JPPIPA 11(10) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Training Science Process Skills with the SETS Model in Biotechnology Learning: Applications and Future Research Directions

Hasan Subekti[1*], Sapti Puspitarini[1], Edi Suwandi[2]

[1] Natural Science Education, Universitas Negeri Surabaya, Surabaya, Indonesia.
[2] Department of Education and Human Potentials Development, National Dong Hwa University, Hualien, Taiwan.

Received: May 15, 2025
Revised: August 22, 2025
Accepted: October 25, 2025
Published: October 31, 2025

Corresponding Author:
Hasan Subekti
hasansubekti@unesa.ac.id

DOI: 10.29303/jppipa.v11i10.11353

Abstract: The purpose of this study is to investigate how biotechnology education focuses on learning implementation, student activities, Science Process Skills (SPS), field constraints, student responses, and to identify future research directions. The study employs descriptive quantitative research involving students at the junior high school Unesa. The data is gathered through observation, test and questionnaire. The data are analysed descriptively. Based on what the observer thought, the data showed that learning went very well. It's mostly made up of talking between students and teachers, like asking questions and having conversations. At most, problem-solving and data collection skills were learned, but things like media, classroom, and time management were not. Student responses were positive to the SETS model, but their understanding of scientific work and evaluation questions needed to be improved. These potentially affect the priority research agenda, which focuses on technology integration, teacher training, contextual learning, interdisciplinary approaches, and the integrated biotechnology of SETS. The study concludes that SETS model learning was carried out very well and received a positive response from students, with active interaction between students and teachers, especially in verbal interaction and SPS, such as formulating problems and data collecting.

Keywords: Biotechnology; Learning constraint; SETS model; Student learning

Introduction

Science is a discipline grounded in both theory and practice (Ismail et al., 2024), concerned with the rationale of the universe (Doyan et al., 2024). In connection with this, SPS are crucial to comprehending science (Kamarudin et al., 2022). Similar expressions also state that SPS are very important in teaching (Fahmi et al., 2024) and Indispensable skills for the 21st century (Anggrella & Sudrajat, 2024; Adhiyah & Pertiwi, 2024). However, the student study suggests SPS may not be maximised (Kamarudin et al., 2022). This outcome matches a study that defines variables, describes experimental steps, tabulates data, and draws conclusions with clarity and consistency (Suyidno, 2017). These conditions may create a mismatch between scientific teaching goals and field applicability. To close this gap, theoretical knowledge and practical experience must be combined. Academic institutions and industry practitioners can collaborate to improve scientific education.

Science education is essential for equipping the upcoming generation (Novriandi et al., 2025) to tackle the challenges posed by globalisation (Ferniawan et al., 2025) and directly fosters national development (Hervi et al., 2024). Studies indicate that the main purpose of

How to Cite:
Subekti, H., Puspitarini, S., & Suwandi, E. (2025). Training Science Process Skills with the SETS Model in Biotechnology Learning: Applications and Future Research Directions. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 270–281. https://doi.org/10.29303/jppipa.v11i10.11353

science instruction is to make it engaging and simple for students to learn in the classroom (Ahanonye et al., 2024). It focuses on real-life events in nature, which lets students interact with these events directly and strengthen their skills (Alifia et al., 2023). Not only does this method help students understand scientific ideas better, but it also helps them think critically and solve problems. By combining hands-on experiments with conversations that engage students (Eko et al., 2025), teachers can help their children develop a lifelong love of science (Obispo & Lim, 2025). This method is necessary because SPS grow as students study (Fahmi et al., 2024). This study integrates multiple abilities associated with SPS, encompassing issue formulation, the identification and nomenclature of manipulation factors and responses, experimental execution, data organisation into tables, data analysis, and conclusion derivation. It is essential to contemplate methods for swiftly adapting science education to integrate contemporary technologies and correspond with students' real-world contexts. Science, Technology, and Society (STS) or SETS model is one that fits these needs and is full of values. This model prompts students to explore the interrelations among scientific principles, technological progress, and social challenges. By encouraging children to think critically and morally, teachers may prepare them to confront the difficulties of the modern world in a meaningful way.

Integration of STS value-laden contextual learning model or SETS model (Poedjiadi, 2005) with stages, including initiation, formation or development of concepts, application of concepts in life, consolidation of concepts, and assessment (Safira et al., 2024), which is also known as the Science, Technology, Society. SETS Model integrates elements of science, environment, technology, and society (Adhiyah & Pertiwi, 2024) to support science education (Khan et al., 2022). Through the provision of cognitive and affective experiences that students have (Junior et al., 2023), based on ethics and moral sensitivity. The results of the study STSE approach promote and encourage students to critically analyse scientific problems from their perspectives, seek out different ways to gain understanding, and assess scientific knowledge (Khan et al., 2022). The study of the SETS includes an analysis of the key actors involved, relevant historical facts, and socio-political milestones (Junior et al., 2023) in their daily lives to make meaningful scientific learning (Chanapimuk et al., 2018). One of the important materials that has the potential to be implemented in SETS learning in junior high schools is the discussion of biotechnology.

Biotechnology is considered to be one of the materials used in science (Arsyim et al., 2022), an important and rapidly developing field (Orhan & Sahin, 2018) because of its role in almost all aspects of life (Banjer et al., 2021), although it is not easy to learn (Lubis et al., 2024). The reference states that Biotechnology is one of the new ways that science is being used in the 21st century (Elladora et al., 2024) and has potential in Indonesia's secondary school science curriculum (Nurtamara et al., 2019) that accommodates simple practices for SPS, including making tapai [fermented from cassava or sticky rice], tempeh [fermented from soybeans], yoghurt [fermented from milk] and so on (Siswati et al., 2024). A hallmark of biotechnology is an interdisciplinary approach through scientific principles by using biological agents in certain processes to make goods and services that help people meet their needs (Kadarsih et al., 2022). In line with these references, biotechnology education is very important because people today are required to be able to make decisions about biotechnology applications and products (Banjer et al., 2021) in anticipation of the advances that will be made in science and technology throughout the period of globalisation (Ernawati, et al., 2024). As a result, biotechnology not only serves as a significant foundation in the development of modern science, but it also plays a critical role in scientific education by giving young people the skills they need to deal with the world's problems in the future.

This study uses the SETS model of biotechnology materials to explore the application of learning, student activities, SPS, student responses, constraints in the educational setting, and the development of future research. The novelty of this study lies in its exploration of how the SETS model can be effectively implemented in biotechnology learning to enhance SPS, especially in the Indonesian secondary school context, where empirical studies remain limited. Unlike previous research that often focused on either general SPS development or the implementation of SETS in other science topics, this study specifically investigates biotechnology as a context for SETS-based learning. The research not only examines classroom implementation, student activities, SPS outcomes, and student responses but also identifies challenges and directions for future research. Therefore, the purpose of this study is to provide empirical evidence on the effectiveness of the SETS model in biotechnology learning, to reveal both its strengths and constraints, and to propose strategies for improving SPS-oriented science education. This study should help make science learning more relevant, active, and meaningful by giving teachers, curriculum developers, and policymakers a model for how to plan science education that is relevant to the future.

Method

The current study used a descriptive quantitative research design complemented by qualitative descriptions. A descriptive quantitative design was elected to measure and illustrate phenomena, including implementation of learning, student activities, SPS student responses, and learning constraints through percentages and categorical classifications. Qualitative descriptions were incorporated to elucidate contextual factors, including challenges encountered during the learning process. The research involved 25 eighth-grade students from the Laboratory Junior High School at the State University of Surabaya. There were 9 males and 16 females among the participants.

The study's instruments are categorised into three types: (a) observation sheets for learning implementation, student activities, and field constraints, (b) SPS test sheets, and (c) student response questionnaire sheets. Implementing student learning and activities was analysed based on the results of observations from each observer, who assessed the form on a dichotomous scale (0 for not being implemented and 1 for being implemented). These values are then calculated in the form of percentages and classified into the category of implementation quality, namely: not good (25.00-43.79%), poor (43.80-62.59%), good (62.69-81.25%), and very good (81.26-100%) (Setyawati, 2017). Reliability between observers (R) is calculated as the frequency of compatibility between the two observers or "Number of Agreements" and the frequency of mismatch between the two observers or "Number of Disagreements" (Moon et al., 2023), where mathematically, reliability observers use the formula presented as follows.

$$R = \frac{Number\ of\ Agreements}{Number\ of\ Agreements + Disagreements} x100 \quad (1)$$

Analysis of the effectiveness of learning in achieving SPS and obtaining positive responses from students if the success percentage reaches at least 80% with the 'good' category (Jafar et al., 2020). The categorization of the level of achievement of SPS and students' responses was categorized with a score range of 90–100 included in the 'excellent' category (A), 80–89 classified as 'good' (B), 70–79 classified as 'adequate' (C), 60–69 classified as 'low' (D), and scores below 60 included in 'very low' (E) (Borich & Blanchette, 2022). This criterion is a reference in evaluating learning success. This study applies quasi-quantitative methods to present results in a descriptive-interpretive manner.

Next, the researcher represents the future research direction departing from Scopus AI by using keywords based on the research title, namely "training SPS with SETS model in biotechnology learning: applications and future research directions". This is in line with the reference that states that Scopus AI combines artificial intelligence and trusted data from Scopus to help researchers search for answers based on references published by journals indexed in the Scopus database from 2003 onwards. Furthermore, based on the questions entered (Nogueira, 2025). Scopus AI is an artificial intelligence that produces document syntheses from a database according to specified instructions. (Cora et al., 2024), From the database Scopus (Nogueira, 2025) to generate an interaction concept map (Scopus, 2025), which is the world's largest repository of abstracts and multidisciplinary citations (Pretolesi et al., 2025), was employed in this research.

Result and Discussion

The results and discussion section presents research findings obtained from the results of observation and data analysis in the field. The discussion focused on several main aspects that became the focus of the research, including the analysis of learning implementation, student activities, SPS, and students' responses to applied learning, as well as future research directions. The next section presents an expanded discussion of the findings from the research activities conducted.

Learning Implementation Analysis

The investigation into the importance of information related to putting learning into practice was conducted by two observers with observation sheets of learning implementation. The data obtained was processed using the equation of the number of steps of each stage in the syntax divided by the total number of stages in the syntax of the SETS model, multiplied by 100. Stages of learning in Science and Technology. The contextual learning model is loaded with values or the SETS model (Poedjiadi, 2005), namely (a) initiation, (b) concept formation or development, (c) application of concepts in life, (d) consolidation of concepts, and (e) assessment (Safira et al., 2024). The schematization of the SETS model is presented in Figure 1.

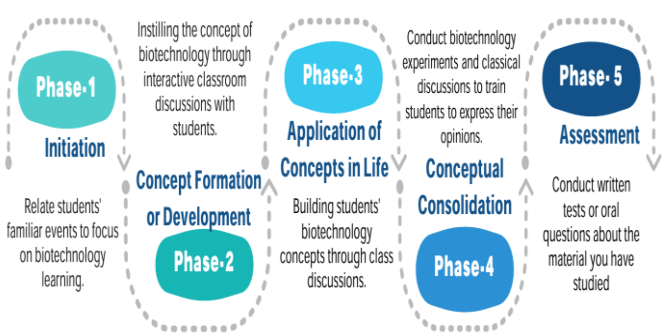

Figure 1. Schematization of the syntax of the SETS model in biotechnology learning

The exploration of the importance of information related to implementing learning into practice. The SETS Model lesson steps in 5 cycles or five meetings with a total of 60 steps (sixty steps) to find out if the planning and carrying out of teaching and learning tasks are consistent and appropriate. The calculation of the percentage of implementation and reliability is presented briefly in Table 1.

Table 1. Percentage and Reliability of Learning Implementation

Description	Implementation		Sum	Categori-zed
	Obs. 1	Obs.2		
Number of implemented steps	56	56	112	-
Percentage of implementation (%)	93.33	93.33	93.33	Excellent
Percentage of Agreement $= \frac{A}{D+A} x100\%$		$\frac{58}{2+58} x100\%$	96.66%	Excellent

The learning implementation analysis's findings demonstrate that 112 (93.33%) of the 120 steps were carried out in the very good category. In addition, inter-observer reliability reached 96.67% in a very good category, which represents inter-observer consistency. This is seen as urgent to ensure that the data obtained truly reflects the conditions of implementation in the field. Excellent reliability and implementation. High-quality learning implementation may help achieve goals. The study showed effective implementation. Demonstrates that the learning design fits field conditions (Wiśniewski et al., 2022) and can be implemented effectively (Almazova et al., 2020). In the context of the SETS model, integrating its implications for society, and essentially, scientific and technological developments have the potential to increase social welfare (Firmino et al., 2019), which is a potential source of SETS integration.

The study indicates that the social, political, and economic contexts have evolved due to the increasing scientific and technological advancement of society (Firmino et al., 2019), in line with the problems of the 21st century. In the context of this expression, important innovations in technology in the 21st century promote transformation within diverse sectors of life (Asrizal et al., 2023). Learning which enables students to connect the SETS theme to various social, cultural, and ethical issues could help them become more adaptable to change.

Student Activities During Learning Analysis

The analysis of student activities during learning aims to assess student involvement and participation in the learning process. The varied activities reflect the dynamics of the classroom as well as the effectiveness of the learning strategies applied. By knowing the proportion of each type of activity, teachers can adjust to make learning more interactive and student centred. The percentage calculation of student activity analysis during the period is presented concisely in Figure 2.

Based on student analysis of activity data in Figure 2, the three activities with the highest percentage are predominantly asking questions to the teacher (17.77%), expressing opinions classically (17.12%), and listening to the teacher's explanation (13.25%). The activity with the lowest percentage was irrelevant behaviour (6.79%), which indicates that student involvement in learning is relatively good, with a low level of distraction during the process. This activity indicates that the SETS model can be an active participant and a constructivist. These results come from studies of STEM or STSE methods that work to improve student outcomes (Wahono et al., 2020), scientific literacy (Agussuryani et al., 2022), and reasoning skills (Barbary, 2024). Understanding of the nature of science (Xiang & Han, 2023) and STEM literacy (Falloon, Hatzigianni et al., 2020). These findings confirm that the SETS model effectively encourages active student engagement and supports the constructive achievement of various aspects of science competencies.

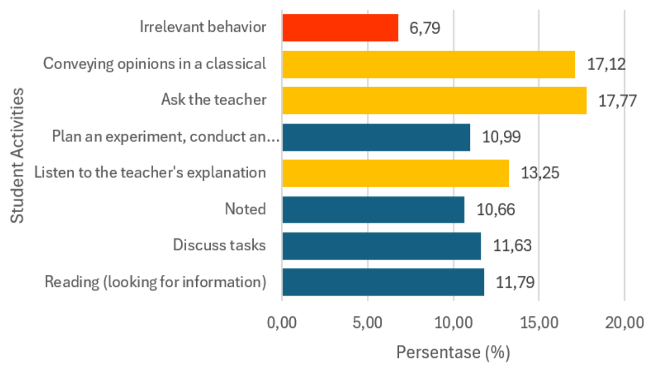

Figure 2. Student activities during learning

Science Process Skills Analysis

The purpose of the SPS analysis is to find out how well students understood the basic skills necessary to do scientific research. SPS in this study include formulating problems and hypotheses, determining and defining variables (manipulation, response, control), demonstrating biotechnology products, collecting data in tables, analysing data, and writing conclusions. This evaluation is important to ensure that learning is not only results-oriented, but also on the student's scientific thinking process. The calculation of the percentage of achievement of the SPS indicator is presented briefly in Table 2.

Table 2. Analysis of Achievement of the SPS Indicator

SPS Indicators	Percentage (%)	Category
Summarising the problem	75.73	Keep
Formulating a hypothesis	64.40	Low
Identify manipulation variables	31.20	Very low
Define manipulation variables	57.20	Very low
Identify variable responses	60.00	Low
Define response variables	47.20	Very low
Identify the control variable	28.80	Very low
Demonstrate the steps of making simple biotechnology products	49.40	Very low
Collect table form data	72.80	Keep
Analyze data	60.53	Low
Writing a conclusion	64.27	Low

The information presented in Table 2 indicates that problem-solving skills hold the highest percentage at 75.73% within the keep category, closely followed by the skill of data collection in tabular form, which stands at 72.80%. Hypotheses serve to generate predictions (Raissa, 2025), which are then operationalised within a specific study design and converted into testable hypotheses. These results indicate that observation and data collection skills are basic skills that are relatively easier for students to master than other, more complex skills. Identifying a problem is a form of question sentence (how, what, when, who, why, or where), containing two or more variables, namely the manipulation variable and the response variable and questioning the relationship between these variables (Samani et al., 2016).

The lowest percentage was shown in the skills of determining control variables (28.80%) and determining manipulation variables (31.20%), indicating that students still had difficulty in identifying and understanding the concept of variables in experimental activities. References state that the ability to design controlled experiments and draw valid conclusions from experimental results is a core competency, along with further experimental skills such as formulating research questions and drawing conclusions (Peteranderl et al., 2023). These findings indicate that variable control skills are one of the most challenging aspects of learning SPS.

The skills of formulating hypotheses by 64.40% and writing conclusions by 64.27%, indicating that students are quite capable of developing temporary conjectures and drawing conclusions from the results of the experiment. The reference states that a hypothesis is a statement that predicts how variables are interconnected and can be tested through research (Leavy, 2017). Hypotheses are employed to generate predictions, which are operationalised within a particular study design and developed into hypothesis-testing possibilities (Lakens & DeBruine, 2021).

The ability of students to demonstrate the steps to make simple biotechnology products is still relatively low, with a percentage of 49.4%, indicating the need to strengthen procedural skills in science learning or experiential learning. Experiential learning is one of the theories that informs this student-centred environment (Gittings et al., 2020), which can expose students to a variety of risks and challenges that may not be explicitly disclosed to them.

Furthermore, an analysis was carried out on the achievement of SPS in each student. This analysis aims to identify the percentage of learners who performed according to the defined standards that have been set. The outcomes of pupils' SPS attainment are presented in Table 3.

Table 3. Analysis of Achievement of SPS for Each Student

Score Interval	Assessment Criteria	Percentage (%)
90–100	Very Good (A)	4.00
80–89	Good (B)	4.00
70–79	Keep (C)	28.00
60–69	Low (D)	20.00
≥60	Very low (E)	44.00

The data in Table 3 reveal the distribution of students' SPS level, with the majority (44.00%) being in the very low category (E) with a score below 60. These results show that there is a gap in the mastery of SPS. The percentage of students who reached the medium category (C) with a score of 70-79 was 28.00%, while those who reached the good (B) and excellent (A) categories were only 4.00% each. The low percentage of students who reach the high category indicates the need for more effective learning strategies to improve SPS. In addition, the distribution of student scores that skew into the low (D) and very low (E) categories, with a total of 64.00%, indicates the importance of targeted pedagogical interventions to improve students' SPS. The reference states that SPS are one of the learning skills with a high-level objective category (Borich, 2017) to prepare students are learning have to cope with the problems, demands and trends of the 21st-century world of work at a higher level of education.

Field Constraint Analysis

During the learning process, the researcher faces various difficulties and obstacles that affect the course of the activity. These obstacles need to be identified so that they can be used for evaluation and improvement in the future. The purpose of this presentation of constraints is to provide a clear picture of the challenges faced during the research. Schematically, the various obstacles found in the field can be seen in Figure 3.

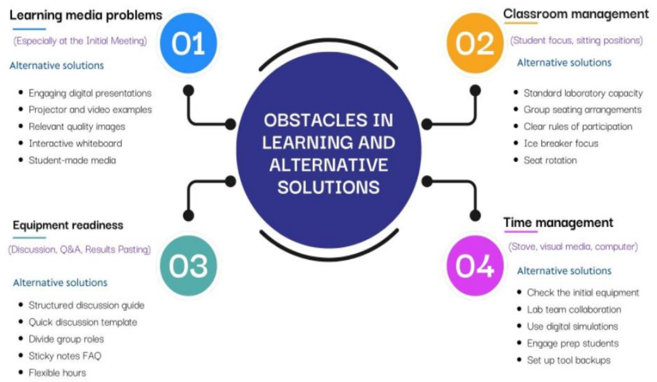

Figure 3. Schematization: obstacles encountered in learning

Based on data from the mind map entitled "Obstacles in Learning and Alternative Solutions", there are four main categories of obstacles in learning, namely: (a) learning media problems, (b) classroom management, (c) tool readiness, and (d) time management. For learning media problems, suggested alternative solutions include the use of engaging digital presentations, video examples through projectors, quality images, interactive whiteboards, and even student-made media. The reference literature states that learning media can increase student involvement (Widodo et al., 2025), concept understanding and learning motivation (Permana et al., 2024) and decision-making (Liu, 2023), learning interests, and learning outcomes (Bunari et al., 2024). possess a broad perspective on the future for students (Alika & Radia, 2021).

Furthermore, field obstacles related to classroom management. Constraints on classroom management, such as laboratory capacity and seating arrangements, can be overcome through group arrangements, clear participation rules, and icebreaker activities. The reference states that classroom management is an important component and has implications for the quality of the lessons (Lazarides et al., 2020) which results in favorable academic achievement, motivation for learning, and emotional growth (Bi et al., 2025) positive social, emotional, and academic outcomes for students, but also improves teacher well-being and social-emotional (Kennedy et al., 2021). Rotation of seats is also recommended so that every student gets an equal learning experience.

In addition, the readiness of the tools is a challenge (Talib et al., 2025), especially at the beginning of the meeting or during the practicum demonstration. The reference source states that one of the important aspects of preparedness is optimising equipment and its use. Readiness means focusing attention on each dimension separately (Holmström, 2022), which requires specialised skills and infrastructure. Suggested solutions include pre-use tool inspection, laboratory team cooperation, use of digital simulations, and preparing backup tools.

In addition, field constraints are related to time management. In terms of time management, which is often constrained during discussions, Q&A, or sticky results, solutions include structured discussion guides, group role sharing, and the use of assistive media such as sticky notes on tool readiness. Literature sources state that time is an important resource for humans (Usman et al., 2021) to achieve their goals effectively and efficiently (Hasanah & Daharnis, 2019) and is an important factor in improving the quality of learning as well as having a positive response to learning motivation and academic achievement (Jiang & Attan, 2024). Flexible time scheduling is also proposed to provide room for adaptation to classroom dynamics.

Student Response Analysis

Student responses are collected at the end of the data collection process at the school. Indicators used to measure students' responses include their interest in the use of learning methods, clarity during the implementation of activities, understanding of the scientific work process, and ease of answering assessments. By using these indicators, researchers can get a more comprehensive picture of students' responses to the learning that has been carried out. A visualisation of the percentage of student responses is presented in Figure 4.

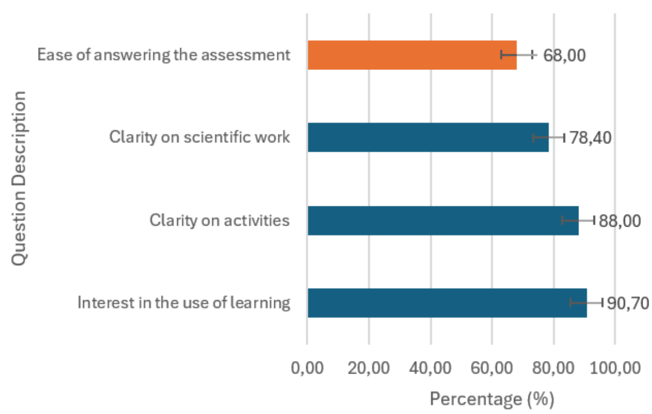

Figure 4. Analysis of student response percentage

Starting from Figure 4, it is known that students' responses to the use of learning are at the highest level, with a percentage of 90.70%. This shows that the SETS model applied successfully attracts the attention and interest of students. The reference states that SETS takes into account its implications for society, and essentialists, where it is believed that more scientific and technological developments mean more social well-being (Firmino et al., 2019). Furthermore, clarity in learning activities also results in a positive response with a percentage of 88.00%, which indicates that students feel that learning activities are quite easy to understand. Clarity in the implementation of scientific work decreased to 78.40%, indicating that there are still some students who have difficulty understanding the scientific process. Then, the lowest response was the ease of answering assessment questions, at only 68.00%. Therefore, educators need to strike a balance between engaging learning activities and reinforcement of the basic concepts of science being studied (Zidny et al., 2020). Habituation and increased guidance in scientific work are expected to help students be better prepared to face the learning of SPS. In addition, comprehension-based reinforcement strategies and contextual exercises are the right solution to overcome this gap and are expected to have an impact on improving overall learning outcomes.

Future Research Directions

Based on a study of the more recent information at Scopus, future research needs to expand the exploration of the application of the SETS model in biotechnology to address the challenges of 21st-century education. The data-driven priority research agenda at Scopus includes five key areas, namely technology integration, teacher training, contextual learning, interdisciplinary approaches, and the development of a SETS-based biotechnology curriculum. The schematization of future research directions is presented in Figure 5.

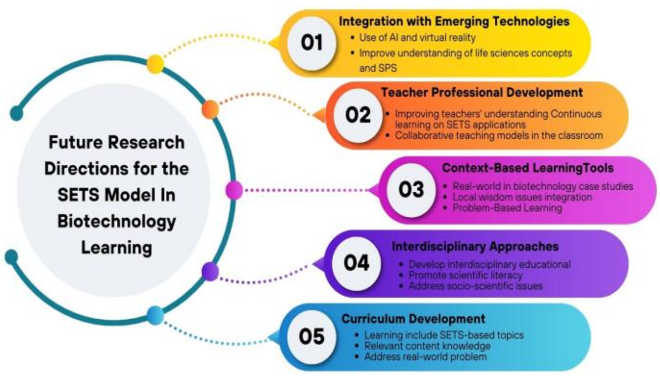

Figure 5. Schematization of future research directions

Referring to Figure 5, Future research directions for the SETS model in biotechnology learning include integration with the latest technologies to make learning useful for the future and flexible to today's challenges. Enhancing teacher training and development as professionals is crucial for educators to be able to implement the SETS approach effectively through context-based and cross-disciplinary learning. In addition, the development of a curriculum that supports interdisciplinary integration needs to be carried out to strengthen the relevance of biotechnology materials to the challenges and needs of modern society. In more detail, the future research direction of the SETS model in biotechnology learning is presented as follows.

The reference states that future learning trends are expected to be increasingly influenced by rapid technological advancements, with an emphasis on digitalisation throughout the method of learning (Burbules et al., 2020). The SETS learning model has been shown to improve the conceptual understanding (Khafah et al., 2023) and critical thinking skills of students in various disciplines (Putri & Rusmini, 2021; Adhiyah & Pertiwi, 2024). However, to maximise its application in the context of biotechnology learning, further exploration is needed in various strategic areas. One of the important areas is the integration of the SETS model with emerging technologies, such as artificial intelligence (AI), to assist students learn more effectively and teachers to teach complex biotechnology concepts.

Teacher training should focus on holistic conceptual mastery of SETS. The results of the study stated that not a few STEM teachers have difficulty applying interdisciplinary approaches (Wang et al., 2020), for example, SETS, STEAM, and others. In overcoming these problems, teacher professional development is an important element in the successful interdisciplinary learning (Wang et al., 2020) and their potential interdisciplinary abilities to explore diverse interrelated disciplines (Tytler et al., 2019). Therefore, the professional development of teachers based on experience and practice collaboratively needs to be developed to equip teachers with pedagogical skills and content that are aligned with current trends and issues.

Future research trends can also investigate the effectiveness of context-based learning using the SETS framework. In the context of SETS or STEAM Learning. The reference states that motivation for success constitutes the drive to do well in the classroom. (Adegboyega, 2018). The average person is capable of motivation as an urgency to meet their needs, like the need for food, shelter, love, and keeping their self-esteem high (Slavin, 2018). In addition, the contextual learning approach provides opportunities for students to relate the subject matter to the real situations that they experience in their daily lives (Widodo et al., 2020). The results of the study reveal that by integrating the local context in the learning process, the material learned has the potential to be more concrete and relevant (Ratri et al., 2024). It also has the potential to encourage active engagement, increase motivation to learn, and assist them in developing critical thinking and problem-solving skills. Sources state real experiential learning, proven student engagement (Almulla, 2020), technical experience, retention, interest (Usman et al., 2020) and meaningful outcomes (Jones et al., 2020) on learners over a relatively long-term period.

Integrating SETS creates transdisciplinary learning, encouraging creativity, problem-solving, and a deep understanding of interdisciplinary relationships through practical projects and innovative modelling (Bedewy & Lavicza, 2023). Important biotechnology learning is being developed. Interdisciplinary is content-specific knowledge, and skills from two or more disciplines are carefully taught to enhance the process of knowledge construction (Ng et al., 2022). An interdisciplinary approach integrates multiple disciplines to promote an in-depth knowledge. (Adiyono, et al., 2024). The study's results indicate that the interdisciplinary approach could assist audiences in growing more knowledgeable about science, learn more, and thinking critically (Suwono et al., 2021). Thus, a cross-disciplinary approach has the possibility of a holistic understanding

Future research trends also need the development of a curriculum or biotechnology learning that accommodates the development of SETS adaptively and dynamically in line with the demands of the dynamics of the times. Literature sources state the importance of a 21st-century competency-based curriculum framework (Carlgren, 2020) to improve students' capabilities in solving increasingly complex biotechnology problems. Systematic curriculum development is an important priority and research issue for further research (Tahirsylaj & Sundberg, 2020) in strengthening the integration of the SETS model. A well-designed curriculum should reflect the interconnectedness between science, technology, the environment, and society in each biotechnology topic.

Conclusion

The study concludes that SETS model learning was carried out very well and received a positive response from students, with active interaction between students and teachers, especially in verbal interaction and SPS, such as formulating problems and data collecting. However, the implementation faced constraints related to limited learning media, classroom management, and insufficient time allocation. In addition, certain science process skills, particularly in data analysis and conclusion, as well as students' ability to answer evaluation questions, still need improvement.

Acknowledgments

The researchers expressed their gratitude to the Dean of FMIPA UNESA and the Principal of the UNESA Laboratory Junior High School for the support and permission given. We would also like to acknowledge the science model teachers and students who participated in this study. Special awards are given to observers, colleagues and all parties who have provided input and suggestions in the process of researching and writing this work.

Author Contributions

All authors (HS, SP, and ES) contribute to paper composition, data analysis, data interpretation, and the visualisation of figures, in addition to providing critical changes to the manuscripts. All writers have granted their approval for the publication of the manuscripts.

Funding

External support from other entities is not obtained for this research.

Conflicts of Interest

The researchers declare that no potential conflict of interest has been made known.

References

Adegboyega, L. O. (2018). Influence of achievement motivation on nigerian undergraduates' attitude towards examination. *International Journal of Instruction, 11*(1), 77-88. https://doi.org/10.12973/iji.2018.1116a

Adhiyah, N. L., & Pertiwi, K. R. (2024). Development of a student worksheet with the sets (science, environment, technology, and society) approach to improve critical thinking skills in reproductive system materials. *Jurnal Penelitian Pendidikan IPA, 10*(12), 10845-10850. https://doi.org/10.29303/jppipa.v10i12.9416

Adiyono, A., Fitri, A. Z., & Al Matari, A. S. (2024). Uniting science and faith: a Re-STEAM interdisciplinary approach in Islamic education learning. *International Journal of Social Learning (IJSL), 4*(3), 332-355. https://doi.org/10.47134/ijsl.v4i3.281

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis. *International Journal of Evaluation and Research in Education (IJERE), 11*(1), 51-60. https://doi.org/10.11591/ijere.v11i1.21647

Ahanonye, U. A., Otulaja, F., Risenga, I., & Dukhan, S. (2024). Secondary school life sciences teachers' understanding of indigenous knowledge in relation to their views on its integration into their classroom practice. *African Journal of Research in Mathematics, Science and Technology Education, 28*(1), 1-11. https://doi.org/10.1080/18117295.2024.2358617

Alifia, N. B., Yulinda, R., & Febriyani, P. R. (2023). Development of a science module integrating local wisdom of biotechnology materials for class IX

Junior High School. *Journal of World Science, 2*(3), 427-444. https://doi.org/10 .58344/jws.v2i3.248

Alika, O., & Radia, E. H. (2021). Development of learning media based on a cross puzzle game in science learning to improve learning outcomes. *Jurnal Penelitian Pendidikan IPA, 7*(2), 173-177. https://doi.org/10. 29303/jppipa.v7i2.667

Almazova, N., Krylova, E., Rubtsova, A., & Odinokaya, M. (2020). Challenges and opportunities for Russian higher education amid COVID-19: teachers' perspective. *Education Sciences, 10*(12), 1-11. https://doi.org/10 .3390/educsci10120368

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *SAGE Open, 10*(3), 1-15. https://doi.org/10 .1177/2158244020938702

Anggrella, D. P., & Sudrajat, A. K. (2024). Development of an integrated project-based learning module based on black soybean ethnoscience to improve students' science process skills. *Jurnal Penelitian Pendidikan IPA, 10*(6), 3038-3045. https://doi.org/10. 29303/jppipa.v10i6.5855

Arsyim, I., Rubini, B., & Pursitasari, I. D. (2022). Socio-scientific issues-based argumentation assessment for middle school students. *Jurnal Penelitian Pendidikan IPA, 8*(2), 1034-1041. https://doi.org/10. 29303/jppipa.v8i2.844

Asrizal, A., Dhanil, M., & Usmeldi, U. (2023). The effect of STEAM on science learning on student learning achievement: a meta-analysis. *Jurnal Penelitian Pendidikan IPA, 9*(4), 1650-1657. https://doi.org/10. 29303/jppipa.v9i4.3108

Banjer, H., Shami, A., Horaib, R. B., Almutiri, S., Alnemari, A., & Althumali, R. (2021). Biotechnology: knowledge, perception and future in Saudi Arabia. *Biotechnology & Biotechnological Equipment, 35*(1), 1200-1206. https://doi.org/10.1080/13102818.2021. 1955007

Barbary, D. S. E. (2024). A proposed digital unit in the geography of risks according to the STSE approach for developing geographical reasoning among the first-year students of secondary school. *Port Said Journal of Educational Research, 3*(2), 118-147. https://doi.org/10 .21608/psjer.2024.271859.1034

Bedewy, S. E., & Lavicza, Z. (2023). STEAM + X-Extending the transdisciplinary of STEAM-based educational approaches: a theoretical contribution. *Thinking Skills and Creativity, 48*(1), 1-23. https://doi.org/10 .1016/j.tsc.2023.101299

Bi, X., Hu, Y., Li, L., Zhang, J., & Yang, X. (2025). Immersive virtual reality for classroom management training: enhancing pre-service teachers' skills, emotions, and learning satisfaction. *Education and Information Technologies, 30*(7), 1-25. https://doi.org/10 .1007/s10639-024-13248-z

Borich, G. D. (2017). *Effective Teaching Methods: Research-Based Practice* (Ninth ed.). Boston: Pearson Education, Inc.

Borich, G. D., & Blanchette, A. D. (2022). *Effective Teaching Methods: Research-Based Practice*. Hoboken: Pearson Education.

Bunari, B., Setiawan, J., Ma'arif, M. A., Purnamasari, R., Hadisaputra, H., & Sudirman, S. (2024). The influence of flipbook learning media, learning interest, and learning motivation on learning outcomes. *Journal of Education and Learning (EduLearn), 18*(2), 313-321. https://doi.org/10.11591/edulearn.v18i2.21059

Burbules, N. C., Fan, G., & Repp, P. (2020). Five trends of education and technology in a sustainable future. *Geography and Sustainability, 1*(2), 93-97. https://doi.org/10 .1016/j.geosus.2020.05.001

Carlgren, D. (2020). Competency-based curriculum transition: a conceptual framework. *The Journal of Competency-Based Education, 6*(2), 1-8. https://doi.org/10 .1002/cbe2.1229

Chanapimuk, K., Sawangmek, S., & Nangngam, P. (2018). Using the science, technology, society, and environment (STSE) approach to improve the scientific literacy of grade 11 students in plant growth and development. *Journal of Science Learning, 2*(1), 14-20. https://doi.org/10.17509/jsl.v2i1.11997

Cora, E. A., Lopezosa, C., & Codina, L. (2024). *Scopus AI Beta: Functional Analysis and Cases*. Barcelona: Universitat Pompeu Fabra.

Doyan, A., Susilawati, S., Annam, S., Muliyadi, L., Megahati, R. R. P., Hutabarat, R. A., . . . Hamidi, H. (2024). Trends research creative thinking skills in students' physics learning (2015-2024): a systematic review. *Jurnal Penelitian Pendidikan IPA, 10*(6), 333-342. https://doi.org/10 .29303/jppipa.v10i6.7826

Eko, A. S., Dwi L. B., Dyah R. R., Dwi, A. M., & Putri, A. A. (2025). Effects of hybrid STEM learning on 21st-century skills and character development in prospective elementary teachers: a mixed-methods study from Indonesia. *Qubahan Academic Journal, 5*(2), 384-401. https://doi.org/10.48161/qaj.v5n2a1716

Elladora, S. T., Gaylan, E. G., Taneo, J. K. B., Callanga, C. H., Becbec, J., Bercero, G. I. M. R., . . . Picardal, M. T. (2024). Challenges in teaching biotechnology in the Philippine STE Program. *International Journal of Learning, Teaching and Educational Research, 23*(3), 367-389. https://doi.org/10 .26803/ijlter.23.3.18

Ernawati, E., Eriyanti, R. W., Rofieq, A., & Huda, A. M. (2024). Analysis of the development needs of the student worksheet based on local wisdom of biotechnology material at Senior High School, Kupang City. *Jurnal Pembelajaran Dan Biologi*

Nukleus, 10(1), 26-37. https://doi.org/10.36987/jpbn. v10i1.5315

Fahmi, Fajeriadi, H., Irhasyuarna, Y., Yulianti, Y. E., & Kusasi, M. (2024). The effect of using the inquiry model on science process skills and student learning outcomes. *Jurnal Penelitian Pendidikan IPA, 10*(12), 10426-10433. https://doi.org/10.29303/jppipa. v10i12. 8658

Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: a framework for developing STEM Literacy. *Journal of Science Education and Technology, 29*(3), 369-385. https://doi.org/10 .1007/s10956-020-09823-x

Ferniawan, F., Ramdani, A., Rokhmat, J., Jufri, A. W., & Sukarso, A. A. (2025). Research trends of SDGs integrated science interactive learning media to improve students' science literacy: bibliometric analysis. *Jurnal Penelitian Pendidikan IPA, 11*(1), 20-29. https://doi.org/10 .29303/jppipa.v11i1.9959

Firmino, E. D. S., Sampaio, C. D. G., Vasconcelos, A. K. P., Nojosa, A. C. B., Saldanha, G. C. B., Guerra, M. H. F. S., & Barroso, M. C. D. S. (2019). STSE approach in high school chemistry: a brief review in national literature. *Acta Scientiae, 21*(3), 196-212. https://doi.org/10.17648/acta.scientiae.v21iss3id 4660

Gittings, L., Taplin, R., & Kerr, R. (2020). Experiential learning activities in university accounting education: a systematic literature review. *Journal of Accounting Education, 52*(100680), 1-13. https://doi.org/10 .1016/j.jaccedu.2020.100680

Hasanah, H., & Daharnis, D. (2019). Learning time management of full-day school students in junior high school and its implications for guidance and counselling services. *Jurnal Neo Konseling, 1*(3), 1-7. https://doi.org/10 .24036/00135kons2019

Hervi, F., Giastituati, N., Rusdinal, R., Ananda, A., & Ardi, A. (2024). A comparison of science education between Germany, China and Indonesia. *Jurnal Eksakta Pendidikan (JEP), 8*(1), 73-85. https://doi.org/10 .24036/jep/vol8-iss1/806

Holmström, J. (2022). From AI to digital transformation: the AI readiness framework. *Business Horizons, 65*(3), 329-339. https://doi.org/10.1016/j.bushor.2021.03. 006

Ismail, A. M. S., Effendi, M., & Matore, E. M. (2024). Strategies for mastering science process skills and manipulative skills in practical work. *International Journal of Academic Research in Progressive Education and Development, 13*(2), 503-514. https://doi.org/10. 6007/IJARPED/v13-i2/21256

Jafar, A. F., Rusli, R., Dinar, M., Irwan, I., & Hastuty, H. (2020). The effectiveness of video-assisted flipped classroom learning model implementation in integral calculus. *Journal of Applied Science, Engineering, Technology, and Education, 2*(1), 97-103. https://doi.org/10 .35877/454RI.asci2144

Jamieson, S. (2016). Analyse qualitative data. *Education for Primary Care, 27*(5), 398-402. https://doi.org/10.1080/14739879.2016.1217430

Jiang, Y., & Attan, S. A. (2024). Time management disposition in learning motivation and academic performance of lacquer art majors in Fujian, China. *SN Computer Science, 5*(5), 1-12. https://doi.org/10.1007/s42979-024-02795-4

Jones, D., Childs, M., Frankel, S., & Loveday, M. (2020). Experience-based learning: exploring meaningful outcomes for students in retail and fashion. *International Journal of Fashion Design, Technology and Education, 14*(1), 58-68. https://doi.org/10.1080/ 17543266.2020.1859625

Junior, P. D. C., Marandino, M., & Scalfi, G. (2023). Biodiversity and science, technology, society and environment (stse): visitor perceptions at a science and natural history museum. *International Journal of Research in Education and Science, 9*(3), 753-773. https://doi.org/10 .46328/ijres.3211

Kadarsih, O., Arif, A. G., & Sulistyono, S. (2022). Development of biotechnology teaching materials based on a hydroponics research system wick to increase creativity and technological literacy in class IX learners at SMP Negeri 2 Majalengka. *Indonesian Journal of Learning and Instruction, 5*(1), 47-54. https://doi.org/10 .25134/ijli.v5i1.5876

Kamarudin, N., Wahida, M., & Ahrari, S. (2022). Exploring basic and integrated science process skills and their impact on science achievement among university students. *Journal of Public Administration and Governance, 12*(4), 74-90. https://doi.org/10 .5296/jpag.v12i4S.20572

Kennedy, Y., Flynn, N., O'Brien, E., & Greene, G. (2021). Exploring the impact of Incredible Years teacher classroom management training on teacher psychological outcomes. *Educational Psychology in Practice, 37*(2), 150-168. https://doi.org/10 .1080/ 02667363.2021.1882944

Khafah, F., Suprapto, P. K., & Nuryadin, E. (2023). The effect of the project-based learning model on students' critical and creative thinking skills in the ecosystem concept. *Jurnal Pendidikan Biologi Indonesia, 9*(3), 244-255. https://doi.org/10.22219/jpbi.v9i

Khan, M., Khan, I. A., & Gulana. (2022). The science, technology, society and environment (STSE) approach: perceptions of secondary school science students. *Journal of Social Sciences Review, 2*(4), 43-54. https://doi.org/10 .54183/jssr.v2i3.42

Lakens, D., & DeBruine, L. M. (2021). Improving transparency, falsifiability, and rigour by making hypothesis tests machine-readable. *Advances in Methods and Practices in Psychological Science, 4*(2), 1-12. https://doi.org/10 .1177/2515245920970949

Lazarides, R., Watt, H. M. G., & Richardson, P. W. (2020). Teachers' classroom management self-efficacy, perceived classroom management and teaching contexts from beginning until mid-career. *Learning and Instruction, 69*(1), 1-14. https://doi.org/10.1016/j.learninstruc.2020.101346

Leavy, P. (2017). *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches*. London: The Guilford Press.

Liu, Y. (2023). Depression clinical detection model based on social media: a federated deep learning approach. *The Journal of Supercomputing, 80*(6), 7931-7954. https://doi.org/10.1007/s11227-023-05754-7

Lubis, W., Diningrat, D. S., Hasairin, A., Azhari, M., & Hartono, A. (2024). Development of biotechnology teaching materials: e-comics complemented by factual videos to improve science literacy skills. *Jurnal Penelitian Pendidikan IPA, 10*(12), 10759-10770. https://doi.org/10.29303/jppipa.v10i12.9303

Moon, J., Webster, C. A., Brian, A., Stodden, D. F., & Mulvey, K. L. (2023). Development of the system for observing virtual real-time lessons in physical education (SOVRTL-PE): a tool to support preservice teachers' applied learning experiences. *Computers & Education, 196*(1), 1-12. https://doi.org/10.1016/j.compedu.2023.104738

Ng, A., Kewalramani, S., & Kidman, G. (2022). Integrating and navigating STEAM (inSTEAM) in early childhood education: an integrative review and inSTEAM conceptual framework. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(7), 1-17. https://doi.org/10.29333/ejmste/12174

Nogueira, L. A. (2025). Chatbots and scholarly databases. *Information Technology and Libraries, 44*(1), 1-8. https://doi.org/10.5860/ital.v44i1.17116

Novriandi, Yulita, E., Sunarti, I., Handayani, T. P., & Hendrizal. (2025). Evolution of science education foundations in Indonesia: trends, paradigms, and future directions. *Jurnal Penelitian Pendidikan IPA, 11*(6), 18-22. https://doi.org/10.29303/jppipa.v11i6.11544

Nurtamara, L., Sajidan, S., Suranto, S., & Prasetyanti, N. M. (2019). The effect of the biotechnology module with problem-based learning in the socioscientific context on enhancing students' socioscientific decision-making skills. *International Education Studies, 13*(1), 11-20. https://doi.org/10.5539/ies.v13n1p11

Obispo, K. P. C., & Lim, J. F. (2025). Strengthening science vocabulary skills through gamification and hands-on learning: a community-based action research. *Asian Journal of Community Services, 4*(6), 503-512. https://doi.org/10 .55927/ajcs.v4i6.225

Orhan, T. Y., & Sahin, N. (2018). The impact of innovative teaching approaches on biotechnology knowledge and laboratory experiences of science teachers. *Education Sciences, 8*(4), 1-24. https://doi.org/10 .3390/educsci8040213

Permana, B. S., Hazizah, L. A., & Herlambang, Y. T. (2024). Teknologi pendidikan: efektivitas penggunaan media pembelajaran berbasis teknologi di era digitalisasi. *Khatulistiwa: Jurnal Pendidikan dan Sosial Humaniora, 4*(1), 19-28. https://doi.org/10 .55606/khatulistiwa.v4i1.2702

Peteranderl, S., Edelsbrunner, P. A., Deiglmayr, A., Schumacher, R., & Stern, E. (2023). What skills related to the control-of-variables strategy need to be taught, and who gains most? Differential effects of a training intervention. *Journal of Educational Psychology, 115*(6), 813-835. https://doi.org/10.1037/edu0000799

Poedjiadi, A. (2005). *Sains Teknologi Masyarakat: Model Pembelajaran Konstekstual Bermuatan Nilai*. Bandung: Remaja Rosdakarya.

Pretolesi, D., Stanzani, I., Ravera, S., Vian, A., & Barla, A. (2025). Artificial intelligence and network science as tools to illustrate academic research evolution in interdisciplinary fields: the case of Italian design. *PLoS One, 20*(1), 1-17. https://doi.org/10.1371/journal.pone.0315216

Putri, D. K., & Rusmini, R. (2021). Hydrocarbon and petroleum with sets approach module to train students' critical thinking skills. *Indonesian Journal of Science and Mathematics Education, 4*(1), 12-24. https://doi.org/10 .24042/ijsme.v4i1.7839

Raissa, Z. (2025). A comparative analysis of financial performance forecasting models: arima, ARIMA-GARCH & LSTM in Indonesian banking stocks. *Jurnal Ilmiah Manajemen Bisnis dan Inovasi Universitas Sam Ratulang, 12*(1), 328-340. https://doi.org/10 .35794/ jmbi.v12i1.61515

Ratri, D. P., Widiati, U., Astutik, I., & Jonathans, P. M. (2024). A systematic review on the integration of local culture into English language teaching in Southeast Asia: current practices and impacts on learners' attitude and engagement. *Pegem Journal of Education and Instruction, 14*(2), 37-44. https://doi.org/10.47750/pegegog.14.02.05

Safira, I., Sahrina, A., Utomo, D. H., & Astina, I. K. (2024). The impact of the science, environment, technology, and society (SETS) learning model integrated with Google Earth on spatial thinking ability in senior high school. *Jambura Geo Education Journal, 5*(2), 149-159. https://doi.org/10.37905/jgej.v5i2.26052

Samani, M., Nurlela, L., Widodo, W., & Inzanah. (2016). *Berpikir Tingkat Tinggi Problem Solving*. Surabaya: Sarbikita Publising.

Setyawati, H. (2017). Pengembangan Perangkat Pembelajaran Berbasis Masalah untuk Meningkatan Keterampilan Proses Sains Siswa. *Bioedukasi, 15*(1), 28-38. https://doi.org/10.19184/bioedu.v15i1.4705

Siswati, B. H., Prihatin, J., & Aloysius, D. C. (2024). Effectiveness of e-module STEM biotechnology to empower metacognitive skills and science process skills of high school students with low academic ability in industrial agriculture areas. *Jurnal Penelitian Pendidikan IPA, 10*(1), 133-142. https://doi.org/10. 29303/jppipa.v10i1.5890

Slavin, R. E. (2018). *Educational Psychology: Theory and Practice* (Twelfth ed.). New York: Pearson.

Suwono, H., Rofi'Ah, N. L., Saefi, M., & Fachrunnisa, R. (2021). Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking. *Journal of Biological Education, 57*(5), 944-959. https://doi.org/10 .1080/00219266.2021.2006270

Suyidno. (2017). *Lembar Kegiatan Mahasiswa: Pelatihan Keterampilan Proses Sains*. Surabaya: Pascasarjana, Universitas Negeri Surabaya.

Tahirsylaj, A., & Sundberg, D. (2020). The unfinished business of defining competences for 21st century curricula—a systematic research review. *Curriculum Perspectives, 40*(2), 131-145. https://doi.org/10 .1007/s41297-020-00112-6

Talib, S. A., Nasri, N. M., & Mahmud, M. S. (2025). Experts' teachers' point of view on mathematics teachers' readiness in becoming professional teachers. *Journal of Education and Learning (EduLearn), 19*(2), 634-644. https://doi.org/10.11591/edulearn.v19i2.21857

Tytler, R., Prain, V., & Hobbs, L. (2019). Rethinking disciplinary links in interdisciplinary STEM learning: a temporal model. *Research in Science Education, 51*(1), 269-287. https://doi.org/10.1007/s11165-019-09872-2

Usman, A. N., Musta'ámal, A. H., Muhammad, H. A., & Mohammed, I. A. (2020). Effects of place-based and activity-based approaches in technical education, interest and retention. *Universal Journal of Educational Research, 8*(5), 73-80. https://doi.org/10 .13189/ ujer.2020.081911

Usman, M. H., Al Idrus, A., Doyan, A., Soeprianto, H., & Hakim, A. (2021). Teachers' basic skills in learning science in junior high schools facing the 21st century. *Jurnal Penelitian Pendidikan IPA, 7*(3), 331-334. https://doi.org/10 .29303/jppipa.v7i3.652

Wahono, B., Lin, P.-L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education, 7*(1), 1-18. https://doi.org/10.1186/s40594-020-00236-1

Wang, H.-H., Charoenmuang, M., Knobloch, N. A., & Tormoehlen, R. L. (2020). Defining interdisciplinary collaboration based on high school teachers' beliefs and practices of STEM integration using a complex system designed. *International Journal of STEM Education, 7*(1), 1-17. https://doi.org/10 1186 s40594-019-0201-4

Widodo, R. M., Triwahyuni, E., & Emyus, A. Z. (2025). The influence of Wordwall game media on students' creativity and conceptual understanding in elementary schools. *Jurnal Penelitian Pendidikan IPA, 11*(1), 828-834. https://doi.org/10.29303/jppipa.v11i1.10239

Widodo, T., Winarso, W., & Abdul, A. (2020). Where exactly to enhance critical and creative thinking: the use of problem posing or contextual learning. *European Journal of Educational Research, 9*(2), 877-887. https://doi.org/10 .12973/eu-jer.9.2.877

Wiśniewski, R., Wojnakowski, M., & Li, Z. (2022). Design and verification of Petri-net-based cyber-physical systems oriented toward implementation in field-programmable gate arrays—a case study example. *Energies, 16*(1), 1-19. https://doi.org/10.3390/en16010067

Xiang, J., & Han, C. (2023). Effect of STSE approach on high school students' understanding of the nature of science. *Journal of Science Education and Technology, 33*(3), 263-273. https://doi.org/10.1007/s10956-023-10053-0

Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education, 29*(1), 145-185. https://doi.org/10.1007/s11191-019-00100-x