecosystem observations in the school environment. Students with audio learning styles can create podcasts or short videos, while kinesthetic students can demonstrate school activities using props or tools. The results of this study show that differentiated-based PBL has a positive impact by creating a more meaningful learning experience, because learning is centered on students by considering their individual learning styles.

PjBL that applies the concept of differentiation not only encourages cooperation in projects, but also strengthens learners' self-confidence and academic outcomes. In the context of PjBL, learners receive activities that are tailored to their respective cognitive levels. Learners can determine and create the final product to solve the problem according to their interest needs (Purba et al., 2024). For example, in learning about biodiversity, learners can determine and create a final product to solve problems related to the preservation of certain species or the impact of climate change on ecosystems. This fosters a sense of comfort and willingness to openly exchange answers with peers.

This collaborative learning structure provides personalized instruction, which is beneficial for challenging high-achieving learners and helping those who are still developing. With peer support, low-achieving learners feel empowered to overcome challenges and develop the skills needed to answer higher-order questions (Fajrina et al., 2024). This finding is in line with current learning principles that prioritize collaboration, critical thinking, interaction, sensitivity, and competency development.

Differentiated learning programs that use learner worksheets that include projects provide opportunities for learners with different levels of understanding to be actively involved. In this context, learners with low initial abilities are assisted more intensively than learners with higher initial abilities. Sulistiani (2024) revealed that a differentiated learning program using worksheets containing STEM is effective in improving creative problem solving (CPS) skills. These worksheets are designed to attract attention by stimulating the imagination and curiosity of learners, as well as emphasizing the practical application and relevance of learning materials in everyday life. Through the STEM projects undertaken with the worksheet, each group is given the freedom to choose the resulting product, allowing learners to hone critical thinking, collaboration and communication skills. It can also develop communication skills when presenting their work (Sutarini et al., 2024). By designing tasks that encourage creative thinking, learners will be trained to look for new and innovative solutions, which overall contributes to the development of science process skills and CPS.

Differentiated learning using the Discovery Learning (DL) model provides learning experiences that hone science process skills in discovering concepts. For example, on the material of the body's circulatory system, learners are preceded by a learning video to generate stimulus, followed by observation and problem identification. Each group is then given a learner worksheet (LKPD) as part of the process differentiation, where they conduct group discussions to collect and process data according to their respective learning styles. Visual learners solve problems by reading posters, readings, and presentations, while auditory learners solve problems by watching and listening to videos about the circulatory system. Kinesthetic students are given practicum activities related to the material. After completing the LKPD, each group presented the results of their discussion, which was then responded to by other groups, ending with a joint conclusion. This process helps learners apply the dimensions of 21st century learning skills such as independence, collaboration, and problem solving. Ilma et al. (2024) also confirmed that differentiated learning can meet the needs of learners with various learning modalities, including visual and kinesthetic.

In applying the DL model, product differentiation learning is done by giving learners the freedom to express their answers through various products, such as drawings. In addition, the division of groups with the names of scientists and the use of virtual laboratories are part of the process differentiation. Content differentiation is done by adjusting teaching materials based on learners' learning abilities and readiness; for example, learners with low readiness are given video shows, while those who are more prepared are given e-modules. In the data collection stage, learners are allowed to find references from various sources, including learning videos, books and journals. The verification stage involves presenting the group work report in front of the class, where other groups conduct peer assessment to check the accuracy of the data presented. Sari et al. (2024) argue that the application of the DL model has a positive effect on students' concept mastery and critical thinking skills.

The learning process starts with a problem that learners discover, which emphasises their ability to identify and critically analyse problem-solving efforts. Group discussions, an integral part of the DL model, help learners master the material and solve problems independently. The syntactic stages of the DL model train learners' thinking processes from finding problems, identifying, collecting, processing, proving, to drawing conclusions, aligning with the learning principles in the independent curriculum that focus on learners, collaboration, and critical thinking. Jannah et al. (2020) explained that the application of the DL model in biology learning has a positive impact on students' science process skills. In this process, learners are trained to formulate hypotheses, plan and conduct experiments, and observe and interpret data. DL learning encourages learners to be more enthusiastic in learning, as they are involved in investigations that generate new knowledge. For example, nature exploration activities around the school environment, which include various locations such as rice fields, gardens, sea, and lakes (Santi, 2023), show how differentiated learning can accommodate learners' diversity, build collaboration, and create a fun learning environment.

Q2: What learning media have been utilized in the application of Biology learning with a differentiated approach in the Independent Curriculum?

Based on the results of the study, learning media used to assist differentiated learning in Biology include differentiated teaching modules, learner worksheets (LKPD), teaching materials, learning videos, learning puzzles, pictures, posters, canva, slide presentations, audio learning. The following is a pie chart showing the learning media used in differentiated learning in biology learning.

Learning modules are designed to present material in various formats and levels of difficulty depending on the needs of the students. For example, in the topic of ecosystems, the module may include descriptive text, graphs, images, and case studies on the impact of environmental damage due to human activities on habitats. Learning modules also accommodate various learning styles such as visual by utilising infographics and auditory by listening to narratives that explain

concepts (Lailiyah & Mas'ud, 2024). Research by Rahmawati et al. (2023) revealed that the science learning module on the topic of biotechnology provides an increase in effectiveness for differentiated learning where students' responses that the topic of biotechnology is very interesting with very practical criteria. This is also supported by research by Variacion et al. (2021) revealing that there is a significant difference between non-differentiated learning modules and differentiated learning modules developed, where respondents believe that differentiated activities developed in learning modules encourage learner-centred learning.

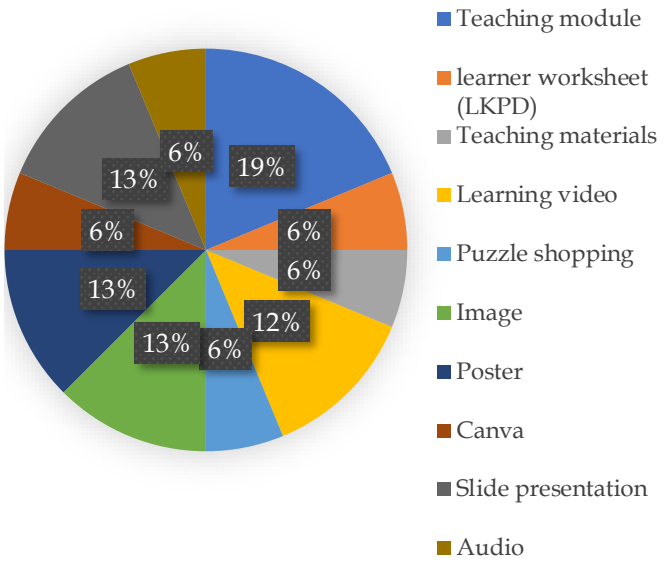


**Figure 3.** Media used in differentiated learning

Learner worksheets (LKPDs) contain activities designed to help students understand the material with the guidance of exercises and group tasks. For example, in a biotechnology topic, the LKPD contains an activity that asks learners to analyse the process of making fermented wine, including drawing a diagram explaining the stages of fermentation, and explaining the role of yeast and amylase in the process. By providing these activities, learners with kinesthetic learning styles can engage in simple experiments, such as making wine from fruit by following a planned fermentation procedure, and inferring the impact of fermentation on the flavour and aroma of the wine. This supports the development of collaborative skills according to students' learning styles based on difficulty levels, such as biology learning activity projects tailored to the material studied (Marzuki & Silvia, 2023). Research by Zuhra et al. (2021) revealed that the learning model combined with student worksheets can improve learning outcomes in guided inquiry on the structure and function of plant tissues compared to learning using conventional strategies. Not only that, research by Safitri & Tanjung (2023) revealed that STEM-based LKPD on virus material was effective in improving science literacy skills from pretest scores to post-test scores by 70%.

Supporting biology teaching materials in differentiated learning are also presented in various formats, such as text, images, graphics, and 3D interactive. For example, in learning about biodiversity, students can access textbooks that include photos of species, habitat distribution charts, and scientific articles on the impact of environmental change. In addition, supporting learning styles using learning videos is very effective in visualising the concept of learning materials in the form of animations and demonstrations (Mazaimi & Sary, 2023). Then to make more memorable information about a concept, it can also use poster support with graphic designs that present it in a concise and attractive manner so that it is useful for better visual learning (Ningrum et al., 2021).

The utilisation of various learning media can provide a more diverse learning experience in differentiated learning, thus attracting student attention and helping to meet the needs of different learning styles. Julianti et al. (2022) revealed that the use of multimedia in the form of animated videos has an influence and is very effective on learning. This is because it combines text, narration and animated graphics to make it easier for students to remember information. For example, on the material of ecosystem components without having to study outside the classroom but can be seen in the classroom. Weng et al. (2020) argue that the importance of using other interactive digital media that can visualise abstract concepts for understanding and structure of an object model, such as the use of augmented reality (AR) media as a supplement to biology learning. Thus, the application of a variety of digital media in differentiation-based biology learning can facilitate students' understanding and meet the needs of learning styles, making lessons more interesting.

Q3: What impacts have resulted from the implementation of Biology learning using a differentiated approach in the Independent Curriculum?

Learning with a differentiated approach in Biology lessons has been proven to be able to foster and improve 21st century skills in students. Based on the results of the study, the 21st century skills that are often discussed in differentiated learning include critical thinking skills, creativity, collaboration and communication skills, as can be seen in the following diagram.

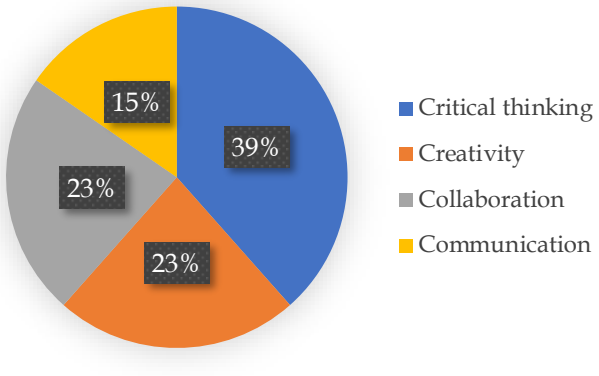


**Figure 4.** 21st century skills developed in differentiated learning

In Figure 4, the critical thinking skills aspect is seen as a percentage of skills that are often developed in school learning. It is in differentiated learning that students are trained to analyse real-world problems based on information that has been gathered in greater depth. By engaging in tasks that require critical evaluation, students develop the ability to assess situations from multiple perspectives, making them relevant and evidence-based. Qorib (2024) argues, that indications of critical reasoning can be shown through answering the questions given. This can be attributed to the high compatibility between different learning styles which is done to train various mental skills when proposing various discussions and expressing opinions, and enabling learners to think (Al-Shehri, 2020). For example, in the topic of climate change, students can analyse global temperature data and formulate arguments about mitigation measures that need to be taken. This process encourages students to evaluate different ideas and make informed decisions, leading to effective solutions.

In the aspect of creativity skills, differentiated learning encourages students to explore various solutions in completing tasks, fostering innovative thinking and creative problem solving. Students can tailor their learning experience to their individual learning styles, thus enhancing their ability to generate new ideas and unique solutions (Safi'i et al., 2024). Research by Solihah et al. (2023) revealed that learning that is projected into various product differentiations can accommodate learners' skills to increase their creativity, such as infographics, power points, and videos. For example, in the ecosystem topic project with the issue of urban flooding, the form of analysis of the news broadcast is the impact of flooding on ecosystem components, causes of flooding, initiatives. This is also supported by Atmojo et al. (2025), that the project-based learning model based on differentiated learning has an influence on creative thinking skills by providing deeper insights. Thus, this approach not only fosters creativity, but also prepares students for complex problem-solving tasks in their future academic and professional endeavours.

In terms of collaboration skills, this is an important part of differentiated learning, where students are trained to work in groups. For example, in the topic of excretory system, students are divided into groups to conduct urine content tests to observe the characteristics of urine, chloride content, protein content, comparing the urine of normal people with diabetic patients. Research by Kanyugi et al. (2024) revealed that learning with a differentiated approach increases learner participation, such as participating in group discussions to ask questions, provide explanations, answer questions, experiment, compare results and conclude. Students often work in groups to share ideas and diverse perspectives, thus enriching discussions and teaching the importance of respecting other people's opinions (Wahyuningsih et al., 2024). This collaboration not only improves understanding of the material, but also equips students with interpersonal skills that are critical in the world of work.

In terms of communication skills, differentiated learning allows students to communicate with each other in designing projects, making projects, discussing project results and project presentations in groups. The ability to express ideas by presenting them in front of the class makes them familiar with oral communication (Kurniahtunnisa et al., 2023). Research conducted by Amalia & Siburian (2025), revealed that biology learning oriented towards differentiated learning can improve 4C skills, one of which is communicative skills to prepare students to have 21st century abilities. For example, in the context of the immune system, students prepare project presentations on various role play props of immune system components and their functional disorders, which help them hone their communication skills and answer analysis questions posed by other groups. Thus, improved communication makes learners active in the learning process and makes it easier to understand information.

But of course, differentiated learning has challenges. The challenges faced in learning biology using differentiated learning such as the lack of teacher understanding and the time needed to design differentiated learning. Putri et al. (2024) revealed that teacher difficulties in planning learning include formulating learning objectives, determining assessments, and choosing appropriate learning strategies and media. Not all teachers have implemented all aspects of differentiated learning such as content, process, and product differentiation. Some teachers only implement differentiated learning on content by providing diverse learning resources

(Mardiyah & Solihat, 2023). In this case, the solution is for educators to be provided with training on teachers' understanding of learning paradigms and practices that are aligned with the independent curriculum, school management support, readiness of facilities and infrastructure, and involvement of school partners to design differentiated learning that can reduce workload By providing appropriate support to educators, the existing challenges can be overcome, so that differentiated learning can be implemented more effectively and have a positive impact on student development.

## Conclusion

The diversity of students' needs and learning styles is the basis for implementing a differentiated approach. Through a differentiated approach that is tailored to student learning characteristics, it is expected to accommodate student learning skills such as critical thinking skills, collaboration, communication, and creativity through applied learning models such as problem-based learning (PBL), project-based learning (PjBL), and discovery learning (DL). The application of a differentiated approach through several learning models also does not escape the use of various types of media in supporting the Biology learning process, such as teaching materials in the form of print, visual or audio that can support the objectives of the Independent Curriculum in developing students' 21st century skills. Through the application of appropriate learning models and media in learning Biology can have a positive impact on the development of 21st century student learning skills such as analyzing problems, exploration, providing solutions, and the ability to communicate their findings, so that differentiated Biology learning can accommodate students' learning abilities optimally. Therefore, future researchers and educators can implement differentiated learning according to the diversity and learning needs of students in learning Biology by understanding student characteristics and collaboration between teachers and students.

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**Author Contributions**
Conceptualization, methodology, data collection and analysis, writing—original draft preparation, N.S. and D.M.S.; review, supervision, A.T.P. All authors have read and agreed to the published version of the manuscript.

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Declare The authors declare no conflict of interest regarding the publication of this paper.

## References

Al-Shehri, M. S. (2020). Effect of Differentiated Instruction on the Achievement and Development of Critical Thinking Skills Among Sixth-Grade Science Students. *International Journal of Learning, Teaching and Educational Research*, *19*(10), 77-99. https://doi.org/10.26803/ijlter.19.10.5

Amalia, R., & Siburian, J. (2025). Meta-Analysis of the Implementation of Problem Based Learning (PBL) Oriented to Differentiated Learning in Biology Learning to Improve Students' 4C Skills of 21st Century Student. *Justek: Jurnal Sains dan Teknologi*, *8*(1), 01-12. https://doi.org/10.31764/justek.v8i1.28332

Aprilianti, A. R., & Siswandari, S. (2024). Keefektifan Model Problem Based Learning (PBL) untuk Meningkatkan Kemampuan Berpikir Kritis Siswa SMK Akuntansi pada Pembelajaran Komputer Akuntansi. *Jurnal Pendidikan dan Pembelajaran Indonesia (JPPI)*, *4*(3), 1255-1266. https://doi.org/10.53299/jppi.v4i3.733

At'haya, A., Hindriana, A. F. H. A. F., & Nur, S. H. N. S. H. (2023). Analisis Profil Pelajar Pancasila dalam Proses Pembelajaran Biologi SMA pada Kurikulum Merdeka Mandiri Belajar: (Analysis of Pancasila Student Profiles in the Biology Learning Process at Senior High School in the Merdeka Curriculum Category Independent Study). *BIODIK*, *9*(3), 60-70. https://doi.org/10.22437/biodik.v9i3.27256

Atmojo, I. R. W., Ardiansyah, R., Pramesthi, A. D., & Adi, F. P. (2025). The Effect of Project-Based Learning Model Based on Differentiation Learning on Creative Thinking Skills in Science Learning. *Multidisciplinary Science Journal*, *7*(4), 2025151-2025151. https://doi.org/10.31893/multiscience.2025151

Avandra, R., & Desyandri, D. (2022). Implementasi Pembelajaran Berdiferensiasi Terhadap Keterampilan Berpikir Kritis Siswa pada Pembelajaran IPA Kelas VI SD. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang*, *8*(2), 2944-2960. https://doi.org/10.36989/didaktik.v8i2.618

Bendriyanti, R. P., Dewi, C., & Nurhasanah, I. (2021). Manajemen Pembelajaran Berdiferensiasi dalam Meningkatkan Kualitas Belajar Siswa Kelas IX SMPIT Khairunnas. *JP (Jurnal Pendidikan): Teori dan*

*Praktik*, *6*(2), 70-74. https://doi.org/10.26740/jp.v6n2.p70-74

Cahya, M. D., Pamungkas, Y., & Faiqoh, E. N. (2023). Analisis Karakteristik Siswa sebagai Dasar Pembelajaran Berdiferensiasi Terhadap Peningkatan Kolaborasi Siswa. *BIOMA: Jurnal Biologi dan Pembelajaran Biologi*, *8*(1). https://doi.org/10.32528/bioma.v8i1.372

Candrikaningtyas, S., Noorhidayati, N., & Putra, A. P. (2024). Validasi Lembar Kerja Peserta Didik Elektronik Berbasis PBL Topik Keanekaragaman Hayati di SMA. *JUPEIS: Jurnal Pendidikan dan Ilmu Sosial*, *3*(3), 1-10. https://doi.org/10.57218/jupeis.Vol3.Iss3.1065

Dinter, V. R., Tekinerdogan, B., & Catal, C. (2021). Automation of Systematic Literature Reviews: A Systematic Literature Review. *Information and Software Technology*, *136*, 106589. https://doi.org/10.1016/j.infsof.2021.106589

Fajrina, S., Anggriyani, R., Arsih, F., Fadilah, M., Restudila, E., Kharisma, A., & Putri, A. M. (2024). The Feature of Project-Based Learning and Differentiated Instruction Practices in Biology Learning. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10142-10151. https://doi.org/10.29303/jppipa.v10i12.8992

Farid, I., Yulianti, R., Hasan, A., & Hilaiyah, T. (2022). Strategi Pembelajaran Diferensiasi dalam Memenuhi Kebutuhan Belajar Peserta Didik di Sekolah Dasar. *Jurnal Pendidikan dan Konseling (JPDK)*, *4*(6), 11177-11182. https://doi.org/10.31004/jpdk.v4i6.10212

Habibi, R., & Manurung, A. G. R. (2023). SLR Systematic Literature Review: Metode Penilaian Kinerja Karyawan Menggunakan Human Performance Technology. *Journal of Applied Computer Science and Technology*, *4*(2), 100-107. https://doi.org/10.52158/jacost.v4i2.511

Halimah, N., Hadiyanto, H., & Rusdinal, R. (2023). Analisis Pembelajaran Berdiferensiasi sebagai Bentuk Implementasi Kebijakan Kurikulum Merdeka. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *8*(1), 5019-5019. Retrieved from https://journal.unpas.ac.id/index.php/pendas/article/view/7552/3479

Ilma, A. Z., Istiandaru, A., & Ritasari, N. S. (2024). Implementing Discovery Learning Model Using Virtual Laboratory: An Insight to Differentiation Learning Strategies. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 2110–2117. https://doi.org/10.29303/jppipa.v10i4.5784

Irma, S., & Prafitasari, A. N. (2023). Implementasi Pembelajaran Berdiferensiasi Proses dengan Problem Based Learning pada Pembelajaran Biologi. *National Multidisciplinary Sciences*, *2*(2), 82–87. Retrieved from https://proceeding.unmuhjember.ac.id/index.php/nms/article/view/489

Jannah, M., Khaldun, I., Safrida, S., & Muhibbuddin, M. (2020). Application of Virtual Laboratory Assisted Discovery Learning Model to Improve Science Process Skills and Learning Outcomes in Circulatory System Material. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 34-40. https://doi.org/10.29303/jppipa.v7i1.470

Julianti, C., Harahap, R. D., & Safitri, I. (2022). The Use of Multimedia in Biology Learning: MAS Subulussalam Sumberjo Student Responses. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, *4*(3), 306-314. https://dx.doi.org/10.20527/bino.v4i3.13812

Kanyugi, D. K., Obote, D., Munanu, S., & Iguna, M. (2024). Effect of Differentiated Instructional Approach on Learners' Participation and Academic Achievement in Biology in Public Secondary Schools in Mbeere North Sub-County, Kenya. *East African Journal of Education Studies*, *7*(3), 1-12. https://doi.org/10.37284/eajes.7.3.2012

Karlina, L., Hindriana, A. F., & Nur, S. H. (2022). Implementasi Profil Pelajar Pancasila dalam Kurikulum Merdeka Mandiri Berubah pada Pembelajaran Biologi di SMA Kabupaten Kuningan. *Edubiologica: Jurnal Penelitian Ilmu dan Pendidikan Biologi*, *10*(1), 9-19. https://doi.org/10.25134/edubiologica.v10i1.10265

Koimah, S. M., Zahra, N. A., Prasitini, E., Sasmita, S. K., & Sari, N. (2024). Implementasi Pembelajaran Berdiferensiasi untuk Memenuhi Kebutuhan Belajar Siswa yang Beragam. *Jurnal Ilmu Sosial dan Budaya Indonesia*, *2*(2), 58-66. https://doi.org/10.61476/49j96838

Kurniahtunnisa, K., Anggraito, Y. U., Ridlo, S., & Harahap, F. (2023). STEM-PjBL Learning: the Impacts on Students' Critical Thinking, Creative Thinking, Communication, and Collaboration Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5007-5015. https://doi.org/10.29303/jppipa.v9i7.2985

Lailiyah, N., & Mas'ud, S. (2024). Analisis Tantangan Guru dalam Menerapkan Pembelajaran Berdiferensiasi pada Kurikulum Merdeka di Sekolah Dasar. *Journal on Teacher Education*, *6*(2), 1-12. https://doi.org/10.31004/jote.v6i2.38501

Lasaiba, I. (2023). Raising Ecological Awareness: A Biological Approach to Sustainable Education. *Jendela Pengetahuan*, *16*(2), 143-163. https://doi.org/10.30598/jp16iss2pp126-146

Lembong, J. M., Lumapow, H. R., & Rotty, V. N. J. (2023). Implementasi Merdeka Belajar sebagai Transformasi Kebijakan Pendidikan. *Jurnal Educatio*

*FKIP Unma*, *9*(2), 765-777. https://doi.org/10.31949/educatio.v9i2.4620

Mahfudz, M. S. (2023). Pembelajaran Berdiferesiasi dan Penerapannya. *SENTRI: Jurnal Riset Ilmiah*, *2*(2), 533-543. https://doi.org/10.55681/sentri.v2i2.534

Mardiyah, F. H., & Solihat, R. (2023). Differentiated Instruction Analysis on the Topic of Cell Reproduction in 12th Grade of Senior High School. *Assimilation: Indonesian Journal of Biology Education*, *6*(2), 109-116. https://doi.org/10.17509/aijbe.v6i2.58538

Marzuki, M., & Silvia, M. (2023). Pengaruh Penggunaan Lembar Kerja Siswa (LKS) Terhadap Hasil Belajar Siswa pada Pembelajaran Biologi Kelas XI IPS 1 di SMA Sinar Kasih Sintang. *Jurnal Pendidikan Tambusai*, *7*(3), 20643–20651. Retrieved from https://jptam.org/index.php/jptam/article/download/9543/7782/17881

Maulani, B. I. G., Hardiana, H., & Jamaluddin, J. (2023). Upaya Peningkatan Hasil Belajar Biologi Melalui Penerapan Model Pembelajaran Problem-Based Learning dengan Pendekatan Pembelajaran Berdiferensiasi di Kelas X IPA 2 SMA Negeri 7 Mataram Tahun Ajaran 2022/2023. *Jurnal Ilmiah Profesi Pendidikan*, *8*(4), 2632-2637. https://doi.org/10.29303/jipp.v8i4.1728

Mazaimi, Z., & Sary, I. (2023). Perbandingan Efektivitas Pembelajaran Tradisional dan Pembelajaran Berbasis Video di Sekolah Menengah Atas. *Jurnal Teknologi Pendidikan*, *2*(1), 72-79. https://doi.org/10.56854/tp.v2i1.221

Minasari, U., & Susanti, R. (2023). Penerapan Model Problem Based Leaning Berbasis Berdiferensiasi Berdasarkan Gaya Belajar Peserta Didik pada Pelajaran Biologi. *Ideguru: Jurnal Karya Ilmiah Guru*, *8*(2), 282-287. https://doi.org/10.51169/ideguru.v8i2.543

Muktamar, A., Yusri, H., Amalia, B. R., Esse, I., & Ramadhani, S. (2024). Transformasi Pendidikan: Menyelami Penerapan Proyek P5 untuk Membentuk Karakter Siswa. *Journal of International Multidisciplinary Research*, *2*(2), 1-8.

Nawati, A., Yulia, Y., & Khosiyono, B. H. C. (2023). Pengaruh Pembelajaran Berdiferensiasi Model Problem Based Learning Terhadap Hasil Belajar IPA pada Siswa Sekolah Dasar. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *8*(1), 6167-6180. https://doi.org/10.23969/jp.v8i1.8880

Ningrum, F. W., Nurheni, A., Umami, S. A., Sufanti, M., & Rohmadi, R. (2021). Revitalisasi Budaya Literasi Melalui Pemanfaatan Infografis di SMK Sukawati Gemolong Kala Pandemi. *Buletin KKN Pendidikan*, *3*(2), 161-168. https://doi.org/10.23917/bkkndik.v3i2.14550

Novitasary, R. R. (2023). Penerapan Pembelajaran Berbasis Proyek pada Kurikulum Merdeka Belajar untuk Meningkatkan Keterampilan Komunikasi Peserta Didik. *Jurnal Inovasi Pembelajaran Biologi*, *4*(2), 100-112. https://doi.org/10.26740/jipb.v4n2.p100-112

Pare, A., & Sihotang, H. (2023). Pendidikan Holistik untuk Mengembangkan Keterampilan Abad 21 dalam Menghadapi Tantangan Era Digital. *Jurnal Pendidikan Tambusai*, *7*(3), 27778-27778. Retrieved from http://repository.uki.ac.id/id/eprint/13167

Pertiwi, A. D., Nurfatimah, S. A., & Hasna, S. (2022). Menerapkan Metode Pembelajaran yang Berpusat pada Siswa Menuju Masa Transisi Kurikulum Mandiri. *Jurnal Pendidikan Tambusai*, *6*(2), 8839-8848. https://doi.org/10.31004/jptam.v6i2.3780

Purba, E., Banjarnahor, E. T., Tampubolon, F. A., Sebayang, R. R., Damanik, S. P., Ambarita, Y., & Harahap, S. (2024). Identifikasi Metode Project Based Learning dalam Pembelajaran Drama pada Sekolah Menengah Atas. *DEIKTIS: Jurnal Pendidikan Bahasa dan Sastra*, *4*(4), 1004-1013. https://doi.org/10.53769/deiktis.v4i4.1149

Putri, A., Anas, N., & Adlini, M. N. (2023). Analisis Keterampilan Abad 21 Siswa dalam Pembelajaran Biologi. *Pendekar: Jurnal Pendidikan Berkarakter*, *1*(5), 01-17. https://doi.org/10.51903/pendekar.v1i5.395

Putri, N. A., Lufri, L., Syamsurizal, S., Arsih, F., & Fajrina, S. (2024). Initial Analysis of the Implementation of Biology Learning in the Merdeka Curriculum. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2776–2785. https://doi.org/10.29303/jppipa.v10i5.7013

Qorib, M. (2024). Analysis the Impact of Differentiated Instruction on Critical Diversity Literacy in Inclusive Education. *Aksaqila International Humanities and Social Sciences [AIHSS] Journal*, *3*(1), 1-19. https://doi.org/10.30596/aihss.v3i1.502

Rahmah, L., Setiono, S., & Ramdhan, B. (2023). Pengaruh Penerapan Bahan Ajar Berdiferensiasi Berbasis Multiple Intelligence Terhadap Kemampuan Berpikir Kritis Peserta Didik. *Bioscientist: Jurnal Ilmiah Biologi*, *11*(2), 908-923. https://doi.org/10.33394/bioscientist.v11i2.8405

Rahmawati, S., Istyadji, M., & Irhasyuarna, Y. (2023). Development of Science Learning Modules on the Topic of Biotechnology for Differentiate Learning Independent Learning Curriculum for Students in Junior High School. *J Adv Educ Philos*, *7*(6), 215-219. https://doi.org/10.36348/jaep.2023.v07i06.003

Rohmah, A., & Zulfitria, Z. (2024). Strategi Pembelajaran Diferensiasi Berbasis Aktivitas dalam Meningkatkan Motivasi Belajar Siswa SD. *Journal of Instructional and Development Researches*, *4*(4), 214-222. https://doi.org/10.53621/jider.v4i4.330

Safi'i, M., Surip, M., & Lubis, M. (2024). Studi Literatur Inkuiri Terbimbing Terhadap Kemampuan Berpikir Kritis Pembelajaran Bahasa Indonesia Kelas X SMK. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *7*(3), 2279-2287. https://doi.org/10.54371/jiip.v7i3.3576

Safitri, N., & Tanjung, I. F. (2023). Development of STEM-Based Student Worksheets on Virus Material to Improve Student Science Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1457–1464. https://doi.org/10.29303/jppipa.v9i3.3288

Santi, T. K. (2023). The Exploration of the Surrounding Nature Approach with the Discovery Learning Model for Biology Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4443-4449. https://doi.org/10.29303/jppipa.v9i6.3508

Sari, B. W. Y., Jufri, A. W., & Kusuma, A. S. (2024). The Effect of Discovery Learning Model on Concept Mastery and Critical Thinking Ability of Biology Students. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4270–4277. https://doi.org/10.29303/jppipa.v10i7.8455

Sayan, H., & Mertoğlu, H. (2020). Equipment Use in Biology Teaching. *Journal of Educational Issues*, *6*(1), 357–371. https://doi.org/10.5296/jei.v6i1.17042

Shafira, I., Rahayu, F. F., Rahman, F. R., Mawarni, J., & Fitriani, D. (2023). Penerapan Model Problem Based Learning Berbasis Berdiferensiasi Berdasarkan Gaya Belajar Peserta Didik pada Pelajaran Biologi Materi Ekosistem Kelas X SMA. *Journal on Education*, *6*(1), 48-53. https://doi.org/10.31004/joe.v6i1.2912

Solihah, R., Minarti, I. B., & Mukaromah, S. (2023). Analysis of Product Differentiation Through Problem Based Learning on the Level of Creativity of Class X Students of SMAN 2 Semarang. *Jurnal Mangifera Edu*, *8*(1), 17-24. https://doi.org/10.31943/mangiferaedu.v8i1.168

Sugiharti, N., & Gayatri, Y. (2021). Profil Kemampuan Berpikir Kritis Siswa SMA Muhammadiyah Kota Surabaya pada Pembelajaran Biologi. *Pedago Biologi: Jurnal Pendidikan dan Pembelajaran Biologi*, *9*(1), 34-40. https://doi.org/10.30651/pb:jppb.v9i1.12414

Suhardi, R. M., Admawati, H., Mutia, N. B., & Faresta, R. A. (2023). Exploring Students' Motivation in The Biology Class Using Differentiated Instruction Integrated with A Problem-Based Learning Model. *Biota*, *16*(2), 100-111. https://doi.org/10.20414/jb.v16i2.465

Sulistiani, S., Suyatna, A., & Rosidin, U. (2024). Differentiated Learning Assisted by Student Worksheets with STEM Content on Alternative Energy Materials to Improve Science Process Skills and Creative Problem Solving. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 385–395. https://doi.org/10.29303/jppipa.v10i1.5253

Sutarini, S., Sutikno, S., Sutikno, M., & Juwita, P. (2024). Penerapan Model Project Based Learning (PjBL) untuk Meningkatkan Kreativitas Mahasiswa Mendesain Media Pembelajaran Berbasis Literasi pada Mata Kuliah Bahasa Indonesia SD 1 UMN Al Washliyah. *Jurnal Pendidikan West Science*, *2*(2), 129-139. https://doi.org/10.58812/jpdws.v2i02.1226

Thurrodliyah, N. I., Usman, A., & Suciati, S. (2024). Penerapan Model Pembelajaran Problem-Based Learning (PBL) Berdiferensiasi untuk Meningkatkan Hasil Belajar Biologi. *Jurnal Biologi*, *1*(3), 1-14. https://doi.org/10.47134/biology.v1i3.1970

Variacion, D. A., Salic-Hairulla, M., & Bagaloyos, J. (2021). Development of Differentiated Activities in Teaching Science: Educators' Evaluation and Self-Reflection on Differentiation and Flexible Learning. *Journal of Physics: Conference Series*, *1835*, 012091. https://doi.org/10.1088/1742-6596/1835/1/012091

Wahyuningsih, D., Noviasari, A., & Azis, Z. (2024). Kontribusi Anak Berkebutuhan Khusus dalam Dinamika Pembelajaran Kolaboratif di Sekolah Dasar. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang*, *10*(04), 263-273. https://doi.org/10.36989/didaktik.v10i04.3668

Weng, C., Otanga, S., Christianto, S. M., & Chu, R. J. C. (2020). Enhancing Students' Biology Learning by Using Augmented Reality as a Learning Supplement. *Journal of Educational Computing Research*, *58*(4), 747-770. https://doi.org/10.1177/0735633119884213

Zuhra, S., Muhibbuddin, M., & Rahmatan, H. (2021). Implementation of Guided Inquiry Strategy Combined with Scientific Student Worksheets on the Structure and Function of Plant Tissues to Improve Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 582-586. https://doi.org/10.29303/jppipa.v7i4.766

Zulaiha, S., Meisin, M., & Meldina, T. (2023). Problematika Guru dalam Menerapkan Kurikulum Merdeka Belajar. *Terampil: Jurnal Pendidikan dan Pembelajaran Dasar*, *9*(2), 163-177. Retrieved from https://ejournal.radenintan.ac.id/index.php/terampil/article/view/13974/6019