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Analysis of Content Representation (CoRes) and TPACK (Technological Pedagogical Content Knowledge) in Biotechnology Material

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ABSTRACT

TPACK is a complete combination of knowledge and skills in the field of material and teaching strategies that are adapted to technological developments. The purpose of this article is to analyze the breadth and depth of molecular biotechnology material in CoRe to find out important concepts that need to be taught to students to summarize modern biotechnology learning with molecular biotechnology sub-material and present TPACK, which has been analyzed and reconstructed. This research method uses a qualitative approach and a literature study. Biotechnology material is difficult to understand and is abstract, especially molecular biotechnology material. Meanwhile, teachers are still not using appropriate learning strategies in the field. So, teachers must have skills in designing effective learning to achieve learning goals. By analyzing which the teacher will provide essential content through Content Representation (CoRes) and then combining it with selecting appropriate learning strategies based on TPACK (Technological Pedagogical and Content Knowledge), it can help students understand biotechnology material that they find difficult and can be referenced for teachers to select appropriate learning models, media, and learning approach.

Keywords: TPACK, Content representation, Biotechnology

Introduction

Education is bringing humans from their current state to their desired state. The hope is that education will create people who have good qualities (Ratini et al., 2018). Designing innovative learning for biology learning is fundamental to developing the next generation with creative, critical, competitive, and decision-making skills in the 21st century. Applying 21st-century skills in learning is important because 21st-century learning not only encourages cognitive knowledge, soft skills, and hard skills (Redhana, 2019). There are challenges in the 21st century, including challenges to teachers' skills in developing development plans involving TPACK. TPACK is a comprehensive combination of subject matter, knowledge, teaching skills, and technological developments. Shulman formulated TPACK in 1987, while Koehler & Mishra developed it in 2008 (Suyamto et al., 2020). TPACK is a framework to understand the relationship between pedagogical knowledge (education knowledge) and technical knowledge (technology knowledge). This framework suggests that to use technology in learning, teachers must have pedagogical knowledge and technical knowledge. By combining these two types of knowledge, teachers can teach it better (Oyanagi & Satake, 2016).

Learning with TPACK requires teachers or prospective science teachers to understand content and resources such as CoRe, which includes explanations of concepts and material important for teaching certain topics (Elvianasti, 2019). In Australia, around a third have limited understanding or do not understand biotechnology at all, while the other third cannot correctly identify the impacts of biotechnology (Dawson & Scbeci, 2003). The low mastery of this science among students and the general public is most likely due to the difficulty of studying biotechnology at school, so studying this field requires thorough preparation. The next difficulty is the lack of tools to observe biotechnological processes (Zulpadly et al., 2016). In the biotechnology field, there is a complex combination of materials between Modern Biotechnology and Molecular Biotechnology, which combines recombinant DNA technology to create a very dynamic and competitive field of study (Suwanto, 1998). So, this article aims to analyze the breadth and depth of molecular biotechnology material in CoRe to find important concepts that students need to be taught to summarize modern biotechnology lessons with molecular biotechnology sub-material and present TPACK, which has been analyzed and reconstructed.

Methods

The research takes approximately one month. The method applied in this research is library research. In literature research, the first step is to search for and analyze data from previous research related to the topic being studied to support research, broaden understanding, and enrich insights about the topic (Amalia et al., 2022; Marzali, 2016).

The research reference sources come from scientific articles obtained from leading journals both domestically and abroad that are relevant to the topic being discussed, especially those indexed by SINTA and SCOPUS, including articles published by well-known academic publishers such as Elsevier, Springer, and leading national journals managed by leading universities in Indonesia that study education regarding biotechnology using Technological Pedagogical and Content Knowledge (TPACK) and Content Representation CoRes as a basis. The literature study process involves several stages: collecting articles, reducing articles based on certain variables, compiling selected articles, organizing and discussing, and drawing conclusions (Asbar & Witarsa, 2020).

Results and Discussion

Curriculum Analysis of Biotechnology Material

A curriculum analysis on biotechnology material was carried out on the 2013 curriculum and the Merdeka curriculum. The analysis was used to compare modern biotechnology materials in the 2013 and Merdeka curricula. Moreover, in certain regions in Indonesia, schools still implement the 2013 curriculum, especially for grade 12, because biotechnology materials are

in grade 12 for the 2013 curriculum. Biotechnology material is taught in class XII, and the 2013 curriculum is still applied in classes 11 and 12 because implementing the Merdeka curriculum starts in class 10.

Based on Minister of Education and Culture Regulation Number 37 of 2018 on Basic Competencies (KD) 3.10 Analyzing biotechnology principles and their implementation can improve human welfare, and KD 4.10 Presenting the results of reports regarding experiments in applying conventional and modern Biotechnology principles based on scientific methods. The teacher delivered this material in class XII, even in the semester of 2013 Curriculum. The breadth and depth of the biotechnology material can be seen in Table 1.

Table 1. Breadth and depth of biotechnology materials

Spaciousness	Depth
Explain the principles of biotechnology.	Basic ideas of biotechnology, variations of biotechnology (traditional and contemporary biotechnology), and methods used in modern biotechnology (DNA extraction, gene or DNA transfer, insertion of recombinant DNA into living cells).
Identify the impact of applying biotechnology and its examples in everyday life.	The application of biology in fields including food, animal husbandry, agriculture, medicine, and the environmental field, the impact of the application of biotechnology on life, the role of biotechnology, and the production of organic materials.
Compile the results of experimental reports regarding the application of conventional biotechnology.	Conduct experiments in making yogurt, dolly sheep, vaccines, and biodiesel.

Meanwhile, in the Merdeka Curriculum, based on the Decree of the Head of the Educational Assessment Curriculum Standards Agency (BSKAP) Number 033/H/KR/2022 Revision of Decree of the Head of BSKAP Number 008/H/KR/2022 concerning Learning Achievements, biotechnology material is included in the learning outcomes Phase E and Phase F in the Biology subject family. The learning outcomes for the Biotechnology material in Phases E and F are explained in Table 2.

Table 2. Learning achievements of biotechnology material

Element	Phase E and F Learning Outcomes
Understanding Biology	At the end of phase E, related to biotechnology learning is biological technology innovation.
Understanding Biology	At the end of phase F, related to biotechnology learning, evaluating new ideas regarding the evolution and innovation of biological technology.
Process Skills	1. Observe 2. Questioning and predicting 3. Plan and conduct investigations 4. Process, analyze data and information 5. Evaluate and reflect 6. Communicate results

Based on Table 2, biotechnology material is included in the learning outcomes in Phases E and F. The depth and breadth of the material in both phases are the same; even when compared to the 2013 curriculum, there is no significant change in content. However, what needs to be emphasized here is how to teach biotechnology concepts according to the phase,

where students in Phase E of Class 10 and in Phase 12 have different thinking ability levels. This causes the learning strategies for biotechnology material in Phases E and F to be different.

Apart from that, general biology learning outcomes in Phases E and F are directed at achieving Sustainable Development Goals (SDGs). Therefore, it is clear that the main focus of the 2013 curriculum can be distinguished from the Merdeka curriculum in teaching students about biotechnology material. In Indonesia, the current curriculum is the Merdeka curriculum, which aims to simplify the material and focus on important material, a project-based learning process that trains collaboration and application and is related to other learning, as well as flexibility in formulating learning outcomes and setting the learning hours. Aims to design operational curricula and implement learning according to student abilities. The Merdeka curriculum strengthens student character, especially in the Pancasila student profile (Satria et al., 2022).

Analysis of the Characteristics of Biotechnology Materials

Biotechnology is the use of biological principles to create products or simplify processes. There are two types of biotechnology, namely traditional and contemporary. Biotechnology uses genetic engineering to create desired products (Fatmah, 2021). The latest biotechnology technology utilizes genetic engineering methods to change the genetic material of living organisms to create desired products, such as transgenic plants that resist pests or diseases or the production of human insulin using recombinant bacteria. This technology greatly influences various sectors, such as agriculture, health, the environment, and industry (Fatmah, 2021). Looking at the scope of material studied in modern biotechnology, modern biotechnology material has a high level of complexity because it includes quite complicated processes and requires a deeper understanding of the application of biological principles (Tood & Murphy, 2003).

The results of research conducted by Zulpadly et al. (2016) show that material with a high level of difficulty is genetic engineering material, with a percentage of 67.44%, and material explaining the process of gene recombination, with a percentage of 63.07. The high level of difficulty experienced by students in biotechnology material is due to the material being mostly abstract. Learning difficulties in biotechnology can also be caused by time constraints, which prevent teachers from practicing, especially because biotechnology is often taught before the semester and final school exams. The lack of facilities and infrastructure in school laboratories to observe biotechnology processes is also an obstacle in carrying out modern biotechnology practicums (Zulpadly et al., 2016; Rahmadani et al., 2017).

CoRes Analysis of Biotechnology Materials

Biotechnology learning about modern biotechnology material focusing on recombinant DNA can be taught using the Content Representation (CoRe) approach, which is designed to help teachers organize knowledge systematically. This approach includes several main aspects, including:

Table 3. Content representation (CoRes) analysis of molecular biotechnology materials

Important Science Ideas/Concepts	**Big Idea: recombinant DNA**
Why do students learn this concept?	Understanding recombinant DNA in the Modern Biotechnology Material section can help students understand how to develop competence in producing goods and services
Why is this concept important to learn	The concept of recombinant DNA can help students generate basic knowledge to create important products that can compete in the 21st century.
In this case, what concepts do students not have time to learn?	A deep understanding of computer science results in Bioinformatics.

Important Science Ideas/Concepts	Big Idea: recombinant DNA
What obstacles might you face when understanding this concept?	The genetic material involved in the concept of recombinant DNA is highly complex, which can be difficult for students to understand at the school level.
What student factors do you consider when teaching this concept?	In teaching this material, Things must be considered, starting from understanding students' initial knowledge of genetics and molecular biotechnology. By knowing students' prior knowledge, teaching approaches can be adjusted to build a solid understanding.
What other factors influence when studying this concept?	Attention to students' interest in recombinant DNA will help design good learning. Utilizing student interest in the learning process can increase student involvement and understanding of the concept.
What sequence/flow have you determined to teach these concepts?	1. The teacher provides a brief introduction to molecular biotechnology related to recombinant DNA 2. The teacher explains the stages in recombinant DNA technology, such as isolating genomic/chromosomal DNA, cutting DNA molecules, isolating vector DNA, inserting DNA fragments into vectors, transforming host cells, and reisolating recombinant DNA molecules from host cells. This will help students understand the technical process of the recombinant DNA concept 3. The teacher explains the applications and benefits of recombinant DNA technology in everyday life, such as plant breeding, large-scale drug production, and genetic engineering. 4. The teacher conducts group discussions or question-and-answer sessions to ensure students' understanding of the fermentation material. 5. Teachers and students make simple visits to regional laboratories to see directly the process of products and services produced, and then carry out evaluations to measure students' understanding.
How do you determine whether students have understood the material or not?	Ask students to reflect on and write down what they have learned and how they will apply theories or concepts from the material they have learned in everyday life.
Technology that can be applied in teaching this concept	Interactive simulations, such as PhET Simulation, in the form of software or applications, can help students visualize the recombinant DNA process more concretely.
How would you address shortcomings at a school to ensure your goals are still realized?	By evaluating school conditions, adjusting recommendations, and monitoring and evaluating regularly, it is hoped that the objectives of studying the concept of Recombinant DNA can still be achieved even when faced with certain absences or limitations.

TPACK Analysis of Biotechnology Materials (Proposed Media, Models, Approaches, Methods in Accordance)

Learning model

Based on an article analysis carried out on biotechnology material, it was found that several models implemented in biotechnology learning can increase the effectiveness of learning. These models include project-based learning, problem-based learning, and guided inquiry.

Choosing the right innovative learning model is necessary to attract enthusiasm and increase student motivation in learning biology (Larson, 2018).

In the project-based learning (PjBL) model, the advantages are that it can train students to collaborate, provide experience in composing, carrying out projects, and providing solutions, and can teach various critical strategies (Fahadah et al., 2021; Bell, 2010; Bonner, 2018). Research conducted by Khalisah et al. (2024) integrated the PjBL model with the Culturally Responsive Teaching (CRT) method to increase students' learning motivation in designing projects according to the sticky rice tape biotechnology product typical of the Jember region. This is because project assignments related to students' daily lives, such as customs and culture, can make students relevant to the topic material. Research by Noviati et al. (2023) shows that implementing the PjBL model in biotechnology material can improve students' process skills.

Research conducted by Helmi et al. (2023) shows that the implementation of the problem-based learning model can be used to train students' critical thinking skills in biotechnology material because the PBL model can facilitate students through the thinking process of the PBL model stages, such as focusing on questions, looking for logical reasons, managing information, making conclusions, understanding situations, explaining meaning, and examining the conclusions made.

The guided inquiry learning model based on biotechnology material effectively improves student learning outcomes, facilitates students in improving their understanding of the material, and creates an interesting atmosphere (Lestari & Rudayatmi, 2023). Apart from that, applying the guided inquiry learning model can teach students to find out problems, find solutions, and prove them so that it can make students understand concepts better and be interested in participating in learning (Indriwati et al., 2018). However, several things are needed to implement the guided inquiry model in the classroom, namely regarding time management and class mastery (Indriwati et al., 2018). Data regarding several learning models used in biotechnology concepts is presented below.

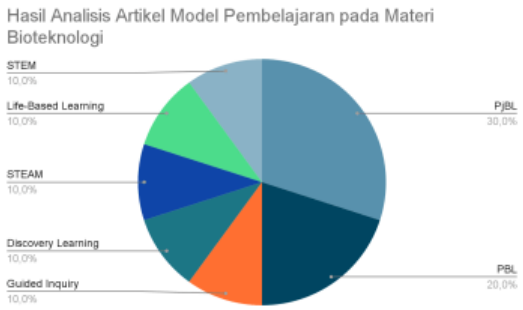

Figure 1. Learning model on biotechnology material

Learning methods

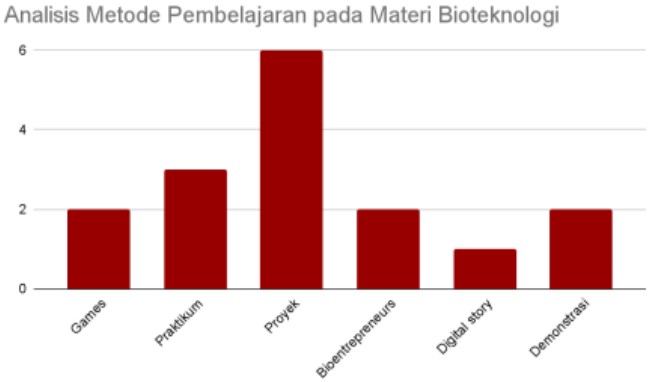

Figure 2. Learning methods on biotechnology material

Based on the articles' analysis, the method most widely used in biotechnology materials is the project method. This is because, in the project learning method, students can work in groups, solve problems, share ideas, and understand team roles to achieve an effective learning process. Collaboration is a very important skill in the workplace and education (Saenab, 2019). Research results by Haerani (2022) show that 98% of students obtained maximum marks in performance assessments, project results, and presentations. Besides, project-based learning in biotechnology material can motivate students, improve problem-solving skills, and increase student collaboration with group friends.

Other effective learning methods used in biotechnology material, namely demonstration methods, were found. Research conducted by Tandaju et al. (2017) shows that the demonstration method of making bioethanol from bananas using the distillation method can improve student learning outcomes. Apart from that, the practicum method is also effectively used, as in research conducted by Sihafudin & Trimulyono (2020); by carrying out practicums for making virgin coconut units enzymatically based on the PBL model, students can train science process skills with an effective percentage of 93.18%. The activities contained in the LKPD include understanding articles, conducting discussions, conducting experiments, and communicating results.

Media

In learning Biotechnology and modern Biotechnology material, by understanding the basics of learning, we can use learning media, including the following:

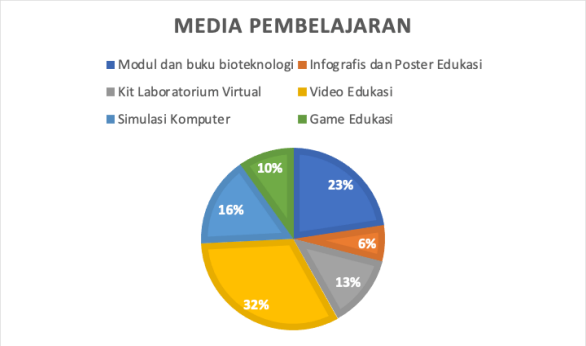

Figure 3. Learning media on biotechnology material

The use of videos can increase students' interest and enthusiasm for the learning process, resulting in a learning achievement level of 92.6% (Widiastuti, 2021). This is also very helpful for teachers because educational video media regarding biotechnology material is widely spread, can be accessed openly, and does not require high costs.

Approach

In learning Biotechnology and modern Biotechnology material, by understanding the basics of learning, we can use learning approaches, including the following:

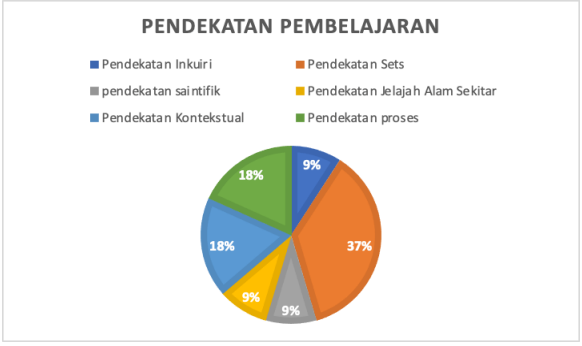

Figure 4. Learning approach to biotechnology material

The SETS approach can improve scientific literacy because many learning media are still inadequate, students still have difficulty understanding the material during teaching and learning, the results of student learning assessments are still below the KKM standard, and students are still dependent on teachers, which ultimately makes them less active and independent when studying (Sholihan et al., 2023).

Conclusion

Based on the results of the analysis above, biotechnology material is found in the 2013 and Merdeka curricula. The material content in the two curricula remains the same. Still, in the Merdeka curriculum, there must be differences in teaching biotechnology material in Phase E in Class 10 and Phase F in Class 12. Biotechnology material is fairly difficult and abstract, especially in molecular biotechnology. Meanwhile, teachers are still not using appropriate learning strategies in the field. So, teachers need the ability to design good learning strategies to achieve learning objectives. Analyzing which teachers will provide essential content through content representation (CoRes) can help students understand biotechnology material that they find difficult. Teachers can also select appropriate learning strategies based on TPACK (Technological Pedagogical and Content Knowledge), such as selecting Project-based learning models or problem-based learning; selecting learning media such as video, models or textbooks, and simulation; selecting simulation, environment, technology, and society (SETS) and contextual learning approach.

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