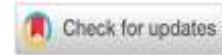




## The learning strategy for biodiversity concept: Pedagogical analysis based on technological pedagogical and content knowledge



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### ABSTRACT

Sustainable Development Goals (SDGs) emphasize quality education and environmental protection. Biodiversity education in Phase E requires students to solve problems related to biodiversity. However, complex terminology and limited learning tools create challenges. This research aims to analyze effective learning strategies for teaching biodiversity using a TPACK framework. The method used in this research is a literature review carried out systematically by PRISMA. The analysis will map pedagogical approaches, content based on CoRes analysis, and technological aspects. Findings will inform the development of effective learning strategies for high school biodiversity education, contributing to achieving SDGs, particularly SDG 15 on terrestrial ecosystems. The finding shows that The use of CoRes to narrow down the information is required to instruct students and promote the attainment of the 15th SDG goal. Based on the findings of the analysis, the pedagogical review of the approach used, namely local wisdom, the field trip method, and the discovery learning model, as well as the use of technology to assist students in identifying PlantNet, Picture This, and iNaturalist, is considered effective to be implemented in learning biodiversity material.

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### INTRODUCTION

A key component of the 2030 agenda is the 17 universal, transformational, and inclusive sustainable development goals (SDGs). The SDGs describe the major development challenges

facing humanity. The SDGs address a wide range of social needs such as education, health, social protection, and employment opportunities while addressing climate change and environmental protection (UNESCO, 2017). Concerning the above, especially education, all students must have access to the knowledge and skills needed to support sustainable development, by the fourth goal of the SDGs, namely quality education (Agirreazkuenaga, 2019; Aleixo et al., 2020; Yuan & Wu, 2021; Zhang et al., 2020).

Following up on the fourth SDG goal, improving the quality of education in Indonesia is the responsibility of all from the government, and education sector institutions including teachers, students, and parents. (Zidan et al., 2023). All countries agree that education comes first. The quality of education is an important factor in the progress of a nation. In other words, the progress of a nation or country can be seen from the quality of its education (Kurniawati, 2022). Teachers play a very important role in the development of the education sector. Teachers are people who teach children in formal schooling, primary and secondary schools. Teachers are the core of education without active participation and the quality of a teacher determines the quality of education (Siregar, 2020). Teachers are responsible for meeting all the needs of their students, so they must have the necessary abilities and competencies to educate students professionally. The purpose of teacher professional development is to improve the quality of teachers (Risdiyana, 2021). The use of technology in teaching is one of the many approaches that have been used to improve teacher professionalism, including the use of technology in teaching. The movement into the digital age has impacted not only the social system but also the education system (Rochintaniawati et al., 2019). To utilize technology in the learning process, teachers must have the ability to combine technological skills, pedagogy, and learning content knowledge. This ability is known as technological content knowledge (TPACK) (Rahayu et al., 2023).

TPACK is a theoretical framework used to combine technology, learning (pedagogics), and subject matter in the learning process it consists of content (Koehler & Mishra, 2009). Technological Pedagogical Content Knowledge is a combination of three main components that serve as a framework for designing learning. In addition to the technological component in TPACK, pedagogy is an important component in understanding learners in psychological and biological learning. Pedagogy emphasizes that successful teachers are not just people who know how to make students smart; they are teachers who help students discover, their interest and their character. (Purnawati et al., 2020)(Nofrion et al., 2018).

In biology learning, biodiversity material is one of the important subjects. Biodiversity material is material whose object of study is very broad. The objects that become the study material are things that are often encountered in the real world, so it needs a strategy for how to teach students the concept of biodiversity (Fitria et al., 2017). The implementation of this biodiversity material is implicitly listed in the biology learning phase E 10<sup>th</sup> knowledge element students are expected to be able to create solutions to problems based on local, national, or global issues related to understanding the diversity of living things and their role. These efforts are directed to support the achievement of sustainable development goals (SDGs) (Kemdikbud, 2022) especially goal 15<sup>th</sup> on terrestrial ecosystems. Goal 15 addresses protecting, restoring, and enhancing the sustainable use of terrestrial ecosystems and halting biodiversity loss (Bappenas, 2020). The material on biodiversity is enough to make students have difficulty in understanding the material, where as many as 65.5% higher students said it was quite difficult, so in studying biodiversity material 44.8% higher students chose quite necessary to be given other teaching media. The shortcomings of the teaching media used in biodiversity material so far, 37.7% more students chose because the explanation of the material was too dense and used complicated language. The Students still struggle when learning the concepts of biodiversity due to the use of complicated terminology, abundant content, the use of many concepts, and the lack of easy-to-understand learning tools

(Sarip et al., 2022). Therefore, pedagogical analysis is needed to identify effective learning strategies for teaching TPACK-based biodiversity materials. The framework of effective learning strategies is expected to be a guide to help teachers develop the learning to be achieved.

The research conducted has a novelty, namely providing learning suggestions based on the TPACK framework that considers the teacher's content skills based on the depth and length of the material, pedagogics in biodiversity material, and the use of technology as a learning medium to make it easier for the student to understand better biodiversity material which is adjusted to phase E learning outcome (Capaian Pembelajaran). This research aims to analyze the learning strategies implemented on biodiversity materials. The mapping in the analysis will be based on TPACK which focuses on pedagogical aspects in the form of skills, approaches, models, and methods, material content aspects based on CoRes analysis (content representation), and technological aspects on biodiversity material. Therefore, this research examines how effective learning strategies can be applied to the concept of biodiversity at the high school level.

## RESEARCH METHODS

### Research Design

The method used in this research is a literature review carried out systematically by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines developed by Page et al (2021) by analyzing relevant international and national articles and focusing on TPACK as a learning strategy for biodiversity material.

### Population and Samples

The population in this study includes scientific works that have been published in various academic databases, university repositories, and other scientific sources that discuss TPACK in teaching biodiversity. By using a purposive sampling technique, samples were obtained in the form of reputable journal articles, both national and international, which studied TPACK in teaching biodiversity from 2019 to 2024.

### Instruments

The types of articles used in this literature review were obtained through Harzing's Publish or Perish software using Google Scholar, Scopus, Crossref, and Semantic Scholar databases by entering keywords: TPACK, learning strategies, learning models, learning methods, learning approaches, learning media, and biodiversity, and by filtering the year range from 2019 to 2024.

### Procedures

The literature review used in the research follows PRISMA guidelines, the procedure of which consists of identification, screening, and inclusion stages. In the identification stage, researchers define research questions clearly and specifically, namely regarding learning strategies for biodiversity material according to the TPACK components. Then proceed with searching for samples of research articles using Harzing's Publish or Perish software. The articles that have been found are then summarized into tables to organize the extracted data complete with bibliographic information (title, author, year, publishing journal, etc). In the screening stage, duplicate articles were removed and initial screening was carried out on titles and abstracts that were irrelevant or did not meet the predetermined inclusion criteria. Then a full-text review is carried out and an article quality assessment is carried out to see whether the article has a significant risk of bias or not. At the inclusion stage, articles were included that met all inclusion and exclusion criteria and had qualified methodological quality.

Significant risk of bias was evaluated using an article quality assessment method based on PRISMA guidelines. This assessment covered various aspects, such as the appropriateness of the research design, data collection, and analysis, as well as the validity of the data used. Additionally,



potential conflicts of interest that could influence the research outcomes were examined to ensure that the included sample articles had a low risk of bias and were reliable.

### Data Analysis

Data analysis in the PRISMA literature review method involves synthesizing findings from various studies to identify patterns, differences, and gaps in the literature. The aspects analyzed include the effectiveness of integrating TPACK into biodiversity teaching material, the diverse pedagogical strategies employed (approaches, methods, and learning models), how technology is harnessed to enhance content understanding, and the challenges encountered in implementing TPACK. This analysis also evaluates how these strategies align with educational goals and highlights areas needing further research to optimize biodiversity teaching strategies through the TPACK framework.

## RESULTS

Based on the results of the literature review, 16 research articles were identified that examined the implementation of TPACK in biodiversity learning materials. The results of the empirical studies related to these articles are presented in Table I.

**Table I.** The Empirical Study on the Implementation of TPACK in Biodiversity Materials Research

No	Authors'	Scope
1	Ramdiah et al (2020)	Local wisdom approach to biodiversity material
2	Sunarsih et al (2020)	Biodiversity module based on local wisdom with discovery learning model
3	Kuswanto et al (2021)	Guided inquiry learning model for biodiversity material
4	Anwar et al (2021)	Problem-based learning model for biodiversity material
5	Shabrina et al (2024)	Problem-based learning model with integrated ESD approach to biodiversity material
6	Amelia et al (2021)	Handbook of biodiversity with a contextual approach
7	Tupas (2019)	Biodiversity teaching materials contain local wisdom with the contextual approach
8	Nugraha & rachmadiarti (2022)	Flipped Book of STEM-based biodiversity material
9	Linawati et al (2023)	Constructivism approach to discovery learning model of biodiversity material
10	Rahma et al (2024)	Field trip method on students' understanding of biodiversity material
11	Fatimah et al (2023)	Learning biodiversity material using the STEM integration PjBL model
12	Nurmaliah et al (2020)	Implementation of the PjBL model in biodiversity material
13	Wilsa et al (2023)	Plant identifier application's capabilities for biology education to plant identification and classification.
14	Mu'minah et al (2023)	Efficacy of the field trip approach with the use of Plantnets as a medium for plant identification
15	Echeverria et al (2021)	Collaborative project with biology students on a citizen science project with iNaturalist.
16	Yusni et al (2023)	Biodiversity learning through an environmental approach, based on local wisdom, assisted by the iNaturalist application.



## DISCUSSION

### Learning materials and scopes

Based on the Merdeka curriculum in phase E, the learning outcomes (Capaian Pembelajaran) are “At the end of phase E, students can create solutions to problems based on local, national or global issues related to understanding the diversity of living things and their role, viruses and their role, biological technological innovation, ecosystem components and interactions between components and environmental changes”. Putra & Kinasih (2023) described the depth and length of biodiversity material in Table 2.

**Table 2.** Depth and Length of Biodiversity Material

Depth	Length
Biodiversity Concept	Diversity in gene, species, and ecosystem level
Indonesia: World Biodiversity Center	Diversity of Endemic Flora and Fauna of Indonesia
Utilization of Indonesia's Biodiversity	Food, Clothing, Board, Health, Energy, Industry, Science and technology
Threats to Biodiversity	Factors Affecting Biodiversity, Endangered and Protected Flora and Fauna
Biodiversity Conservation	Maintaining Forest Sustainability, Determine In Situ and Ex Situ Natural Protection Areas

According to Table 2, we are analyzing the scope of biodiversity learning which is grouped into 4 major characteristics: Content characteristics, dimension of knowledge, difficulty level, and complexity. The development of biodiversity learning media provides direct and concrete learning experiences for students (Pratiwi, et al., 2019). Bridging biodiversity learning in schools with concrete learning experiences is crucial to fostering a deeper understanding and appreciation for the natural world. Concrete learning, as defined by Jerome Bruner (1966), emphasizes hands-on, experiential approaches to grasp abstract concepts.

Biodiversity has a wide range of material that has concepts and theories that can be applied in everyday life (Kusumawardhani and Indana, 2021). Especially in Indonesia which has a broad and rich biodiversity (Dewi et al, 2020). Ngabekti et al. (2021) described the characteristics of biodiversity as clear, contextual/factual. Effective biodiversity learning requires a balance between factual knowledge and conceptual understanding. While memorizing facts about species, ecosystems, and biological processes is essential, it is equally important to develop a deeper comprehension of the underlying principles that govern the natural world (Ausubel, 1960).

Based on a preliminary study conducted by Septian (2018) revealed that 10 out of 14 students faced difficulties in determining the appropriate level of biodiversity, whether genetic diversity, species diversity, or ecosystem diversity, based on the provided examples. The study of biodiversity has a broad enough concept that students find it difficult to understand the material, as well as the level of material difficulty that is quite high, such as the level of genetic diversity and species, the distribution of flora and fauna according to Wallace and Weber lines (Arifin et al., 2021; Novita et al., 2022; Dewi et al., 2020).

### Determining the big idea as content representation (CoRes)

Effective science teaching requires more than just scientific knowledge. Science teachers also need to understand their students, the curriculum, and various teaching methods and assessments. This allows them to transform scientific knowledge into engaging learning experiences for their students (Susilowati, 2017). CoRes (Content Representations) is a tool that helps teachers unpack

their knowledge about teaching specific science topics to particular student groups. CoRes guides teachers through key questions, prompting them to consider the content, student understanding, learning objectives, and appropriate teaching strategies. Bertram & Loughran (2011) offered the CoRes framework to science teachers. The 'Big Idea' is meant to represent the major idea and concept within the particular science content area. According to this research, we are going to analyze the topic of biodiversity learning based on the CoRes framework.

The CoRes framework which is analyzed in this research based on Table 2 offers a valuable tool for educators aiming to effectively teach the concept of Indonesia as a mega biodiversity country. This structured approach highlights key learning objectives, addresses potential challenges, and outlines engaging teaching strategies. By carefully considering these elements, teachers can ensure students grasp the significance of Indonesia's rich biodiversity.

The CoRes emphasizes several key learning points for students. Firstly, it aims to instill an understanding of Indonesia's unique position as a mega biodiversity country. The framework underscores the critical importance of biodiversity for environmental health, ecological balance, and human well-being. Additionally, students will develop a foundational understanding of core biodiversity concepts like species diversity, ecosystem diversity, and genetic diversity. Finally, the curriculum equips students with knowledge of current and future environmental challenges related to biodiversity loss, empowering them to become informed stewards of their environment.

The CoRes framework goes beyond simply outlining these learning points. It also offers a toolbox of engaging teaching strategies. Teachers are encouraged to begin by clearly defining and explaining biodiversity, emphasizing its importance and benefits. Real-world connections are fostered by presenting case studies and examples of biodiversity phenomena specific to Indonesia. Thought-provoking questions further engage students and stimulate their curiosity, encouraging critical thinking skills. Citizen Science Projects (CSPs) as Aripin et al (2021) carried out, provide a valuable platform for hands-on learning and application of these newly learned biodiversity concepts. Finally, the framework promotes the development of critical thinking skills, as students analyze and propose solutions to biodiversity conservation challenges.

By utilizing CoRes, teachers can design lessons that are tailored to their students' needs and learning styles. This framework helps them identify the most effective ways to present the subject matter, ensuring students grasp the importance of the material and engage with the learning process (Susilowati, 2017).

### Learning approach based on research sources

An approach is a strategy for achieving learning objectives chosen when designing learning (Widodo, 2021). The learning approach is an important component because it can influence the way students understand and absorb learning material. Thus the learning approach must be adapted to the needs, interests, and level of understanding of students. Based on the results of the literature review, there are four types of approaches to learning strategies for biodiversity material, they are contextual, local wisdom, constructivism, and integrated approaches.

The contextual approach is a learning strategy that helps students connect the concept of material with real experiences or situations. Biodiversity material is very close to students' lives because it covers various aspects of the environment that students encounter every day, such as local flora and fauna around students, as well as practices such as agriculture and conservation that may be implemented in communities. Therefore, a contextual approach is suitable for use in biodiversity material. The contextual approach allows students to relate biodiversity concepts to students' real experiences so that learning becomes more relevant and easy to understand. As in research by Amelia et al (2021), the development of a biodiversity handbook by utilizing the Bintan coastal environment was able to increase student motivation and learning outcomes. Then in Tupas (2019), it was stated that the use of biodiversity in the Sampunong Bolo Wildlife Reserve in Sara



Municipality, Iloilo, Philippines was able to create enjoyable learning for students so that students were comfortable learning and had an impact on student learning outcomes. By observing biodiversity directly, students can link the theory learned in class with reality in the field, so that their understanding becomes deeper and more meaningful. This is because the information received is not only stored in short-term memory but can be stored in long-term memory (Amelia et al., 2021).

The local wisdom approach is an integral part of the contextual approach because it connects learning material with students' real experiences and environments (Ramdani, 2018). The local wisdom approach has become a research trend in studying biodiversity material. Local wisdom is an important part of understanding the culture and life of a community which cannot be separated from the community itself because it is a constructive identity that must be maintained and at the same time becomes a filter, so that it is not eroded by foreign culture (Afif, 2022; Lenga et al., 2024; Jumriani et al., 2021). In the Merdeka Curriculum, local wisdom is one of the themes of the project to strengthen the profile of Pancasila students, which is specifically a form of implementation of the global diversity dimension. Integrating local wisdom as material content in biology learning makes it easier for students to understand the material thereby supporting the achievement of learning objectives (Festiyed et al., 2022; Sriyati et al., 2022). Apart from theoretically strengthening students' cognitive abilities, this can also strengthen students' attitudes and skills. This is as shown in research by Sunarsih et al (2020) that the development of a biodiversity module containing local potential, apart from improving student learning outcomes on biodiversity material, is also able to train an attitude of caring for the environment. This is confirmed by Karmadi et al (2023) that folklore as a source of student learning on biodiversity material can train critical, creative thinking skills and an attitude of caring for the environment.

The constructivism approach is a learning strategy in which educators act as facilitators and guides, allowing students to explore their knowledge and develop scientific concepts through learning experiences (Yuliani, 2021). Constructivist learning theory emphasizes the importance of interaction in the process of acquiring knowledge, with teachers playing an important role in directing and supporting students during the learning process (Kibirige, 2021). This approach encourages students to actively engage in their learning, connect new knowledge to previous experiences, and build deeper understanding through reflection and discussion. This is as in research by Linawati et al (2023) which explains that learning biodiversity material using a constructivist approach makes students more active in the learning process. Thus, students not only receive information passively but also actively participate in the learning process.

Learning biodiversity material using an integrated STEM-ESD (Science, Technology, Engineering, Mathematics - Education for Sustainable Development) approach is an innovative step in education that combines science and technology with the principles of sustainable development. This approach not only focuses on a theoretical understanding of biodiversity but also invites students to engage in practical projects involving engineering, mathematics, and technology to solve real environmental problems Fatimah et al (2023). Learning tools have a crucial role in the educational process, as they provide the structure, resources, and guidance necessary for teachers and students to achieve learning goals. ESD-laden learning devices can increase students' scientific literacy (Shabrina et al., 2024). Apart from that, research by Nugraha & Rachmadiarti (2022) also explains that STEM-based flipped books as a learning tool can improve students' critical thinking abilities.

### Learning model based on research sources

Based on the results of the literature review, there are four types of learning models in biodiversity material, discovery learning, guided inquiry, problem-based learning, and project-based learning models. The discovery learning model is a learning model that makes learning student-



centered so that students are encouraged to be more active and understand concepts, meanings, and relationships through an intuitive process to reflect on a teaching and learning activity (In'am A & Hajar S, 2017; Yuliani, 2021). Learning biodiversity material using the discovery learning model can increase students' learning motivation because they are directly involved in discovering a concept through examples and phenomena found in the students' environment (Steward, 2023; Sunarsih et al., 2020). Apart from that, research by Linawati et al (2023) also stated that student learning outcomes on biodiversity material using the discovery learning model increased.

Apart from the discovery learning model which makes students actively involved in discovering concepts, the guided inquiry model is also able to encourage students to be actively involved in the learning process through exploration, observation, and discovery. In the biodiversity learning material, through the guided inquiry learning model students are allowed to directly observe various plant and animal species in the environment around them, carry out simple research, and analyze the data they collect (Kuswanto et al., 2021). With teacher guidance, students learn to formulate questions, design experiments, collect and interpret data, and draw conclusions based on the evidence found, so that learning is more meaningful.

The problem-based learning (PBL) model is a learning model that uses problems that occur in the student's environment to teach a concept to develop critical thinking and problem-solving skills. The problem-based learning model is the right choice for teaching biodiversity material, including issues surrounding the protection and conservation of biodiversity. Through PBL, students not only learn about biological concepts but are also actively involved in solving real problems related to biodiversity. They are invited to identify problems such as habitat loss, species extinction, or environmental degradation, and then look for sustainable solutions. This is as in the research of Komala et al (2021) and Anwar et al (2021) that the problem-based learning model influences students' argumentation and problem-solving abilities regarding learning material on biodiversity issues.

Starting from the case of problems that threaten biodiversity, problem-solving skills alone are not enough to solve these problems. Students need to be equipped with creativity to face various challenges and problems that arise. One real example is project creation. In the project, students are expected to use their imagination and knowledge of biodiversity to solve problems that arise. For example, they may design conservation projects to protect endangered species or create ecosystem mock-ups that reflect the diversity of plants and animals in a region. The Project Based Learning (PjBL) model is a learning model that provides the opportunity to work independently to construct knowledge through creating projects based on the things learned. In research by Fatimah et al (2023) and Nurmaliah et al (2020), the PjBL model was able to increase students' creativity in biodiversity material.

### Learning methods based on research sources

Learning methods are not only a strategy for delivering learning material, but also a link between students and comprehensive knowledge. By utilizing variations in learning methods, teachers can accommodate the different learning styles of each student, strengthen their understanding, and increase learning motivation. When studying biodiversity material, students' lack of knowledge about biodiversity and environmental sustainability occurs because students only learn in the classroom and school environment, so they do not enjoy the environment outside of school (Rahma et al., 2024). This problem can be overcome by using the field trip method. The field trip method can teach real biodiversity material and provide informal learning opportunities for students with an emphasis on cultivating a sense of enjoyment, interest, and curiosity so that this method can increase knowledge of biodiversity and environmental sustainability attitudes among students (Hassan et al., 2022; Rahma et al., 2024).



The field trip method can be used well if students have learning styles outside of school. Therefore, before using the field trip method, teachers must first know what students' learning styles are. Some students may tend towards a visual learning style, so direct experience through field trips can strengthen students' understanding. However, for students with other learning styles, the field trip method is less effective. Thus, teachers must pay attention to variations in student learning styles when planning field trips so that learning will be optimal.

### Learning media based on research sources

The important thing to learn from biodiversity material is to identify plants or animals based on taxonomy or grouping of living things based on their characteristics. Ex. plants are often identified by comparing them with identification books and utilizing a determination key (Santri et al., 2021). Utilizing technology in the modern day can make the process of identifying and classifying more easier (Prasvita, 2012; Rifai et al, 2020). Based on the results of the literature review, there are three best practices using technologies that can be used to assist learning students, they are Plantnet, Picture This, and iNaturalist.

Previous studies have demonstrated the benefits of integrating technology and contextual learning for plant identification and classification (Wilsa et al., 2023). Besides that, it can use the Plantnet application to learn about biodiversity. PlantNet is an image-sharing and retrieval application for plant identification. Previous research by Joly, 2015 (Rifa et al., 2020) PlantNet is a plant identification and image capture application, it is simple to identify plant species that have detailed descriptions in the botanical database amount 20.000 plant species (Wilsa et al., 2023). Using this application, students find it helpful in identification and classification because they do not need to export images to Google, modules, or specialized websites to identify plants. This makes finding related information from other literature easier (Mu'minah et al., 2023). Besides that there's. The next application plant identifier is PictureThis. The purpose of this application is to locate plants that can provide comprehensive details about objects they have identified. This imaging program offers information up to the taxonomic level about these plants in addition to presenting scan results. The results of mosses, ferns, dicots, and monocots' identification recognize more than 1,000,000 different types of plants with 98% accuracy. PictureThis application can provide fairly complete taxonomic information for the various plant species tested (mosses, ferns, dicots, and monocots). The taxonomic information presented is also valid when compared to taxonomic information available in the literature and online searches (Wilsa et al., 2023).

The application of Naturalist can also be used as a best practice in biodiversity learning. Using the Naturalist platform, students can record their various experiences with biodiversity in today's world. Documentation of organisms can be saved in the form of photos, videos, and sounds. Besides that, this application identifies an organism and then records all the characteristics observed until guided to see the spread of the organism around the world on an ongoing basis supporting the local wisdom approach and environment approach (Pernat et al., 2022; Boone & Basille, 2019; Ramdani, 2018). The integration of this activity is a way to show the power of citizen science to gather biodiversity observations. The students could also see how their observations could be merged with data from academic institutions in the online repository of the GBIF. Additionally, iNaturalist gave them access to additional information like global distribution maps, phenology patterns, conservation status, or position in the taxonomical tree, and citizen-science platforms offer a great potential to add value to traditional field activities (Echeverria et al., 2021; Unger et al., 2020).

## CONCLUSION

In studying biodiversity material, students are required to observe various species and ecosystems. In addition, learners must also be able to provide conservation proposals through



prediction and communication activities. The use of CoRes in narrowing down the material is necessary to teach students and strive to support the achievement of the goals of the 15th SDG point. Based on the results of the analysis of the findings, the pedagogical review of the approach used namely local wisdom, using the field trip method and discovery learning model, as well as the use of technology to assist students in identifying PlantNet, Picture This and iNaturalist, is considered effective to be implemented in learning biodiversity material.

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