VOLUME 8 ISSUE 2
JANUARY 2024
E-ISSN: 2622-3384
P-ISSN: 2527-9939

JURNAL MEdu Mangifera Edu

The potential of TPACK-based biology learning to improve students' habits of mind

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ABSTRACT

The significance of habits of mind in achieving student success was contrasted with the low level of students' habits of mind in biology learning. TPACK is a 21st-century learning approach that has the potential to improve students' habits of mind. However, this was not followed by biology teachers' mastery of TPACK, which was relatively low. So far, there has been no research that examines the role of TPACK on students' habits of mind in biology learning. This paper aims to find out the potential and implementation of TPACK-based biology learning in improving students' habits of mind. The method used was a Systematic literature review with 20 sample international and national articles. Access to digital resources enriches students' ideas and supports the development of critical thinking, creativity, and self-regulation skills. In this way, teachers are expected to not only increase their knowledge of content and pedagogy but also integrate technology into learning, allowing students to gain more meaningful knowledge. The form of implementing this technology integration can be in the form of learning media or learning assessments. What was found in this writing is that students' habits of mind can be formed through classroom learning, one of which is the TPACK approach. Recommendations for choosing more diverse biological material were also proposed in this paper so that learning becomes more dynamic, contextual, and then students' habits of mind are achieved.

ARTICLE INFO

Keywords
Biology learning, Habits of mind, TPACK.

Received
November 29, 2023

Revised
January 16, 2024

Accepted
January 19, 2024

Published
January 31, 2024

How to cite
Bariroh, G., Surtikanti, H.K., & Riandi. 2024. The potential of TPACK-based biology learning to improve student's habits of mind. *Jurnal Mangifera Edu*, *8*(2), 27-40. https://doi.org/10.31943/mangiferaedu.v8i2.178

INTRODUCTION

High-quality education indicates that a Nation has attained an improved quality of life, thus positioning education as a benchmark for the advancement of a nation's civilization. In line with this, the Indonesian government launched the "Merdeka Belajar" program as part of Education Reform. This program aims to give students greater autonomy in determining their learning path and developing skills aligned with their interests and potential. *Merdeka Belajar* is also designed to elevate the quality of education and create a more inclusive learning environment. The Pancasila student profile serves as a manifestation of the goals outlined in the *Merdeka Belajar* curriculum, serving as a guide for teachers in building student character and competence. Pancasila student profile consists of six dimensions: 1) faith, devotion to God Almighty, and noble character, 2) independence, 3) cooperation, 4) global diversity, 5) critical reasoning, and 6) creativity (Badan Standar Kurikulum dan Asesmen Pendidikan, 2022). These dimensions form an integrated unit so

that every student becomes a competent lifelong learner with a well character, and guided by the values of Pancasila. The dimensions of the Pancasila student profile intersect with aspects of habits of mind. Habits of mind, are one of the dimensions of long-term learning (learning outcomes). Categorized into three criteria: self-regulation, critical thinking, and creative thinking (Marzano, 1992; Rustaman Nuryani, 2008; Susilowati *et al.*, 2018). Habits of mind refer to the cognitive, social, and emotional skills that support creative thinking, problem-solving, and lifelong learning. Consequently, the skills acquired through habits of mind are not only relevant at school but extend throughout an individual's life.

Habits of mind can evolve into intelligent behavior patterns that facilitate productive actions and contribute to the development of positive student character in problem-solving within their lives (Dwirahayu et al., 2017; Nahadi, 2015). The intellectual behavior patterns adopted by students when facing problems can enhance individual success in solving these problems. Miliyawati (2014) supports this nation, asserting that individual success is determined by the habits they carry out. Thus, the habits of mind play a crucial role in determining their success, particularly in the context of learning biology. Habits of mind in biology learning can be described as students' habits of thinking effectively in constructing and using their understanding of biological knowledge. The importance of habits of mind in students, especially in biology learning, becomes apparent when contrasted with the lower habits of mind observed in high school students (Dwirahayu *et al.*, 2017; Haka *et al.*, 2022; Rikizaputra et al., 2021). Additionally, Yakob *et al* (2021) teachers often find some students with good intellectual abilities have poor behavioral abilities, such as ineffective communication, reluctance to work together with their friends, not having a sense of empathy, and easily giving up when they are faced with challenges. The low habits of mind of students are influenced by teachers who are less innovative in learning, students communicate concepts using the language in books rather than the language they understand so the material is difficult to understand. Furthermore, student tends to be passive in their learning experiences (Haka et al., 2022).

In the framework of Marzano (1992), enjoyable learning is the main factor that must be fulfilled in developing habits of mind so that students can apply their knowledge meaningfully. The Integration of materials, pedagogy, and technology in the learning process enhances students' thinking abilities and makes learning more enjoyable (Wardani *et al.*, 2022). The ability of Biology teachers to incorporate material, pedagogy, and technology into their classes can be seen through Technological Pedagogical and Content Knowledge (TPACK). TPACK consists of main components and integrated components. The main components of TPACK consist of Technological Knowledge (TK), Content Knowledge (CK), and Pedagogical Knowledge (PK). In contrast, the integrated components consist of Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK) (Koehler, 1993; Nurina *et al.*, 2019; Valtonen, 2015). Effective integration of technology in the TPACK framework has the potential to create a learning environment that can encourage critical and creative thinking skills while developing student learning independence so that students can apply their knowledge more meaningfully. This aligns with the finding from research (Rakhmawati *et al.*, 2020) that the integration of technology in learning can improve students' habits of mind.

The role of teachers in 21st-century learning is both interesting and a challenge. The presence of teachers in 21st-century learning is crucial to ensure a meaningful learning process, has character, and is oriented toward developing important 21st-century skills. The role of TPACK as a 21st-century learning approach that must be mastered by teachers is inversely proportional to field conditions. Based on the research results of Paidi *et al* (2021), biology teachers have not mastered TPACK and do not meet good teacher performance standards, especially in the technology knowledge component. Furthermore, additional research also states that biology teachers continue to utilize media and learning methods that are not well aligned with students' needs and do not maximize the use of technology to achieve learning outcomes (Janah, 2022; Rahayu *et al*., 2023).

The emphasis on technology and learning innovation in the Merdeka Curriculum is highly emphasized (Khoirurrijal et al., 2022; Wang et al., 2022). The role of educational technology in the independent learning perspective in the 4.0 era is very influential in terms of making it easier to implement independent learning programs in real terms. This is as stated by Widiyono & Millati (2021) that the integration of technology in learning not only facilitates the planning and learning process but also at the management, utilization, development, and assessment stages which ultimately has an impact on effective, efficient, and meaningful learning for student. Thus, the application of TPACK can guide teachers in integrating technology effectively into the learning process. The application of TPACK in the Independent Learning Curriculum can help teachers design learning experiences that are contextual, innovative, and appropriate to students' needs (Armiyati & Fachrurozi, 2022; Afwan et al., 2021). By combining content knowledge, pedagogy, and technology, teachers can create a learning environment that supports the development of students' thinking abilities or habits of mind.

Based on the two problems regarding students' habits of mind and TPACK in biology teachers above, a study of TPACK is needed, especially in its influence on the three categories of habits of mind: self-regulation, critical thinking, and creative thinking. Presently, there is a gap in research that investigates the role of TPACK on students' habits of mind abilities. Most of the literature studies on the integration of learning technology only focus on measuring one aspect of habits of mind such as self-regulation, critical thinking, or creative thinking (Hidayati et al., 2019; Rakovi et al., 2021; Vari & Bramastia, 2021). In-depth content through literature review using various scientific journals is intended to answer the following questions: 1) What biology topics or materials are often used to investigate habits of mind in learning? 2) How does TPACK-based biology learning have the potential to improve students' habits of mind? 3) How does the implementation of TPACK-based biology learning improve habits of mind? This literature review can provide an overview of the influence of the TPACK learning approach on students' habits of mind abilities as well as make biology teachers in Indonesia aware of the importance of mastering and knowing the important role of TPACK in biology learning. In addition, this article can be used as a reference for teachers to improve students' habits of mind, especially in biology learning.

METHOD

This type of research is a literature review carried out systematically following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines developed by Page

et al., (2021). The methodology employed a systematic literature review by analyzing relevant international and national articles and focusing on TPACK to improve students' habits of mind. The types of articles used in this literature review were obtained through Harzing's Publish or Perish software by entering the keywords: TPACK, habits of mind, critical thinking, creative thinking, self-regulation, and biology learning so that 285 articles were obtained from Google Scholar, Scopus, Crossref, OpenAlex, and Semanticsholar databases.

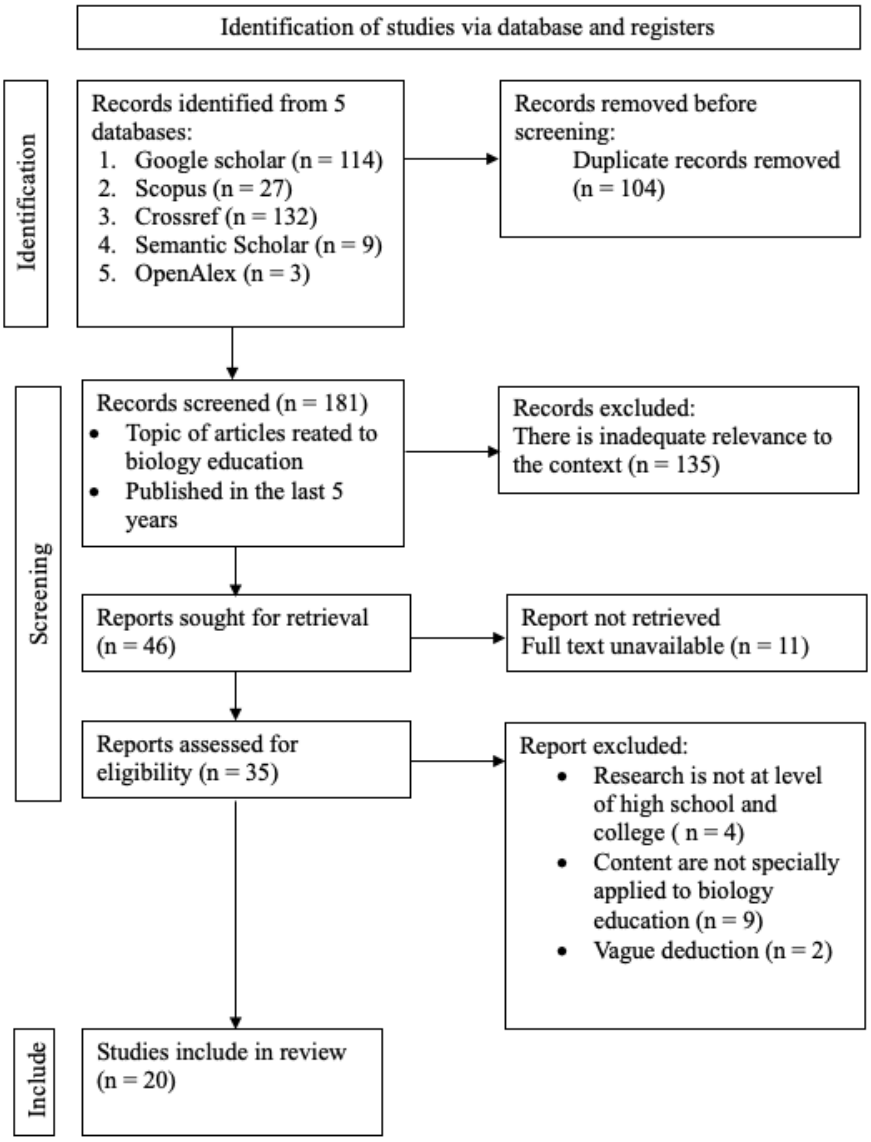

Figure 1. PRISMA Flowchart of Source Search Process

The article selection process in this literature review involves several stages to ensure the relevance, quality, and accuracy of the research focus. These stages include applying year limits from 2018 to 2023, aiming to ensure the inclusion of the latest information, accommodating changes in paradigms, methods, and new concepts, as well as focusing the review on current challenges and issues in the field of research. After going through various stages of reducing the number with various quality assurances, 20 Scopus and SINTA-indexed articles published from 2018 to 2023 were obtained that were relevant to the topic discussed. To ensure the inclusiveness and quality of the

literature, the percentage distribution in the selection of Scopus and SINTA-indexed articles in this literature review is carried out proportionally. 70% focuses on Scopus-indexed articles to ensure the accuracy and credibility of the source, while 30% is allocated to SINTA-indexed articles to accommodate local and national aspects in the context of TPACK and habits of mind. The stages of the article selection process using PRISMA guidelines are explained in Figure 1.

RESULTS AND DISCUSSION

Biology Topics Trends in TPACK Research and Habits of Mind

Biology is a part of science that has a wide range of topics. Some biology topics are considered easy and some are still difficult for students (Fauzi & Fariantika, 2018). Starting from the analysis, several publications only focus on one particular topic, while others highlight several topics.

Table 1. Percentage of Biology Topics Discussed in 20 Articles

No.	Topic	Number of Articles	Percentage (%)
1	Locomotion Systems of Living Creatures	2	10
2	Plant Structure and Function	3	15
3	Human Digestive System	1	5
4	Excretory System	1	5
5	Human Respiratory System	1	5
6	Biodiversity	3	15
7	Environmental Change	4	20
8	Genetics	1	5
9	Ecosystem	3	15
10	Reproduction system	1	5

Table 1 shows the limitation of biological material in the study of habits of mind and TPACK. through the conducted analysis, several studies did not review the reasons for explaining the research background regarding the factual conditions between habits of mind or TPACK and the chosen topic. However, the description of the results of this article's analysis shows that other researchers have the potential to find solutions to help students have habits of mind through TPACK for other biology topics. Biological topics that are still rarely discussed can be studied in more depth in future research. As the biological topics discussed become more widespread, it means that research related to TPACK and habits of mind is starting to receive attention. This refutes the notion that biology is just rote learning.

Several topics were selected by the researchers for their research at the high school and college levels. Especially in the field of ecology which contains the topic of environmental change and ecosystems are most often chosen for conducting research related to TPACK. Additionally, when exploring thinking habits, research related to plants is mostly conducted. Yani et al (2021) bring attention that case studies of environmental and ecosystem change provide a rich context for biology learning, especially its relevance to global issues. This helps students concretely understand biological concepts and relate them to daily life. Through ecological data, students can access, analyze, and use the data to ask and answer broader ecological questions. In addition, understanding these biological concepts in the context of everyday life can stimulate the desire to continue learning and build scientific thinking habits that can be applied in various situations. This can help students improve critical, analytical, and contextual thinking in facing daily challenges.

The teaching of biology material in schools is differentiated at each level, but the material is related to each other. Biodiversity and plant structure often emerge as a key focus of research on habits of mind and TPACK. Biodiversity material is often the focus of research in biology education for several fundamental reasons. Firstly, biodiversity presents the complexity of biological diversity at various levels, including gene, species, and ecosystem levels (Asril et al., 2022). Secondly, the study of biodiversity can stimulate students' curiosity regarding the role of species in maintaining ecosystem balance and its impact on human life (Utina et al., 2018). Engaging students with biodiversity concepts can improve critical and creative, and habits of mind, as they are exposed to biodiversity and its important role in maintaining ecosystem balance. This supports Hayat et al (2019) that the field of plant studies is rich in natural potential and has the value of developing entrepreneurial concepts which are indirectly oriented toward lifelong learning if integrated into learning. Thirdly, understanding biodiversity is also relevant to global issues such as climate change, sustainability, and environmental policy (Pettorelli et al., 2021). By exploring biodiversity material, students can develop critical thinking and analytical skills, while realizing the importance of preserving and protecting the environment (Zubaidah, 2019). Therefore, the use of biodiversity materials in biology education research plays a main role in building a deep and contextual understanding of life on Earth and motivating students to take a role in nature conservation.

In addition to the previously mentioned topics, some researchers also use other topics such as organ systems in TPACK studies and habits of mind. Learning organ systems such as respiration and excretion not only provides a deep understanding of the structure and function of the human body but also fosters critical and analytical thinking habits (Hamdani et al., 2019; Suryani et al, 2018). Students are invited to observe the interrelationships between various organs, analyze the adaptation of organisms to the environment, and infer health implications from changes in organ systems. Incorporating TPACK into the teaching of organ systems allows teachers to effectively integrate technology into learning. This is as Murdhani et al (2022) explain that technology-assisted learning media for the introduction of organ system material such as Augmented Reality (AR) makes it easier to understand the material, provides an interactive learning experience, and increases students' interest in learning.

The Potential of TPACK-Based Biology Learning to Improving Students' Habits of Mind

Science and technology have become an integral part of global culture, so we need to balance the development of science and technology, one of which is through education. Mastery of content and pedagogical skills alone is not enough to achieve learning goals. Teachers must integrate technology into the learning process to enhance the student's comprehension of the material concepts being taught so that the knowledge students gain becomes more meaningful.

Technological Pedagogical Content Knowledge (TPACK) is the knowledge that teachers require to use technology appropriately in learning activities across various material content. It involves the ability to teach material using appropriate technology and pedagogical methods (Rorimpandey, 2023). Thus, it can be concluded that TPACK is a combination of 3 important aspects of the learning process: they are technology (technological knowledge) which can be used to facilitate

the delivery of material, pedagogy (pedagogical knowledge) which contains the learning methods and models applied, and content (content knowledge) which in the form of learning materials.

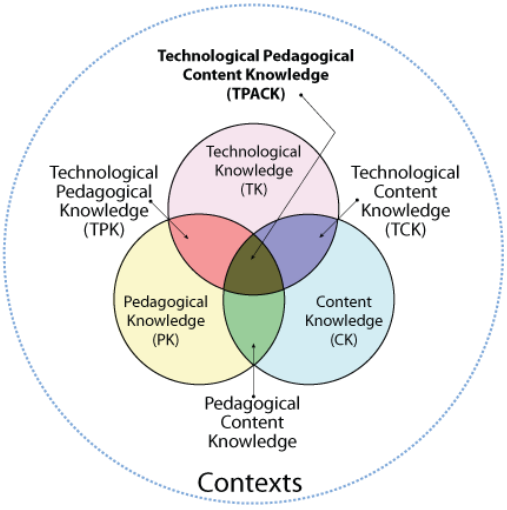

Figure 2. TPACK Framework (Mishra & Kohler, 2006)

Content Knowledge (CK) refers to knowledge about the subjects to be studied or taught (Schmidt, 2009). If the teacher lacks mastery of content, then the teacher does not have the materials or basis to modify or expand the application of concepts according to students' needs (Amalia & Hayat, 2021). A teacher must master this ability in teaching because it has an impact on students' thinking abilities. Teachers with deep content knowledge can provide good constructive feedback on complex concepts and can relate the material to students' daily lives. This contributes to students' comprehension of the foundation aspect of the material, representing the first step in developing students' habits of mind abilities, especially in the aspects of critical and creative thinking.

Table 2. The Potential Aspects of TPACK on Habits of Mind

Aspect	Finding	Author
Content Knowledge (CK)	Content Knowledge is the first step to improving habits of mind, especially in critical and creative thinking.	(Amalia & Hayat, 2021)
Pedagogical Knowledge (PK)	The CIRSA learning model can improve students' habits of mind, especially critical and creative thinking.	(Djamahar et al., 2018; Ristanto et al., 2020)
	OIDDE learning model can improve students' critical and creative thinking, and also independence of thought.	(Husamah et al., 2018)
	Teachers with good Pedagogical Knowledge will understand how to improve students' habits of mind and positive learning attitudes.	(Rahayu, 2017)
	Teachers' Pedagogical Knowledge affects students' self-regulation.	(Senovska & Pryshliak, 2020)
Technological Knowledge (TK)	Students who learn through a task-oriented or performance-oriented technology approach will demonstrate excellent habits of mind.	(Nurmaulita, 2014)

The next TPACK component is pedagogical knowledge (PK). Pedagogical knowledge is a teaching process that involves methods including knowledge of managing classes, providing assessments, and developing learning plans and student learning processes (Schmidt, 2009). Teachers who have good pedagogical knowledge will understand how students build knowledge, acquire skills, and develop habits of mind and positive learning attitudes (Rahayu, 2017). The teacher's pedagogical ability to use models, methods, approaches, and learning techniques can be the key to successful learning. The Cirsa learning model is a development of CIRC (Cooperative Integrated Reading and Composition) with a scientific approach. The Cirsa learning model can empower students' thinking habits, especially critical and creative thinking in biology learning (Djamahar *et al*., 2018; Ristanto *et al*., 2020). Cirsa as a cooperative learning model that focuses on the student center provides students with opportunities to demonstrate decision-making, interpreting, analyzing, evaluating, concluding, communicating, and self-regulation skills. Thus, the implementation of the CIRSA model as a manifestation of teacher PK has the potential to improve students' habits of mind.

Apart from CIRSA, the OIDDE (Orientation, Identify, Discussion, Decision, and Engage in behavior) learning model is also thought can improve students' habits of mind. OIDDE is a modification of two types of learning models, that is behavioral systems (Joyce & Weil, 1978) and tri prakoro (Akbar, 2013). Research by Husamah et al (2018) regarding the effect of the OIDDE model on students' HOTS levels, shows that the average scores of the three thinking components, they are independence of thought, critical thinking, and creative thinking scores, show an increasing trend. These three components are components of students' habits of mind. Some researchers have implemented the OIDDE model on various subjects which gained significant results in teacher candidate's abilities in thinking (Setyawan, 2017) and ethical decision-making (Pantiwati et al., 2016).

Teachers who have good pedagogical skills can manage collaborative learning activities and stimulate students' critical thinking. This includes open-ended questions, assignments that require problem-solving, and research projects that give students opportunities to explore new ideas, which can indirectly strengthen students' learning independence. Self-regulation as part of habits of mind has a positive correlation with students' learning motivation which can be formed through evaluations or assignments such as making practical reports in inquiry learning (Basey *et al*., 2020; Mustopa *et al*., 2020; Raković *et al*., 2022). This is supported by Costa & Kallick (2008) that students' habits of mind can be formed through types of assignments, even though the tasks carried out by someone are different, all of these tasks can lead to the formation of habits of mind if the tasks are carried out consistently and continuously. Self-regulation is not only needed by students in developing habits of mind but is also needed by teachers as an important component of a teacher's professional activities in applying their pedagogical skills (Senovska & Pryshliak, 2020).

TPACK plays a crucial role for students in forming a positive learning environment (Nurina *et al*., 2019). Therefore, teachers are expected to not only improve their content and pedagogy knowledge but also develop their technological knowledge. Technological knowledge (TK) is the ability and adaptation of technology within an educational context. In biology learning, technology can be incorporated through the use of multimedia resources or simulators to integrate biological

content or material into these tools (Rolando *et al*., 2021). Nurmaulita (2014) found that students who learn through a task-oriented or performance-oriented technology approach will show excellent habits of mind, this can be seen from their self-regulation, critical thinking, and creative thinking abilities. Technology makes it easier for students to access various information and learning resources online. This stimulates students to be aware of and use the resources around them. Students will collect, organize, and analyze data more efficiently thereby supporting the development of critical thinking skills. Apart from that, access to digital resources such as video, images, or sound will further enrich students' ideas such as producing new ways of completing projects.

The Implementation of TPACK-Based Biology Learning to Improve Students' Habits of Mind

TPACK as a development of PCK is very important for teachers in integrating technology into learning so that the learning process becomes more effective. However, the reality in the field is that the TPACK of biology teachers in Indonesia is still low. In Paidi *et al* (2021) research, TPACK is influenced by factors such as teacher certification, education level, and academic background. Teachers with a Master's degree tend to have good TK (Technological Knowledge), however, teachers with an academic background in biology education tend to have lower TK when compared to those with other academic backgrounds. Biology teachers' low mastery of TPACK is supported by the discovery that only 4 of the 16 articles studied utilized technology to enhance students' habits of mind or one of the three categories of students' habits of mind. The implementation of technology in learning to improve students' habits of mind can be in the form of media or teaching materials. The integration of technology in biology learning material content makes it easier for students to understand the material and be actively involved in learning (Ibe & Abamuche, 2019; Wilsa, 2019).

Table 3. The TPACK Implementation and its Affect on Habits of Mind

Implementation	Result	Author
Virtual reality video	Students' habits of mind increased, with the highest increase in creative thinking indicators, while critical thinking skills had the least increase	(Rakhmawati et al., 2020)
E-module with local ecosystem potential	Improve students' self-regulation and thinking abilities.	(Aminatun et al., 2022).
Performance assessment with technology integration	Performance assessment with technology integration provides a positive response to each indicator of students' habits of mind.	(Yakob et al., 2021)
Portfolio	Portfolio assessment improves students' habits of mind	(Rikizaputra et al., 2021).

The implementation of TPACK to enhance students' habits of mind can take the form of learning media, such as Video VR (Virtual Reality). Virtual Reality Video is a three-dimensional video technology that allows users to live real life with the help of VR glasses. The videos shown in VR are animated videos with biological content. VR videos can significantly improve students' habits of mind with the highest increase in the creative thinking aspect and critical thinking skills have the least

increase (Rakhmawati *et al*., 2020) However, critical thinking skills can be improved through the learning methods used by teachers in delivering material, of course, this is related to the teacher's pedagogical knowledge (PK).

Mobile learning is a learning model that visualizes biological content as a response to the rapid advancement in today's technological landscape. E-modules with the potential of Indonesia's local ecosystem can improve students' self-regulation as well as thinking skills (Aminatun *et al*., 2022). By utilizing these e-modules with the potential of the local ecosystem, students have good independence. Students learn independently without the role and assistance of the teacher as a whole. This is following the teacher's role as a facilitator whose job is to facilitate student learning so that learning is not centered on the teacher. Beyond fostering students' learning independence, this e-module with the development of the PjBL model and problem solving improves students' thinking abilities which can be seen through the creativity of their work. The problems in this e-module are contextual problems that occur in the environment around students and are presented through video shows. The hope is that students can provide arguments for solving problems by looking at local potential. This e-module is set with the target of achieving certain competencies. If students can master topic 1 then students can continue to topic 2 and so on.

Pedagogical knowledge (PK) includes teachers' comprehension of general educational goals, understanding of learner characteristics, proficiency in classroom management, and ability to assess learning processes and outcomes. This notion is reinforced by (Manang & Bunga, 2020) that pedagogical competence requires a teacher to be able to develop assessment or evaluation tools. Performance assessment as a form of formative assessment can reveal the process skills and products produced by students. Performance assessment plays an important role in improving students' habits of mind. Assessment and learning are integrated units that cannot be separated so that in the assessment process teachers do not need to wait for learning to end. In the inquiry learning approach, performance assessments can be carried out during practicum preparation (before the investigation), during the practicum, or the presentation of practicum results (after the investigation). Thus, the purpose of the performance assessment here is to measure skills which include the ability to observe, try, ask, reason, present, and create. Furthermore, after the lesson, students were given a response questionnaire regarding the role of learning using performance assessments in improving habits of mind. In research by Yakob *et al* (2021) performance assessment learning with technology integration provided a positive response across various indicator habits of mind.

In addition to utilizing performance assessment, portfolios can assess students' habits of mind in the form of assignment strategies (Sriyati, 2010). Within the learning context, Portfolios expose students to a multitude of tasks, to complete these tasks requires intelligence in thinking and acting as well as the active participation of students so that completing tasks can be effective and efficient. The portfolio assessment component in the form of written feedback and self-assessment influences students' habits of mind (Rikizaputra *et al*., 2021). The self-assessments provided through portfolios enable students to evaluate the way they work and think. The impact of providing written feedback and self-assessment, such as being aware of mistakes in taking tests, being open, being able to work independently, and getting used to assessing one's strengths and weaknesses so that they can be improved immediately, continuously and sustainably will become a habit (habit of mind).

CONCLUSION

We have conducted reviewed articles focusing on efforts to improve students' habits of mind through TPACK-based biology learning. The reviewed articles show that the integration of TPACK consisting of content knowledge, pedagogy, and technology as a whole in biology learning has the potential to assist in developing and improving students' habits of mind. Although there is great potential there are challenges to be overcome, such as access to technology and changes in teaching paradigms. However, with the appropriate strategies, these challenges can be transformed into opportunities for improved learning. Teacher training in developing and applying TPACK is the key to the successful implementation of TPACK-based biology learning. Furthermore, this literature review, revealed that the biological material that is most widely used in TPACK and habits of mind research is ecosystems, environmental changes, and plants. Thus, the use of more diverse topics is recommended in further research by utilizing relevant technology.

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