Journal of Information Technology Education: Innovations in Practice

An Official Publication of the Informing Science Institute InformingScience.org

JITEiip.org

Volume 24, 2025

DEVELOPMENT OF PROJECT-BASED LEARNING WITH TECHNOLOGY INTEGRATION AND SCIENCE RECONSTRUCTION TO BOOST CREATIVITY

Wenny Pinta Litna Tarigan*	Biology Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Sleman Regency, Indonesia	wennypintalitnatari-gan@uny.ac.id
Paidi	Biology Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Sleman Regency, Indonesia	paidi@uny.ac.id
Antuni Wiyarsi	Chemistry Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Sleman Regency, Indonesia	antuni_w@uny.ac.id
Suhartini	Biology Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Sleman Regency, Indonesia	suhartini@uny.ac.id

* Corresponding author

ABSTRACT

Aim/Purpose	This study aims to develop and assess the effectiveness of the Project-Based Learning with Technology Integration and Science Reconstruction (PROLE TISRE) learning model, an innovative project-based approach that integrates technology and ecology courses with local wisdom, to foster creativity among college students in ecology courses.
Background	Creativity is a vital competence in higher education, facilitating innovative thinking in addressing complex societal issues. Existing project-focused learning activities have not provided sufficient opportunities for college students to engage in real-world problem-solving and integrate local wisdom in the learning stages. The PROLE TISRE model seeks to address these limitations by incorporating local wisdom and technological resources, thus promoting more meaningful and contextually relevant learning experiences.

Accepting Editor Zlatko J. Kovacic │ Received: January 4, 2025 │ Revised: July 30, August 25, September 10, September 21, 2025 │ Accepted: September 22, 2025.

Cite as: Tarigan, W. P. L., Paidi, Wiyarsi, A., & Suhartini. (2025). Development of project-based learning with technology integration and science reconstruction to boost creativity. *Journal of Information Technology Education: Innovations in Practice, 24,* Article 20. https://doi.org/10.28945/5630

Methodology	This study employed a research and development (R&D) design, based on Borg and Gall's model, which comprises ten stages ranging from preliminary investigation to dissemination. The study involved 500 colleges across four universities, alongside five expert validators and nine practitioners. A quasi-experimental research design with pre-test and post-test assessments was employed to evaluate the model's effectiveness. Aiken's V was used for content validation, confirming the instruments' high reliability and validity. The Likert-scale creativity data were transformed into an interval scale using the Method of Successive Intervals (MSI) before being analyzed with a t-test for main field testing and a MANOVA for operational field testing to assess the impact of model on creativity.
Contribution	This research contributes to the educational field by providing the PROLE TISRE model, which offers a structured, technology-integrated framework grounded in local ecological knowledge. It develops essential educational tools, including a model book, a lecturer's guide, instructional modules, and student worksheets, to improve students' creativity and other relevant nurturing effects in college. The study further demonstrates the model's efficacy in enhancing college students' learning outcomes, offering a novel approach to ecological education that integrates cultural and scientific perspectives.
Findings	The PROLE TISRE model yielded significant improvements in student creativity, with an effect size of 0.895, outperforming the Project-Based Learning (PjBL) and Direct Instruction (DI) models, which showed effect sizes of 0.769 and 0.687, respectively. The findings from field testing validated the model's feasibility and practicality, revealing an enhancement in creativity among college students.
Recommendations for Practitioners	It is recommended that educators incorporate technology into each phase of the learning process to maximize creativity and student engagement. A structured project cycle, spanning at least two sessions, should be implemented to facilitate the comprehensive development and evaluation of student projects. The integration of local wisdom and technology in ecological education is crucial for fostering authentic, context-specific learning experiences.
Recommendations for Researchers	Future research should explore the broader applicability and scalability of the PROLE TISRE model across various disciplines. Longitudinal studies are recommended to examine the long-term impact of this model on students' problem-solving skills and career development. Additionally, the role of cultural and contextual factors in enhancing creativity within educational frameworks warrants further investigation.
Impact on Society	The PROLE TISRE model promotes the preservation and application of local ecological knowledge, including the practices of mina surjan, mina padi, and sawah surjan, thereby fostering environmental awareness and sustainable practices. By enhancing student creativity, the model prepares college students to address real-world ecological challenges and contribute to community-based solutions.
Future Research	Future studies should assess the adaptability of the PROLE TISRE model in non-ecology subjects, particularly focusing on how it can be expanded across diverse educational contexts. Research should also investigate the potential integration of emerging technologies such as Artificial Intelligence (AI) and virtual reality into the learning model. Additionally, future research should explore the

model's impact on diverse student populations to ensure inclusivity and equitable access.

Keywords creativity, local wisdom, project, science reconstruction, technology

INTRODUCTION

In the current higher education landscape, cultivating creativity in college students is essential for preparing them to tackle complex societal challenges. Creativity is widely recognized as a fundamental skill that drives innovation, enhances critical thinking, and supports effective problem-solving (Beghetto & Kaufman, 2007; Hennessey & Amabile, 2010; Robinson, 2011). Observations in multiple classrooms reveal a significant gap between the intended learning outcomes of many courses and their actual implementation. Teacher-centered approaches dominate, focusing primarily on the delivery of theoretical content and leaving limited opportunities for college students to engage in real-world problem-solving activities (Tarigan, Paidi, et al., 2023). This situation suggests that the learning outcomes are not fully realized in practice, highlighting the need for educational strategies that promote creativity and support the development of innovative, contextually relevant solutions to academic challenges.

Project-Based Learning (PjBL) has proven effective in enhancing creativity by allowing college students to engage in complex, real-world problems (Krajcik & Blumenfeld, 2005; Miller & Krajcik, 2019). The integration of technology with PjBL further enriches this approach by enabling college students to analyze and construct scientific concepts, deepen their understanding, and stimulate innovative thinking (Hmelo-Silver & DeSimone, 2013; Irdalisa et al., 2020). Barak and Raz (2000) found that college students engaged in technology-supported PjBL tasks exhibited greater creativity and innovation in their academic work. Moreover, a meta-analysis by Condliffe et al. (2017) highlighted the positive impact of PjBL on college students' ability to apply knowledge across various domains creatively.

PjBL faces several challenges that hinder its full potential, particularly in higher education. For example, PjBL is often restricted to manual projects or those based on simple tools, which are less aligned with the demands of 21st-century skills (Barak & Raz, 2000; Capraro et al., 2013). Furthermore, reflection in PjBL is often superficial and merely supplementary to the evaluation process, which limits its ability to deepen college students' understanding of the learning process (Faediyah et al., 2024). Additionally, PjBL tends to focus more on the final product of the project rather than the process of knowledge reconstruction that college students undergo (Krajcik & Blumenfeld, 2005). The existing PjBL frameworks do not specifically integrate local wisdom, which is crucial for contextualizing the learning experience and fostering a deeper connection to real-world issues. PjBL also lacks a dedicated phase for designing, modeling, and reflection, which are crucial for fostering deeper learning and creativity (Armstrong & Shaffner, 2007; Condliffe et al., 2017).

Modeling provides concrete examples of how experts approach challenges, allowing college students to visualize and apply theoretical knowledge in real-world contexts, thereby enhancing comprehension and fostering critical thinking (James, 2024; Wilson et al., 2020). Reflection enables college students to evaluate their learning experiences, identify strengths and weaknesses, and refine their problem-solving strategies, promoting self-regulation (Cho et al., 2017; Park et al., 2021). This metacognitive process not only deepens understanding but also encourages flexibility in thinking, which is crucial for creativity (Jia et al., 2019). Stages of designing models and reflection ensure that college students focus not only on the final product but also on internalizing the process, fostering both innovative thinking and the ability to apply knowledge in diverse, real-world situations (von Thienen et al., 2023).

The integration of local wisdom into learning models has been shown to enhance student creativity by providing culturally relevant and contextually meaningful perspectives. For example, incorporating indigenous knowledge in education encourages college students to think critically and creatively about local environmental and social issues, fostering innovation rooted in cultural understanding (Berkes, 2012; Lubis et al., 2022; Tarigan, Kuswanto, & Tarigan, 2023). This connection to local wisdom enables college students to engage with real-world problems more effectively, stimulating creative solutions grounded in their own communities, as supported by situated learning theories (Lave & Wenger, 1991; Wiyarsi et al., 2024).

These gaps have been addressed through the development of the Project-Based Learning with Technology Integration and Science Reconstruction (PROLE TISRE) model. This model is original and integrates the theoretical foundations of sociocultural theory (Vygotsky, 1978), social learning theory (Bandura, 1977), and instructional framework (Joyce et al., 2003). The PROLE TISRE model emphasizes social interaction through group learning activities, encouraging collaboration, argumentation, and reflection, which foster cognitive development. Vygotsky's sociocultural theory highlights the importance of social interaction in learning, where college students exchange ideas and build arguments collaboratively. Bandura's social learning theory informs the model by encouraging cognitive stimulation through demonstration and guided practice, where instructors provide concrete examples to facilitate understanding. The learning model is structured around specified core elements such as its theoretical base, instructional impacts, syntax, reaction principles and nurturant effects (Joyce & Weil, 1986). All designed to foster creativity and computational thinking (CT) in college students.

The PROLE TISRE model integrates local knowledge into the learning process, such as sustainable agricultural practices and community-based solutions. This integration connects college students with real-world applications of their academic knowledge (Berkes, 2012; Lubis et al., 2022; Tarigan, Kuswanto, & Tarigan, 2023). By bridging the gap between traditional wisdom and modern science, the model fosters a holistic understanding of scientific phenomena. Implementing local knowledge as a learning resource for exploration, reconstruction, and innovation enables college students to engage in deeper scientific inquiry, creating a more connected and meaningful learning experience.

The objective of this study is to design and evaluate the PROLE TISRE model, assessing its validity, practicality, and effectiveness in enhancing creativity among college students. Specifically, this research aims to investigate how the integration of technology, local knowledge, and project-based learning can improve college students' creativity across various disciplines. The PROLE TISRE model offers a comprehensive and structured approach to PjBL, integrating technology and local knowledge to provide a more engaging and meaningful learning experience. This approach aims to bridge the gap between theoretical learning and practical application, ensuring that college students are better prepared to solve real-world problems innovatively.

LITERATURE REVIEW

PHILOSOPHICAL FOUNDATIONS

The PROLE TISRE model is based on the philosophies of constructivism, progressivism, and several relevant learning theories, supporting the development of creativity among college students. Constructivism emphasizes the idea that knowledge is not something given from the outside, but rather a result of active construction by individuals. In this context, college students construct their own knowledge by interacting directly with their social and cultural environment. The PROLE TISRE model adopts this approach by providing college students with the opportunity to apply knowledge through locally contextualized projects integrated with technology. This approach not only enhances conceptual understanding but also develops critical thinking and collaborative skills that are relevant to contemporary social, cultural, and digital life (Suyono & Hariyanto, 2015; Thobroni & Mustofa, 2013; Yaumi, 2013).

Progressivism emphasizes student-centered learning grounded in real-world experience, teachers design environments that ensure the continuity and interaction of experience, guiding growth rather than merely delivering content (Dewey, 1938). This approach fosters learning to create active, creative individuals who can adapt to changing times. In the PROLE TISRE model, progressivism is reflected in the way college students are given the freedom to explore their potential through real-world problem-based projects, enabling them to develop reflective and collaborative thinking. It aligns with the goals of 21st-century education, which demand the development of critical, creative, and collaborative skills to address global challenges (Dewey, 2004; Tröhler, 2017). Therefore, the progressivism theory provides a solid foundation for a learning design that encourages college students to think critically, innovate, and develop themselves in addressing real-world problems.

SUPPORTING LEARNING THEORIES

Constructivist learning theory further strengthens the foundation of the PROLE TISRE model. This theory emphasizes that knowledge is built through active interaction with the physical and social environment. In this theory, college students are viewed as active builders of their own knowledge, with the educator serving as a facilitator who creates challenging and meaningful learning experiences (Bruning et al., 2004; Schunk, 2012). College students not only learn theory but also engage in the exploration of local issues contextualized with technology. This learning experience encourages college students to construct new understandings and solve problems relevant to their social environment, thereby strengthening creativity and critical thinking skills (Park et al., 2021; Schunk, 2012). This theory supports the development of competencies focused on project-based learning that integrates local knowledge and technology, equipping college students with skills that can be applied in their daily lives (Schunk, 2012; Wilson et al., 2020).

Experiential learning theory, developed by Kolb (2015), also serves as a fundamental basis for the development of the PROLE TISRE model. Experiential learning emphasizes that the best learning occurs through direct experience followed by reflection and abstract conceptualization. College students are involved in projects addressing local issues that combine real-world experiences and reflection, two core elements of experiential learning theory. Through concrete experiences (e.g., exploring local wisdom or technology-based solutions in the field), college students can construct relevant and applicable knowledge, which is then processed through reflection and abstraction (Kolb, 2015).

The model developed in this study focuses not only on the project's outcome but also on the learning process that integrates practical experiences with relevant theories. College students go through the active experimentation stage by developing technology-based solutions or social initiatives related to local wisdom, which reflects the experiential learning cycle. Local issue-based projects enable college students to apply the knowledge they have learned in real-world contexts. This process reflects the principles of constructivism, where learning is an active process built upon experiences and collaboration with others (Lave & Wenger, 1991).

Sociocultural and situated approaches are fundamental in promoting socially and culturally mediated learning interactions. Vygotsky argued that knowledge development occurs through social interaction, and the Zone of Proximal Development (ZPD) plays a key role in supporting college students in reaching their potential through guidance and collaboration (Vygotsky, 1978). College students work in groups to solve projects, enabling them to exchange ideas, collaborate, and develop solutions together. Situated learning theory (Lave & Wenger, 1991) supports the use of local wisdom as relevant teaching material, as college students learn about and from their social environment, enriching their learning experiences and deepening the local context that is part of their education (Schunk, 2012; Scrimsher & Tudge, 2003). The integration of local wisdom into learning aligns with the situated learning theory proposed by Lave and Wenger (1991), which posits that long-term memory is formed through active participation in relevant and contextual social communities.

PROLE TISRE combines the principles of constructivism, progressivism, and relevant learning theories, such as experiential learning, situated learning, and sociocultural theories, to create a richer, more contextual, and profound learning experience. The integration of technology and local wisdom into this model helps college students not only develop conceptual understanding but also enhance their critical thinking, creativity, and collaboration skills, which are essential to address real-world challenges in the 21st century (Berkes, 2012; Lubis et al., 2022; Tarigan, Kuswanto, & Tarigan, 2023).

LEARNING MODEL

Joyce et al. (2003) argue that a learning model provides a framework for shaping curricula, designing instructional materials, and guiding classroom practices by integrating perspectives from constructivist, behavioral, cognitive, and social learning theories, which consist of several elements such as reaction principles, social systems, supporting systems, and instructional impact. The Project-Based Learning (PjBL) approach prioritizes solving real-life problems through collaboration and reflects the view that education should be rooted in authentic experience (Armstrong & Shaffner, 2007; Dewey, 1938). On the other hand, the Direct Instruction (DI) model offers a more structured, teacher-directed approach, focusing on the delivery of knowledge (Sangur et al., 2024). The PROLE TISRE model, built on these foundational learning theories by integrating technology and local wisdom into the learning process, promotes critical thinking, creativity, and the application of knowledge in real-world contexts. PROLE TISRE ensures that students engage in both collaborative and individualized learning, thereby fostering essential 21st-century skills (Suprijono, 2019). Table 1 highlights the key shortcomings of PjBL and DI models and how the PROLE TISRE model addresses these gaps with a more contextually relevant approach.

Table 1. Comparison of PjBL, DI, and PROLE TISRE models

Aspects	Existing models (PjBL and DI)	Shortcomings	How PROLE TISRE addresses the shortcomings
Focus on the final product vs process	PjBL tends to focus on the final product of the project rather than the process of knowledge reconstruction. DI focuses on the learning outcomes, less on the learning process.	Limited emphasis on the learning process and knowledge science reconstruction from local wisdom.	PROLE TISRE emphasizes both the product and the process of knowledge reconstruction, ensuring college students engage deeply in the learning process, not just the outcome.
Reflection	Reflection in PjBL is treated as supplementary to the evaluation process. DI focuses more on content mastery.	Reflection is not deeply integrated into the learning process, undermining its potential for metacognition.	PROLE TISRE integrates a structured, dedicated reflection phase, encouraging metacognitive development and deeper self-regulation in learning.
Integration of local wisdom	PjBL models generally do not specifically incorporate local wisdom or contextual knowledge. DI has limited integration of local wisdom.	Lack of integration of culturally relevant or locally significant knowledge.	PROLE TISRE integrates local wisdom into learning through project-based activities, ensuring that college students engage with and apply culturally and contextually relevant knowledge in their projects.
Technology integration	PjBL may not consistently integrate technology. DI often relies on traditional teaching methods.	Limited technological engagement and a lack of tools for deeper learning and innovation.	PROLE TISRE integrates advanced technology throughout the learning process, allowing students to use tools and digital resources for deeper exploration, innovation, and problem-solving.
Collaborative learning	PjBL includes collaboration, and DI primarily involves individual work, with limited collaboration among college students.	Collaboration is often informal and lacks clear guidance and structured interaction.	PROLE TISRE provides a structured collaborative framework, guiding college students through group tasks with defined roles and clear objectives to enhance group learning and interaction.

Aspects	Existing models (PjBL and DI)	Shortcomings	How PROLE TISRE addresses the shortcomings
Creativity	PjBL addresses critical thinking but does not always involve contextual problem-solving. Creativity in DI is often restricted by a structured, teacher-driven approach.	Gaps in developing advanced cognitive skills like computational thinking, innovation, and critical analysis.	PROLE TISRE emphasizes creativity and critical problem-solving by guiding college students to explore local issues through technology, applying their knowledge in innovative ways.
Design models and reflection	PjBL does not have a specific syntax for design models and reflection. DI lacks project-based or open-ended tasks; it focuses on structured assignments and evaluations.	Insufficient structure and detailed phases for project development, reflection, and revision.	PROLE TISRE includes clear stages of design models, reflection with an emphasis on both the process and the results.

Science Reconstruction

Indigenous science refers to the knowledge systems developed by traditional communities, shaped through cultural symbols, customs, religious rituals, and daily social practices (Battiste, 2002; Porsanger, 2004). This knowledge contains scientific concepts that, although empirical, have not been formalized into academic frameworks (Duit & Treagust, 2003). The integration of indigenous science with modern scientific knowledge enhances students' understanding of scientific concepts by grounding learning in real-life, culturally relevant issues (UNESCO, 2006). For instance, Bali's local wisdom and Javanese agricultural practices illustrate how indigenous knowledge can be used to bridge scientific understanding with cultural beliefs (Suastra, 2006; Sudarmin, 2014). These examples highlight the paradigm shift in science education, making it more contextual and rooted in local wisdom.

The process of reconstructing indigenous science into formal scientific knowledge involves an empirical foundation based on local experience through the processes of identification, verification, and conceptualization, integrating traditional knowledge with scientific understanding (Ogawa, 1995). Ogawa (1995) emphasizes that the cultural and local knowledge is examined and interpreted to develop scientific theories that are both scientifically valid and culturally relevant. According to George (2001), principles for integrating local knowledge into science education include ensuring a connection between culture and science, validating indigenous knowledge as meaningful and applicable to everyday life, and bridging traditional knowledge with scientific methodologies. The reconstruction of indigenous ecological knowledge, as illustrated by Snively and Corsiglia (2001), demonstrates how traditional knowledge systems, such as botany, agriculture, and climatology, can be transformed into academic science through observation, classification, problem-solving, and prediction (Suastra, 2006).

Creativity

Creativity in science education is defined as the ability to generate new ideas or products characterized by originality and imagination (Gallagher, 2015; Pamilu, 2007). It involves mental processes in which individuals combine existing knowledge in novel ways or create entirely new ideas (Gallagher, 2015). Creativity is fundamental to scientific progress, as it drives the formulation of hypotheses, experimental design, innovative discoveries, and data analysis (Runco & Jaeger, 2012). It also plays a critical role in developing interdisciplinary applications and advancing technology (Sawyer, 2012). Creativity in science often requires thinking beyond conventional boundaries and approaching problems from different perspectives. For instance, major scientific breakthroughs, such as Einstein's theory of relativity or Watson and Crick's discovery of the DNA structure, are products of creative thinking that revolutionized our understanding of the world (Sawyer, 2012). This study assesses the college students' creativity based on the five dimensions proposed by Guilford (1950), which include fluency (the ability to produce many ideas), flexibility (the ability to approach problems with various solutions), originality (the ability to generate unique ideas), elaboration (the ability to detail ideas comprehensively), and redefinition (the ability to reconsider problems in novel ways).

METHODOLOGY

RESEARCH DESIGN

This study employed a Research and Development (R&D) model by Borg and Gall (2007), which included ten stages, namely preliminary study, planning, development of the preliminary form of the product, preliminary field testing, product revision, main field testing, operational product revision, operational field testing, final product revision, dissemination, and implementation. A preliminary version of the product was developed and tested in a single class at the first sample university. This stage focused on learning processes assessed in four meetings, which produced college students' responses and product evaluations. The main field testing employed a pre-experimental design, involving pre-test and post-test assessments conducted in a single class at a second sample university, without the use of a control group. Revisions were made based on this feedback, followed by larger field testing to assess effectiveness.

The operational field testing employed a quasi-experimental design, incorporating pre-test and post-test assessments conducted across three classes at two universities, totalling six classes. Each learning model was applied at both universities. In this testing, Class A implemented the Project-Based Learning with Technology Integration and Science Reconstruction (PROLE TISRE) model that was developed in this study, Class B implemented Project-Based Learning (PjBL) that was adopted from The George Lucas Educational Foundation (Armstrong & Shaffner, 2007), and Class C employed the Direct Instruction (DI) model that was adopted from Sangur et al. (2024). The quasi-experiment reflects how these teaching models would be implemented in actual classroom settings and allows us to observe whether PROLE TISRE produces significant differences in college students' creativity.

PARTICIPANTS

Participants were divided into three categories: five expert validators, nine practitioners (lecturers and program coordinators), and 500 biology education college students (empirical instrument testing and research sample). Empirical testing of the creativity instrument was conducted on 200 college students, and field-testing research (main and operational field testing) on 300 college students from biology education programs at several universities. Purposive sampling was used to select experts based on specific criteria. For educator specialists, a minimum of ten years of experience in developing learning models and a PhD/Dr were required. Lecturers and program coordinators were selected from all four universities.

The research employed a random sampling method for the preliminary field testing (n=20, first sample university) and the main field testing (n=40, second sample university). A total sampling method (all three classes from each university were included in the study) was used for the operational field testing conducted at the third and fourth sample universities (n=240, with 80 participants for PROLE TISRE, 80 for PjBL, and 80 for DI). Random sampling was applied for the assignment of the classes to the different teaching models. This approach ensured that classes from each university would be randomly assigned to implement one of the following teaching models: PROLE TISRE, Project-Based Learning (PjBL), and Direct Instruction (DI) to minimize potential bias and allow for an objective distribution of the models across the classes. All college student samples met the criteria for homogeneity and normality (p-value > 0.05).

The college participants were from the Semester 4 Biology Education Study Program and ranged in age from 18 to 22 years old. They were enrolled in ecology courses that integrated local wisdom, such as the traditional polyculture system called "sawah surjan" and integrated rice-fish systems known as "mina surjan" and "mina padi," which are found near the research sample locations. This demographic group is appropriate for examining the effects of different teaching models, integrated with local wisdom, on creativity outcomes. Informed consent was obtained from all participants, with particular emphasis on its importance due to the involvement of college students in the study.

PROCEDURE AND INSTRUMENT

A preliminary study using a questionnaire was conducted to assess college students' creativity. The questionnaire consisted of 30 items across four indicators: fluency, originality, elaboration, and flexibility (Rhodes, 1961; Torrance, 1966), as detailed in Table 2. Each item was measured using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The Likert-scale questionnaire data were first recoded for reverse-keyed items and then transformed into an interval scale using the Method of Successive Intervals (MSI), thereby satisfying the assumptions of parametric inferential statistical analysis (Febriana & Setiawati, 2024).

The instrument design was validated in two stages, namely content validation by expert judgment and practitioners, and analyzed using Aiken's V coefficient. The Aiken's V coefficient value for the creativity instrument was 0.93 based on expert judgment and 0.90 from practitioners, both of which fall into the category of excellent validity. The construct validation was conducted through empirical testing on 200 college students. Informed consent was obtained from all participants, and the research protocol received approval from the institutional ethics committee prior to data collection. The data from the empirical testing were analyzed using the Winstep application, where 30 out of 32 items were found to be valid. Cronbach's alpha was used to assess internal consistency, and provided values where applicable, confirming that the instrument was reliable for measuring creativity. Additionally, Confirmatory Factor Analysis (CFA) in JASP indicated that all 30 items had factor loadings greater than 0.3. Factor loadings above 0.3 suggest that the items reliably represent the factor structure, supporting the construct validity of the measurement model. PROLE TISRE learning model validated by five experts, nine lecturers, as presented in Figure 1.

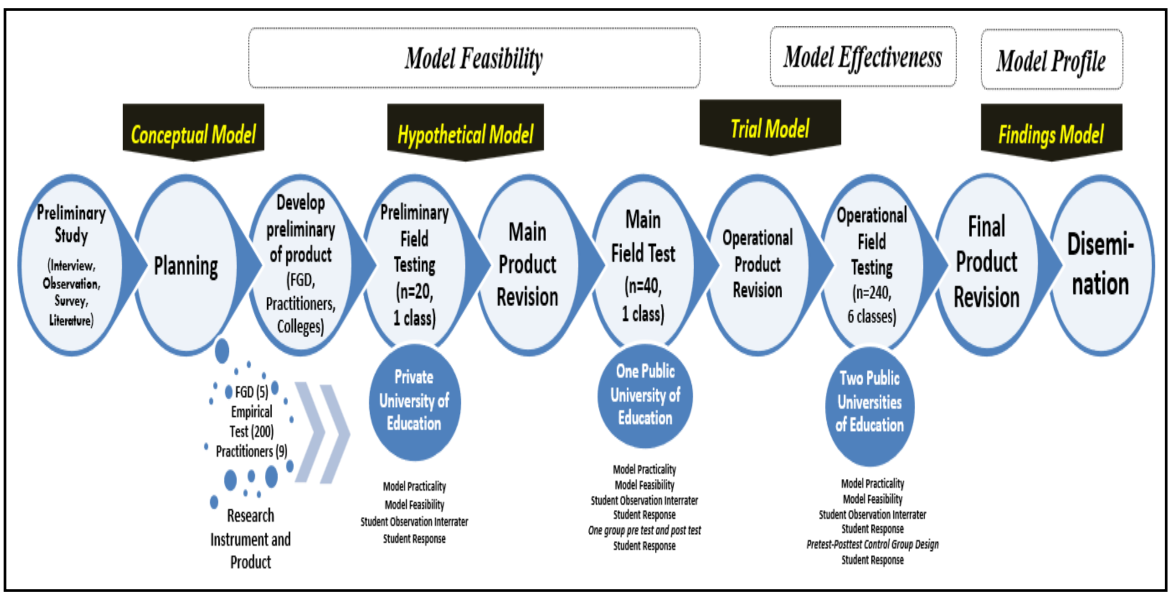

Figure 1. Research and development procedure Borg and Gall (2007)

The results from the preliminary study, planning, and development of the product, including its components, were used to develop the conceptual framework of the PROLE TISRE learning model. A preliminary version of the product was designed to gather initial feedback and identify areas for improvement. This initial testing aimed to assess the product's feasibility and provide insights into its practical application. Main field testing focused on evaluating the product's impact on student outcomes and refining the model based on observed results and participant feedback. Operational field testing expanded the effectiveness results. The final product underwent revisions to ensure its readiness for broader application and was fully prepared for large-scale.

Table 2. Personal creativity instrument framework (Rhodes, 1961; Torrance, 1966)

Aspects	Indicators	Item number
Fluency	Generating many ideas, answers, and solutions to problems or questions.	1
	Independence in learning ecology.	2
Originality	Able to produce new and unique expressions.	3
	Thinking of unconventional ways to express oneself.	4, 5
	Strong determination to solve ecological problems.	6, 7
Elaboration	Responding to questions with enthusiasm, actively, and eagerly in completing challenging tasks.	8, 9, 10, 11, 12
	Willing to take on or perform difficult tasks.	13, 14
	Enjoy finding practical methods or approaches in learning.	15, 16
	Critical in examining the work results.	17, 18, 19
	Actively asking questions.	20, 21, 22
Flexibility	Generating a variety of ideas, answers, or questions.	23, 24
	Viewing a problem from different perspectives.	25, 26
	Seeking many different alternatives or directions.	27, 28, 29, 30

Table 3 presents a detailed comparison of the instructional designs used in each group: PROLE TISRE, Project-Based Learning (PjBL), and Direct Instruction (DI). The table outlines the learning tasks and activities implemented during each phase of the teaching process for each instructional model, illustrating how creativity was elicited differently across treatments.

Table 3. The instructional designs used in each group

PROLE TISRE syntax developed	Learning activities	PjBL syntax (Armstrong & Shaffner, 2007)	Learning activities	DI syntax (Sangur et al., 2024)	Learning activities
Learning orientation	Learning conditioning by providing explanations about standards and evaluation criteria. Identification of culture and content found in the presented video.	Start with the essential question.	Lecturer presents learning material along with a triggering question to encourage college students to identify and formulate solutions to the problem raised. *"What makes the mina surjan/sawah surjan/mina padi system important for the ecosystem and local community life?"*	State the learning objectives and prepare the learning environment.	Lecturer explains the learning objectives, provides background information, explains the relevance of the material to students, and prepares a conducive learning environment.
Content exploration	Identify the connection between culture and material. Identify learning tools to visualize the selected material.	Design a plan for the project.	Lecturer guides each group member to choose a project.	Demonstrate knowledge or skills.	Lecturer presents the material about the procedure or concept being studied.
Designing models	Design the project plan. Set project schedule and create project model.	Create a project schedule and implementation.	Lecturers and college students create an agreement on the project schedule, including activity stages and project deadlines.	Guiding Practice	Lecturer guides college students through guided practice, providing direct instructions.

PROLE TISRE syntax developed	Learning activities	PjBL syntax (Armstrong & Shaffner, 2007)	Learning activities	DI syntax (Sangur et al., 2024)	Learning activities
Project development	Develop the project design prototype. Create a logbook for prototype design progress.	Monitoring	During the project, the lecturer monitors student participation, evaluates progress, and provides assistance when obstacles arise in the process.	Check understanding and provide feedback.	Lecturer evaluates student understanding of the material taught through questions, assignments, or quizzes, and gives clear and constructive feedback.
Project simulation	Present the created product.	Assess the outcome	Lecturer oversees student participation and assesses the achievement of expected competency standards.	Provide an opportunity for further practice and application.	Lecturer provides independent practice and opportunities for students to apply knowledge or skills in broader contexts or real-life situations.
Project evaluation	Evaluate the process, experience, and results of the created product. Evaluate the product's benefit from environmental, social, and economic perspectives.	Evaluate the experience (reflection)	Lecturer facilitates the presentation of the project by college students, gives feedback on the displayed results, and guides the reflection and conclusion process collaboratively.	-	-
Learning reflection	Reflect on the learning activities related to the identified local wisdom.	-	-	-	-

PRODUCTS

The research developed and produced four key products to support the implementation of the PROLE TISRE learning model, which integrates polyculture and rice-fish farming systems, including the PROLE TISRE model book, which provides a comprehensive overview of the model's theoretical framework, principles, and development process, serving as a foundational reference for educators. The PROLE TISRE Lecturer's guide handbook offers practical guidance on classroom application, including lesson planning, implementation strategies, and assessment methods to evaluate student progress. College student worksheets (LKM) promote active learning by engaging college students in exercises, project tasks (Figure 3), and problem-solving activities that encourage critical thinking and collaboration. Their products form a cohesive package, ensuring the successful application of the PROLE TISRE model in educational environments as presented in Figure 2.

The final products in this study were the project designs and prototypes (Figure 3) that students created as part of the learning tasks. These products were evaluated for creativity based on the creativity indicators (fluency, originality, elaboration, and flexibility) and qualitative observations during project presentations and reflections.

DATA ANALYSIS

Feasibility testing involved five validators, including experts in media, instructional design, learning models, and subject matter, who assessed the product's validity using Aiken's V. Practicality testing was conducted through questionnaires distributed to validators, practitioners, and college students, with results analyzed as percentages based on SDi (Standard Deviation of the Ideal Score) criteria (Mardapi, 2008). Normality tests, including graphical methods and the Shapiro-Wilk test, were performed to confirm data distribution before applying parametric tools like t-tests and MANOVA. These tests were used to compare group means and assess multivariate differences, ensuring assumptions were met. A quasi-experimental one-group pretest-posttest design, along with comparisons between the experimental and control classes (PjBL and DI), was employed to test the model's effectiveness. Data analysis was conducted using t-tests for main field-testing and MANOVA for operational field-testing, after confirming normality and homogeneity.

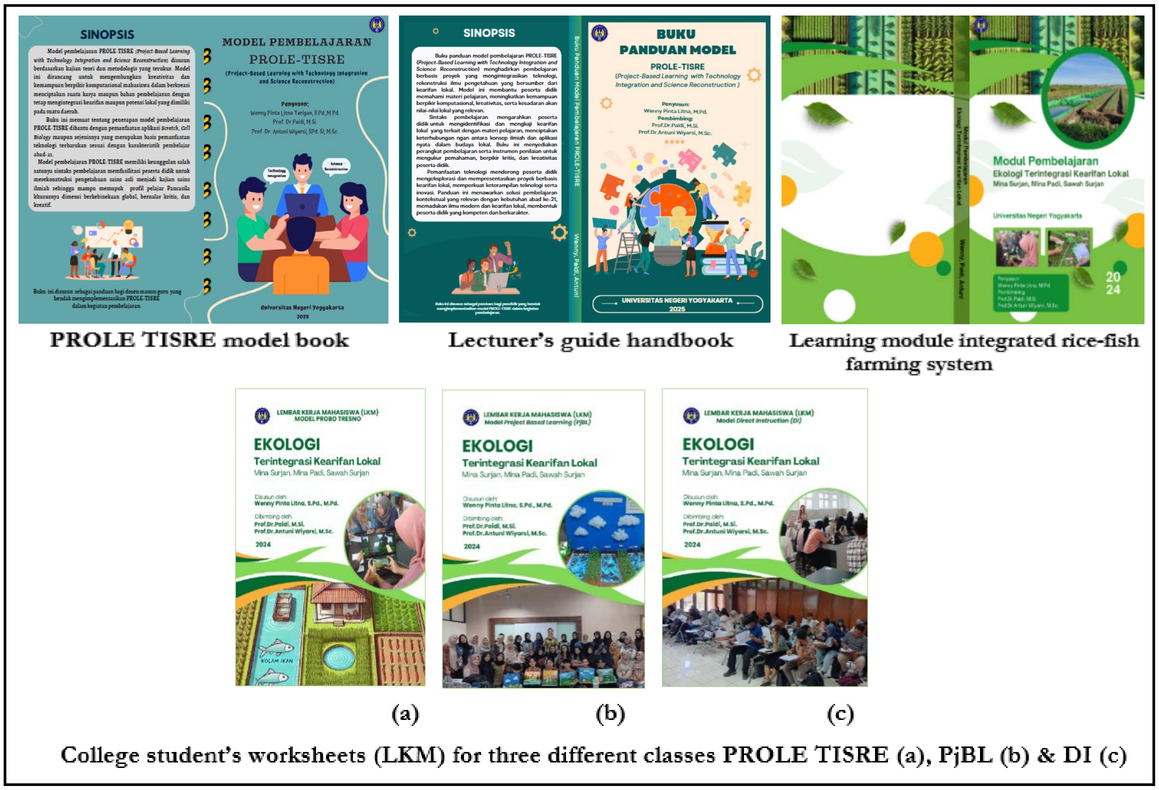

Figure 2. Research products

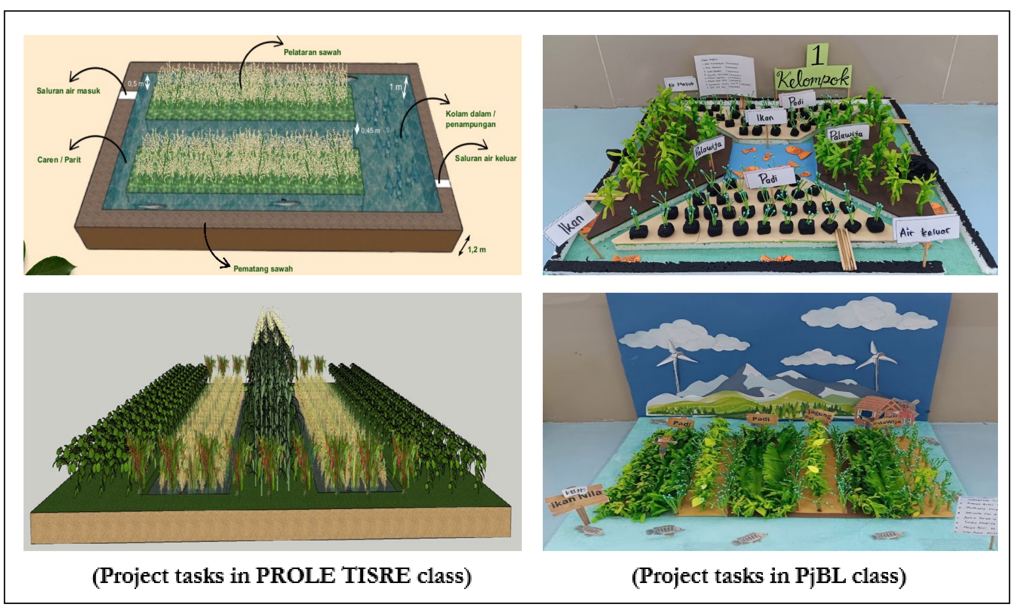

Figure 3. Student project tasks

FINDINGS

PRELIMINARY STUDY

Preliminary observation results showed that lecturing remained largely lecturer-centered, which led to minimal student participation in discussions and Q&A sessions (Tarigan, Paidi, et al., 2023). As one college student stated, "I felt more engaged in the projects because they were grounded in real-world issues that connected to my community." This information suggests that when projects are relevant to real-world issues and closely linked to students' communities, they become more engaged and actively involved in the learning process. The lack of integration of contextual environmental issues further restricts the development of college students' problem-solving skills, which are essential for addressing real-world ecological challenges (Paidi et al., 2020). Lecture media are primarily limited to PowerPoint presentations and static images, providing little interactivity or engagement, while educational videos addressing environmental issues from the perspective of local wisdom are rarely used. Project-based media are repetitive and do not effectively utilize ICT to foster creativity and creative thinking.

Existing learning tools that incorporate local wisdom and technology do not adequately support the enhancement of these skills. Discussions are often unstructured and lack well-designed worksheets that align with specific competency targets, reducing their overall effectiveness. The absence of integrated learning tools that combine local wisdom and ICT highlights the urgent need for innovation in lecture delivery to promote student engagement, creativity, and higher-order thinking skills necessary for ecological problem-solving (Tarigan, Paidi, et al., 2023).

PLANNING

Defining the Course Learning Outcomes (CPMK) that align with the context of the Ecology lectures. The selected CPMK aims to enhance college students' understanding of ecological concepts, such as organism interactions, ecosystems, biodiversity, and the impact of human activities on the environment. The learning process is structured to analyze ecosystem interaction patterns, the effects of pollution, and the role of biodiversity in maintaining ecosystem balance. The learning products designed include the PROLE TISRE model book, RPS (Semester Learning Plan), SAP (Lesson Plan), locally based instructional modules, student worksheets (LKM), creativity questionnaires, and classroom learning activity observation sheets to record students' participation. The model book and its implementation guide serve as references for lecturers, while the instructional materials and LKM are developed to support active student learning in alignment with the university curriculum.

DEVELOPMENT OF PRELIMINARY PRODUCT

The PROLE TISRE model is designed to enhance creativity, both personal and product-based, by integrating traditional polyculture practices, such as mina surjan, mina padi, and sawah surjan, with ICT-based media in ecology lectures. This integration is applied to measure ecological concepts, including the diversity index, energy flow, nutrient cycle, and population structure within traditional polyculture areas. The model is grounded in constructivist theory, encouraging exploration-based learning and sociocultural theory, which emphasizes the role of social environments, group discussions, and cultural contexts (Vygotsky, 1978). It further integrates an experiential learning approach grounded in authentic experiences alongside an information-processing view that highlights turning information into knowledge (Arends, 2012; Kolb, 2015).

Technology plays a vital role in facilitating modern learning (Kolb, 2015). The model consists of syntax (structured phases of learning) and follows seven phases: Learning Orientation, Content Exploration, Designing Models, Project Development, Project Simulation, Project Evaluation, and Learning

Reflection, a social system that fosters interaction, principles of reaction guiding teacher-student responses, a support system providing resources and tools, and measurable learning impacts. This comprehensive approach blends traditional ecological practices with innovative technology, fostering creativity and holistic student development, as presented in Figure 4.

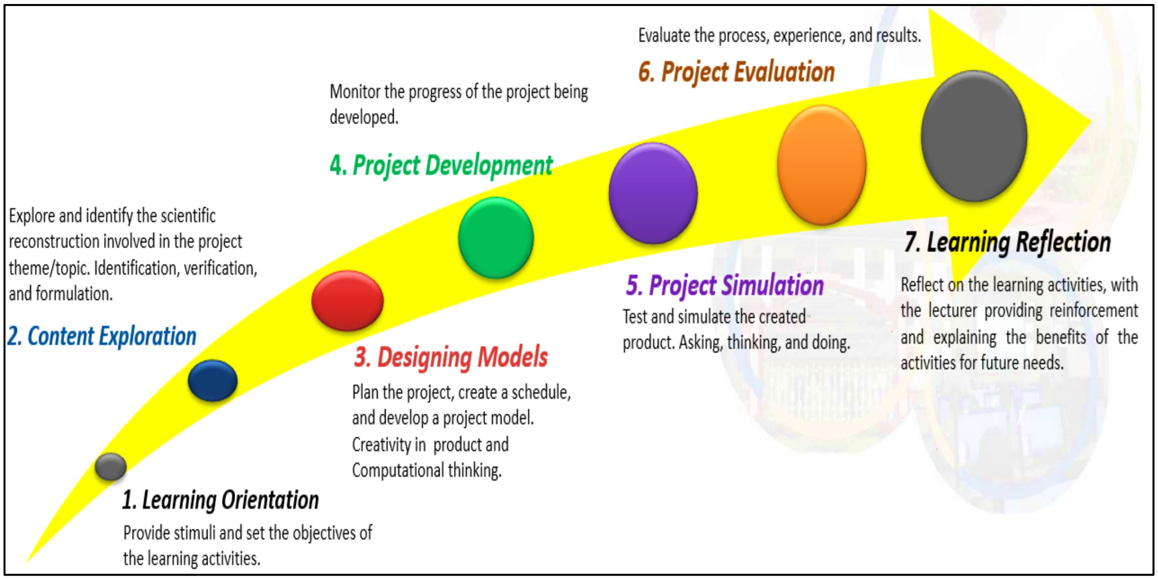

Figure 4. Prototype the syntax of PROLE TISRE learning model

Preliminary Field Testing

Preliminary field testing was conducted in a single class of the Biology Study Program at a private university of education in Yogyakarta, involving 20 college students. This stage focused on evaluating the learning model's implementation cycle over three cycles. The inter-rater assessment from observers of the syntax showed average scores ranging from 90 to 92.5, indicating a high level of agreement between Rater 1 and Rater 2. However, there is a need to add one additional session to accommodate the Project Presentation, Project Evaluation, and Learning Reflection phases, considering the time required for product design. The average of creativity was 82, reflecting strong but improvable performance in these areas as presented in Figure 5.

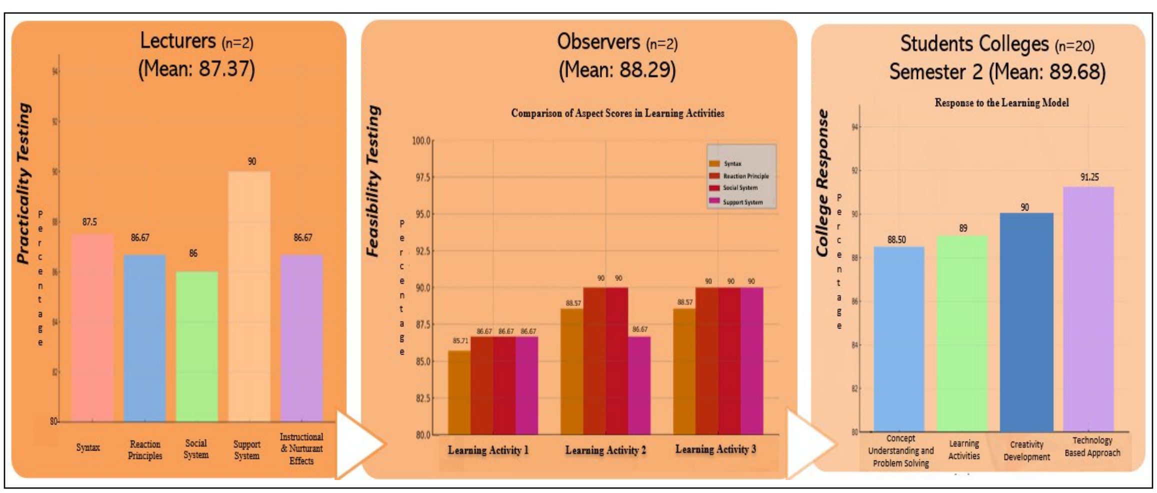

Figure 5. Preliminary field-testing results

PRODUCT REVISION

Feedback from validators, practitioners, and college students led to several suggested revisions aimed at enhancing the integration of technology, strengthening theoretical foundations, and improving the overall coherence of the materials, as detailed in Table 4. This table highlights that all suggestions have been implemented in the revisions, ensuring that each component supports the development of college students' skills and understanding to the fullest extent. The revised syntax of the PROLE TISRE learning model is explained in Figure 6.

Table 4. Product revisions

Research products	Respondent suggestions	Revisions made
PROLE TISRE learning model	Integration of technology at each stage of learning, with an emphasis on using specific tools or applications. Learning reflection focuses on fostering college students' understanding of science reconstruction and the preservation of local wisdom.	Technology has been integrated into each phase of the model. Learning reflection now emphasizes science reconstruction and local wisdom.
Learning model book	Expansion of the background with theoretical and empirical studies, needs assessment, and analysis of other learning models. Learning syntax is designed to be more operational and clearer, supported by extended theoretical references. Consistency in the use of the term "college students," spelling corrections, additional references, and the inclusion of a logo and synopsis on the book cover.	Background expanded, syntax refined for clarity, and current references added. Spelling corrections, logo, and synopsis included.
Model implementation guidebook	Addition of more appropriate subheading descriptions, structured numbering, consistency in language and technical terms, detailed explanation of the learning model with step-by-step implementation and example, adding a logo, and synopsis.	Subheadings and numbering refined. Detailed descriptions of the model and practical examples added. Logo and synopsis included on the cover.
Modules and student worksheets	Integration of worksheets with learning modules to create a coherent flow, updated cover design with modern visual elements, improved grammar and formatting, and detailed guidelines on creativity ability, adding a logo and synopsis.	Worksheets integrated with modules, cover redesigned, grammar corrected, and creativity guidelines. Logo and synopsis added.

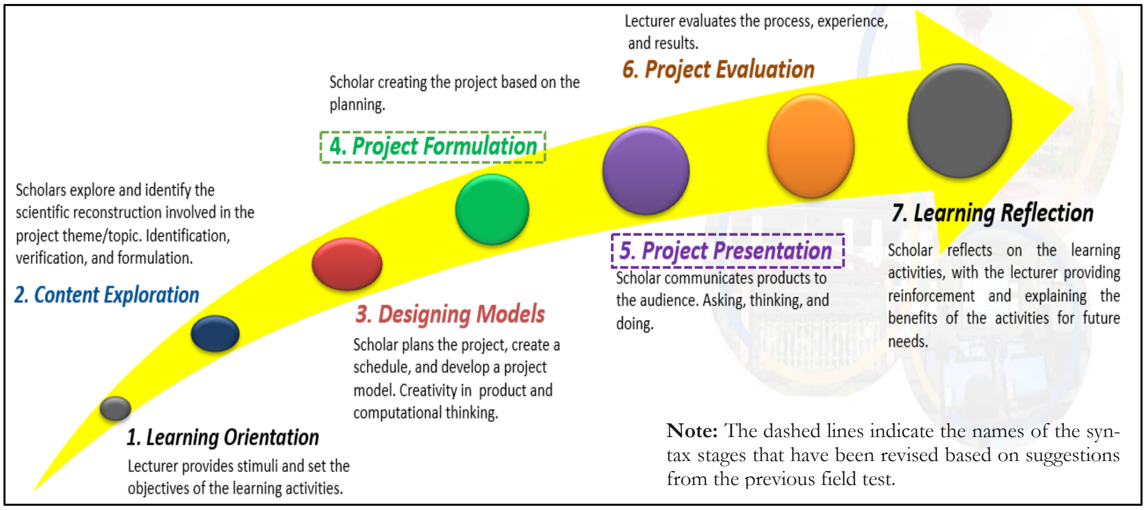

Figure 6. Revision syntax of PROLE TISRE learning model

MAIN FIELD TESTING

Main field testing was conducted in one class of the Biology Education study program at a Public University of Education in Yogyakarta, involving 40 college students. The testing used a pre-post experimental design without a control group. This stage focused on evaluating the effectiveness of the learning model's implementation cycle over five cycles to enhance creativity. The inter-rater assessment on the learning model's syntax showed an average score ranging from 90 to 95, reflecting a high degree of agreement between Rater 1 and Rater 2. This consistency indicates that the evaluation process was reliable and that both raters had a similar understanding and interpretation of the model's structure and implementation. The significance value of the t-test was 0.00 ($\alpha<0.05$). The results highlight the robustness of the model's design and suggest that the syntax aligns well with the intended learning objectives and instructional flow, as explained in detail in Figure 7.

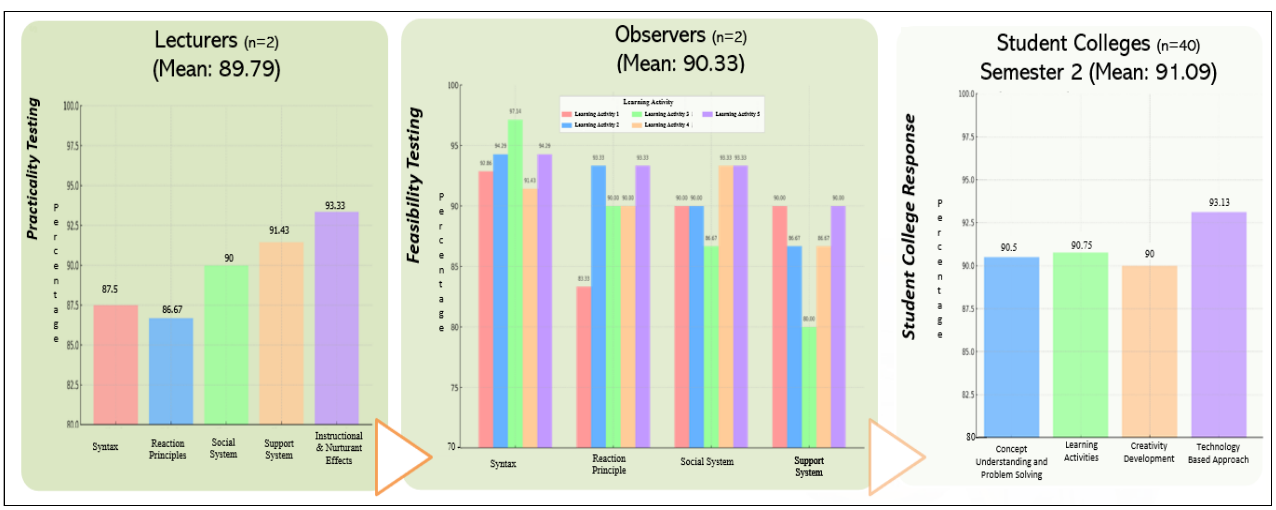

Figure 7. Main field-testing results

Operational Product Revision

Various revision suggestions have been implemented based on evaluations and feedback from validators and practitioners. These revisions include technology integration, material adjustments, and improvements to the visual and content aspects of various learning components. Table 5 summarizes the revision suggestions and the changes.

Table 5. Operational product revisions

Research products	Respondent suggestions	Revisions made
Learning model	Technology integration at each stage of learning, with an emphasis on the use of specific tools or applications. Learning reflection is directed at fostering college students' understanding of scientific reconstruction and the preservation of local wisdom.	Technology has been integrated into each phase of the model. Learning reflection now focuses on scientific reconstruction and local wisdom.
Learning model book	Expansion of the background with theoretical and empirical studies, needs assessment, and analysis of other learning models. Detailed syntax, consistent terminology, corrected spelling, additional references, logo, and synopsis.	Background expanded, operational syntax refined, and current references added. Terminology, spelling, logo, and synopsis corrected and included.
Model implementation guidebook	Addition of appropriate subheading descriptions, structured numbering, consistency in language and technical terms, and more detailed implementation steps with practical examples. Logo and synopsis added.	Subheadings and numbering revised. Detailed descriptions of the model and examples added. Logo and synopsis included on the cover.
Modules and student worksheets	Integration of worksheets with learning modules for a more coherent flow, updated cover design with modern visual elements, and detailed guidelines on creativity skills. Logo and synopsis added.	Worksheets integrated with modules, cover redesigned, and creative ability. Logo and synopsis added.

Operational Field Testing

Operational field testing was conducted within the Biology Education study program during the odd semester at two universities, namely the Public University of Education in Magelang and the Public University of Education in Yogyakarta. Each university had three classes: one implementing the PROLE TISRE model, one using Project-Based Learning (PjBL), and one following Direct Instruction (DI). In total, six classes participated, with 40 college students in each class (n=240). An increase in the average score (M) from pre-test to post-test was observed across all three learning models PROLE TISRE (PT), Project-Based Learning (PjBL), and Direct Instruction (DI), as presented in Table 6.

Table 6. Pre-test dan post-test of creativity (n=240)

Test	N			Mean			Standard deviation			Standard error		
	PT	PjBL	DI	PT	PjBL	DI	PT	PjBL	DI	PT	PjBL	DI
Pre-test	80	80	80	55.35	55.90	55.76	5.58	7.07	6.72	0.61	0.79	0.75
Post-test	80	80	80	89.42	82.07	72.94	5.71	6.18	6.49	0.64	0.69	0.73

Note: PT: PROLE TISRE Model; PjBL: Project-Based Learning Model; DI: Direct Instruction Model

The probability value of Wilks' Lambda shows a significance of 0.000 < 0.05, leading to the rejection of the null hypothesis (H_0). This indicates that there is a significant simultaneous difference in the improvement of creativity among the groups subjected to the experimental model, control group 1, and control group 2. N-gain and effect size in partial eta squared are presented in Table 7.

Table 7. Effect size and N-gain (n=240)

Variable	Partial eta squared			N-gain		
	PT	PjBL	DI	PT	PjBL	DI
Creativity in Learning	0.895	0.769	0.687	0.75	0.57	0.38

Note: PT: PROLE TISRE Model; PjBL: Project-Based Learning Model; DI: Direct Instruction Model

Final Product Revision

Research tools and instruments have been revised to align with learning objectives, ensuring their appropriateness for dissemination to broader educational institutions following validation. Group discussions have been optimized by guiding college students to engage in preliminary discussions before scheduled lectures, with a requirement to review the LKM materials beforehand. The structured field observations and data collection on *mina surjan*, *mina padi*, or *sawah surjan* are implemented to enable college students to identify and solve real-world problems. Final learning syntax of PROLE TISRE model consists of seven stages, namely learning orientation, content exploration, designing models, project formulation, project presentation, project evaluation, and learning reflection. Table 8 summarizes the key suggestions and the revisions made.

Table 8. Final product revision

Aspects	Respondent suggestions	Revisions implemented
Learning model	One model cycle should span two sessions to address time constraints and ensure optimal learning.	The model's implementation was adjusted to allow two sessions per cycle for better learning outcomes.
Research tools and instruments	Ensure alignment with learning objectives and improve based on feedback from validators.	Instruments revised and validated to align with learning goals and objectives.
Group discussion optimization	Guide college students to conduct preliminary discussions before class and ensure they study LKM materials beforehand.	College students are now required to complete preliminary discussions and review LKM materials prior to class sessions.
Field observation activities	Structure field observation and data collection on *mina surjan*, *mina padi*, or *sawah surjan* to facilitate problem-solving.	Field observation activities were structured to promote organized data collection and problem-solving.

Dissemination and Implementation

Based on the results of large-scale operational trials, the PROLE TISRE learning model has proven to be practical and effective in enhancing college students' creativity. However, several challenges were identified during field testing:

(a) Limited class time required two sessions to complete one full cycle of the PROLE TISRE model to ensure each phase was optimally implemented.
(b) Group discussions were optimized by encouraging college students to conduct preliminary discussions before class to understand problems and find solutions. College students were required to review LKM materials beforehand.

(c) Observation and data collection activities needed to be structured to help college students develop solutions to assigned problems.
(d) Research tools and instruments were revised based on feedback to ensure accuracy and alignment with learning objectives.

The final version of the PROLE TISRE model and its supporting tools has been validated and deemed suitable and effective for use. The model is now ready for dissemination and distribution to a broader range of educational institutions.

DISCUSSION

The findings from this study underscore the necessity for innovative and interactive pedagogical models to enhance creativity among college students. Traditional lecture-based methods, while efficient for knowledge delivery, often fail to stimulate active engagement, critical thinking, and creativity (Barak & Raz, 2000; Cukurova & Luckin, 2018; Global Education Monitoring Report Team, 2023; Robinson, 2011). Research by Beghetto and Kaufman (2007) and Tarigan et al. (2024) suggests that creativity thrives in learning environments that promote autonomy, problem-solving, and open-ended inquiry, which traditional teaching methods may not adequately provide. The PROLE TISRE learning model, developed through this research, reflects an effective response to these limitations by incorporating experiential and contextual learning activities that actively engage college students. This aligns with findings from Hwang et al. (2008), who demonstrated that technology-supported, project-based learning environments significantly improve creative performance and problem-solving skills.

Vygotsky (1978) sociocultural constructivism enriches the model by emphasizing the social nature of learning. His concept of the Zone of Proximal Development (ZPD) underlines the importance of collaborative learning, where college students are guided by more knowledgeable peers or instructors. The PROLE TISRE model leverages this by incorporating group activities and interactive discussions that enhance cognitive development through social interaction (Kolb, 2015). Experiential learning theory completes the foundational trio by introducing the idea that knowledge is acquired through cycles of experience, reflection, conceptualization, and experimentation. This approach aligns with the PROLE TISRE model's focus on hands-on learning, ensuring that college students apply their knowledge in practical contexts, thereby reinforcing and deepening their understanding (Kolb, 2015).

The PROLE TISRE learning model's design, rooted in constructivist theory and sociocultural approach, emphasizes active, collaborative, and contextual learning experiences (Kolb, 2015; Vygotsky, 1978). Constructivist frameworks, as noted by Jonassen (1999), highlight the importance of authentic tasks and collaborative learning in fostering deeper understanding and creativity. By integrating local ecological knowledge, such as mina surjan, mina padi, and sawah surjan, with ICT, the model bridges traditional ecological practices and modern scientific inquiry (Berkes, 2012; Voogt & Pelgrum, 2005). This approach resonates with the work of G. A. Smith and Sobel (2014) and K. Smith et al. (2022), who advocate for place-based education as a means to enhance student engagement and creativity by grounding learning in local contexts. The synthesis of local wisdom and technology not only enriches the learning experience but also fosters a deeper connection between college students and their local environment, promoting sustainability and innovation (Gruenewald, 2003). The model's multi-phase structure includes Learning Orientation, Content Exploration, Designing Models, Project Formulation, Project Presentation, Project Evaluation, and Learning Reflection, which supports iterative learning and continuous improvement, thereby reinforcing the development of higher-order thinking skills. Iterative learning facilitates the acquisition of knowledge and the improvement of performance through repeated cycles of practice, feedback, reflection, and refinement (Hmelo-Silver & DeSimone, 2013).

Table 9 provides a detailed mapping of the PROLE TISRE model, demonstrating the relationship between each phase of the learning process, associated creativity aspects, relevant indicators, and examples of college student activities. It highlights how the model fosters creativity through different stages, guiding students to actively engage with content, generate innovative solutions, and apply learning in real-world contexts. This framework helps to highlight the role of creativity in shaping effective learning experiences.

Table 9. Mapping PROLE TISRE phases to creativity aspects, indicators, and college student behaviours

PROLE TISRE syntax	Creativity aspects	Creativity indicators	Student behaviours
Learning orientation	**Fluency**	Generating multiple ideas, questions, or answers related to the topic.	Students ask various questions about the ecological topic and local culture shown in the video.
	Flexibility	Viewing problems from multiple perspectives.	Students consider social, cultural, and scientific perspectives of the observed problem.
Content exploration	**Originality**	Producing new and unique ideas or expressions.	Students creatively link the subject matter to local cultural practices.
	Fluency	Generating multiple ideas about tools or media for learning.	Students suggest various visualization models for data interpretation.
	Flexibility	Exploring multiple alternatives for visualization.	Students consider different methods for presenting the material.
Designing models	**Elaboration**	Actively developing the plan and enthusiastically completing tasks.	Students create detailed schedules and step-by-step plans for project model development.
	Originality	Generating new project ideas.	Students design project concepts that are innovative and different from typical solutions.
	Fluency	Generating multiple project design alternatives.	Students propose several design options for the project to choose from.
Project formulation	**Elaboration**	Actively developing the prototype and evaluating progress.	Students record daily prototype development and assess strengths and weaknesses.
	Originality	Adding innovative solutions or improvements.	Students integrate unique features or creative modifications into the prototype.
	Fluency	Experimenting with multiple approaches to prototype development.	Students try different materials or construction methods for the prototype.
Project presentation	**Elaboration**	Critically evaluating the presentation results.	Students assess the strengths and weaknesses of their product during the presentation.
	Fluency	Proposing multiple ideas for improvement.	Students suggest several ways to improve the product for the next simulation.
Project evaluation	**Elaboration**	Evaluating project quality and effectiveness.	Students assess whether the product meets learning objectives and has a positive impact.
	Flexibility	Considering multiple perspectives.	Students evaluate the product from environmental, social, and economic viewpoints.
	Originality	Providing innovative suggestions for improvement.	Students propose modifications to make the prototype more effective and beneficial.

PROLE TISRE syntax	Creativity aspects	Creativity indicators	Student behaviours
Learning reflection	**Originality**	Formulating new ideas based on reflection.	Students write reflections with unique ideas about applying the content in society.
	Elaboration	Developing reflection in depth.	Students relate practical experiences to theory and local context.
	Flexibility	Connecting experiences to multiple contexts.	Students compare their learning experiences with similar practices in other locations or cultures.

Table 9 shows the mapping of PROLE TISRE phases to creativity aspects, indicators, and college student behaviours, which highlights how each phase fosters personal creativity in learning. It supports the development of the creativity of college students in field testing. The results from field testing show the model's effectiveness. The significant improvement in post-test scores across the experimental class (M=89.42) compared to the PjBL (M=82.07) and DI (M=72.94) groups confirms the model's effectiveness to enhance creativity in creating innovative products and creative thinking. This aligns with research by Capraro et al. (2013), who found that project-based learning incorporating technology leads to greater student achievement and creativity compared to direct instructional approaches. The rejection of the null hypothesis (Wilks' Lambda = 0.150, $p < 0.05$) highlights the statistically significant differences in learning outcomes, demonstrating that PROLE TISRE contributes more effectively to student development than conventional teaching methods (Condliffe et al., 2017).

This model gives a high effect size in creativity (Partial Eta Squared = 0.895), suggesting substantial practical significance, reflecting its broad applicability and potential for widespread adoption. The integration of ICT into project-based activities, as seen in the PROLE TISRE approach, aligns with prior studies by Voogt and Pelgrum (2005), which emphasize the role of technology in enhancing creative thinking and collaborative learning. This study further reinforces the growing consensus that technology-supported pedagogies, especially those grounded in contextual and community-based knowledge, offer a comprehensive framework for developing essential 21st-century skills.

The PROLE TISRE learning model empowers college students to design prototype products, incorporating local wisdom into their academic courses while leveraging ICT-assisted media for enhanced learning experiences. This model not only fosters creativity and innovation but also strengthens the connection between traditional knowledge and modern education methods, ensuring a more holistic learning process. The PROLE TISRE approach offers distinct advantages, which are highlighted in Figure 8.

The hands-on, project-based design of PROLE TISRE encourages college students to engage in real-world problem-solving, which fosters deeper cognitive processing and enhances their ability to generate novel ideas. Research has shown that experiential learning models, like PROLE TISRE, stimulate higher-order thinking by requiring college students to apply knowledge in dynamic, practical contexts, thus promoting creativity (Amabile, 1996; Kolb, 2015). The model's focus on collaborative learning, critical reflection, and designing real-world projects helps college students to think flexibly and explore multiple solutions, which are key components of creativity. In contrast, while PjBL and DI also aim to support learning, they may not engage college students as deeply or provide the same level of autonomy and real-world application, potentially explaining the lower creativity improvements observed in these groups. Therefore, the high effect size and N-Gain in the PROLE TISRE group suggest that its holistic, integrative approach is more conducive to creativity development than the more structured or traditional methods employed in PjBL and DI.

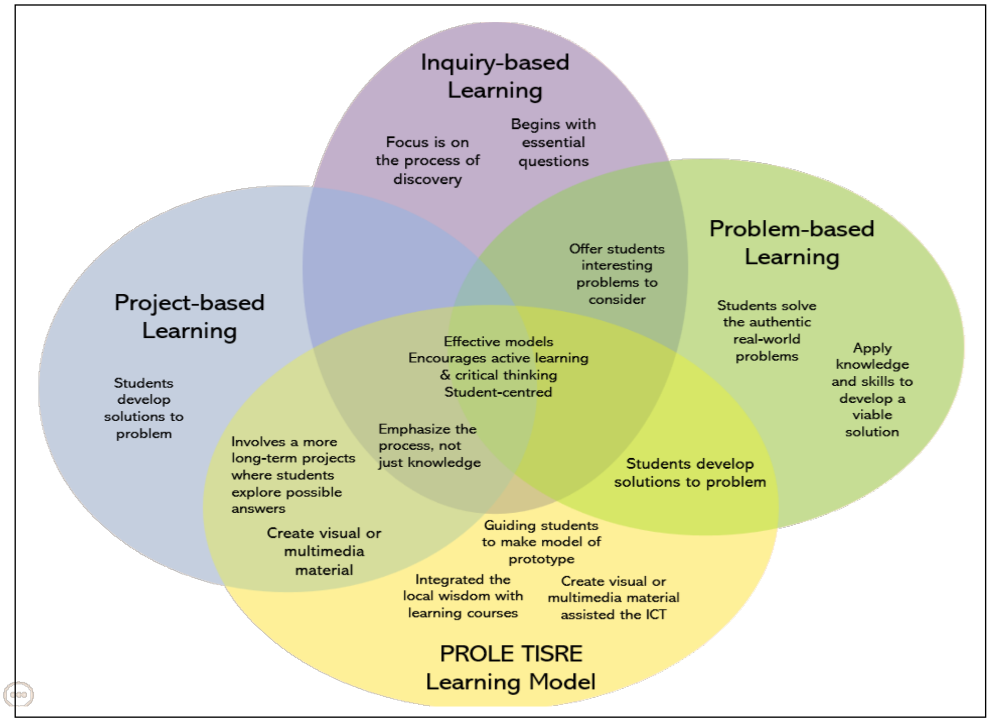

Figure 8. Comparison between the main goals of PROLE TISRE and other existing learning models

CONCLUSION

The research and development of the PROLE TISRE (PROBO TRESNO) learning model has demonstrated its significant potential to enhance student learning, particularly in promoting community-oriented ecological education. This model is built on constructivist and socio-constructivist principles, incorporating a structured seven-stage syntax, interactive and collaborative learning strategies, and a comprehensive support system that includes teaching materials, worksheets, and technology-based resources. These elements foster creativity, encourage curiosity, and nurture essential skills, including collaboration, digital literacy, and resilience. Feasibility testing confirmed the model's validity and reliability, with high content and construct validity scores, indicating that the developed tools are suitable for educational use. Practicality and implementation testing further demonstrated positive student responses, with participants expressing engagement and enthusiasm, suggesting the model effectively supports student learning and understanding. The effectiveness of the model was clearly highlighted through pretest-posttest comparisons, which revealed significant improvements in creativity among college students using PROLE TISRE. Empirical results show that PROLE TISRE fosters creativity more effectively than traditional PjBL and Direct Instruction (DI), making it the stronger option for developing higher-order thinking skills. These findings reinforce the model's potential to advance ecological education by incorporating local wisdom into active, hands-on learning experiences. The PROLE TISRE model presents valuable insights for curriculum design and teacher training, particularly in fostering community-oriented ecological education. It advances the field by providing a robust, evidence-based approach to cultivating creativity and critical thinking, positioning it as a promising tool for future educational practices.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to all parties who have provided inspiration, encouragement, and support throughout the completion of this study. The authors also gratefully acknowledge the financial support for the Article Processing Charge (APC) provided by the Program World Class University, Badan Pengelola Perguruan Tinggi Negeri Berbadan Hukum (WCU–BPPT-NBH) Universitas Negeri Yogyakarta (UNY) in 2025.

REFERENCES

Amabile, T. M. (1996). *Creativity in context: Update to the social psychology of creativity*. Westview Press. https://doi.org/10.4324/9780429501234

Arends, R. I. (2012). *Learning to teach* (9th ed.). McGraw-Hill Education.

Armstrong, S., & Shaffner, M. (2007). *Project-based learning professional development guide.* The George Lucas Educational Foundation. https://www.edutopia.org/project-based-learning-guide

Bandura, A. (1977). *Social learning theory*. Prentice Hall. https://www.asecib.ase.ro/mps/Bandura_SocialLearningTheory.pdf

Barak, M., & Raz, E. (2000). Hot-air balloons: Project-centered study as a bridge between science and technology education. *Science Education, 84*(1), 27-42. https://doi.org/10.1002/(SICI)1098-237X(200001)84:1<27::AID-SCE3>3.0.CO;2-8

Battiste, M. (2002). *Indigenous knowledge and pedagogy in First Nations education: A literature review with recommendations*. National Working Group on Education.

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for "mini-c" creativity. *Psychology of Aesthetics, Creativity, and the Arts, 1*(2), 73-79. https://doi.org/10.1037/1931-3896.1.2.73

Berkes, F. (2012). *Sacred ecology*. Routledge. https://doi.org/10.4324/9780203123843

Borg, R. W., & Gall, M. D. (2007). *Educational research and introduction* (8th ed.). Pearson. https://archive.org/details/educationalresea0008gall

Bruning, R. H., Schraw, G. J., Norby, M. M., & Ronning, R. R. (2004). *Cognitive psychology and instruction* (4th ed.). Pearson.

Capraro, R. M., Capraro, M. M., & Morgan, J. (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2nd ed.). Sense Publishers. https://doi.org/10.1007/978-94-6209-143-6

Cho, M.-H., Kim, Y., & Choi, D.-H. (2017). The effect of self-regulated learning on college students' perceptions of community of inquiry and affective outcomes in online learning. *The Internet and Higher Education, 34*, 10-17. https://doi.org/10.1016/j.iheduc.2017.04.001

Condliffe, B., Quint, J., Visher, M. G., Bangser, M. R., Drohojowska, S., Saco, L., & Nelson, E. (2017). *Project-based learning: A literature review*. MDRC. https://www.mdrc.org/sites/default/files/Project-Based_Learning-LitRev_Final.pdf

Cukurova, M., & Luckin, R. (2018). Measuring the impact of emerging technologies in education: A pragmatic approach. In J. Voogt, G. Knezek, R. Christensen & K. W. Lai (Eds.), *Second handbook of information technology in primary and secondary education*. Springer. https://doi.org/10.1007/978-3-319-53803-7_81-1

Dewey, J. (1938). *Experience and education*. Kappa Delta Pi.

Dewey, J. (2004). *Democracy and education: An introduction to the philosophy of education*. Aakar Books.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688. https://doi.org/10.1080/09500690305016

Faediyah, F., Anjelli, S., & Fasihaturrohmah, S. (2024). Pengembangan model pembelajaran berbasis proyek lingkungan untuk meningkatkan literasi ekologi mahasiswa [Developpment of an environmental project-based learning model to enhance university students' ecological literacy]. *SEMAR: Jurnal Sosial dan Pengabdian Masyarakat, 2*(3), 1–7. https://doi.org/10.59966/semar.v2i3.881

Febriana, B. W., & Setiawati, F. A. (2024). Increasing measurement accuracy: Scaling effect on academic resilience instrument using Method of Successive Interval (MSI) and Method of Summated Rating Scale (MSRS). *Jurnal Penelitian dan Evaluasi Pendidikan*, *28*(1), 32-42. https://doi.org/10.21831/pep.v28i1.69334

Gallagher, S. A. (2015). The role of problem-based learning in developing creative expertise. *Asia Pacific Education Review, 16*(2), 225-235. https://doi.org/10.1007/s12564-015-9367-8

George, J. (2001). *Culture and science education: A look from the developing world*. https://www.actionbioscience.org/education/george.html

Global Education Monitoring Report Team. (2023). *Technology in education: A case study on Indonesia*. https://doi.org/10.54676/WJMY7427

Gruenewald, D. A. (2003). The best of both worlds: A critical pedagogy of place. *Educational Researcher, 32*(4), 3-12. https://doi.org/10.3102/0013189X032004003

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*(9), 444-454. https://doi.org/10.1037/h0063487

Hennessey, B. A., & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology, 61*, 569-598. https://doi.org/10.1146/annurev.psych.093008.100416

Hmelo-Silver, C. E., & DeSimone, C. (2013). Problem-based learning: An instructional model of collaborative learning. In C. Hmelo-Silver, C. Chinn, C. Chan & A. O'Donnell (Eds.), *The international handbook of collaborative learning* (1st ed). Routledge. https://doi.org/10.4324/9780203837290

Hwang, W.-Y., Wang, C.-Y., Hwang, G.-J., Huang, Y.-M., & Huang, S. (2008). A web-based programming learning environment to support cognitive development. *Interacting with Computers, 20*(6), 524-534. https://doi.org/10.1016/j.intcom.2008.07.002

Irdalisa, I., Paidi, P., & Djukri, D. (2020). Implementation of technology-based guided inquiry to improve TPACK among prospective biology teachers. *International Journal of Instruction, 13*(2), 33-44. https://doi.org/10.29333/iji.2020.1323a

James, S. (2024). *Understanding the role of modeling in education*. Education Walkthrough. https://educationwalkthrough.com/understanding-the-role-of-modeling-in-education/

Jia, X., Li, W., & Cao, L. (2019). The role of metacognitive components in creative thinking. *Frontiers in Psychology, 10*(2404), 1-11. https://doi.org/10.3389/fpsyg.2019.02404

Jonassen, D. (1999). Designing constructivist learning environments. In C. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory*. Pennsylvania State University.

Joyce, B., & Weil, M. (1986). *Models of teaching* (3rd ed). Prentice-Hall.

Joyce, B., Weil, M., & Calhoun, E. (2003). *Models of teaching* (7th ed.). Allyn & Bacon.

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education. https://www.researchgate.net/publication/315793484_Experiential_Learning_Experience_as_the_source_of_Learning_and_Development_Second_Edition

Krajcik, J. S., & Blumenfeld, P. C. (2005). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317-334). Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.020

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Lubis, S. P. W., Suryadarma, I. G. P., Paidi, P., & Yanto, B. E. (2022). The effectiveness of problem-based learning with local wisdom oriented to socio-scientific issues. *International Journal of Instruction, 15*(2), 455-472. https://doi.org/10.29333/iji.2022.15225a

Mardapi, D. (2008). *Teknik penyusunan instrumen tes dan non-tes* [Techniques for developing test and non-test instruments]. Mitra Cendekia Press.

Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research, 1*(7), 1-10. https://doi.org/10.1186/s43031-019-0009-6

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583-593. https://doi.org/10.1002/sce.3730790507

Paidi, P., Mercuriani, I. S., & Subali, B. (2020). Students' competence in cognitive process and knowledge in biology based on curriculum used in Indonesia. *International Journal of Instruction, 13*(3), 491-510. https://doi.org/10.29333/iji.2020.13334a

Pamilu, A. (2007). *Mengembangkan kreativitas dan kecerdasan anak* [Developing children's creativity and intelligence]. Citra Media.

Park, J. H., Niu, W., Cheng, L., & Allen, H. (2021). Fostering creativity and critical thinking in college: A cross-cultural investigation. *Frontiers in Psychology*, *12*(760351), 1-12. https://doi.org/10.3389/fpsyg.2021.760351

Porsanger, J. (2004). An essay about indigenous methodology. *Nordlit, 15*, 105-120. https://doi.org/10.7557/13.1910

Rhodes, M. (1961). An analysis of creativity. *Phi Delta Kappan, 42*(7), 305-310. https://www.jstor.org/stable/20342603

Robinson, K. (2011). *Out of our minds: Learning to be creative*. Capstone Publishing. https://doi.org/10.1002/9780857086549

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*(1), 92-96. https://doi.org/10.1080/10400419.2012.650092

Sangur, S. D., Lawalata, H. J., & Warouw, Z. W. M. (2024). Application of direct learning model to improve student learning outcomes on digestive system materials in class XI Science 2 SMA Negeri 7 Southeast Maluku. *Polygon: Jurnal Ilmu Komputer dan Ilmu Pengetahuan Alam*, *2*(6), 61-70. https://doi.org/10.62383/polygon.v2i6.277

Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation* (2nd ed.). Oxford University Press. https://doi.org/10.1093/oso/9780195161649.001.0001

Schunk, D. H. (2012). *Learning theories: An educational perspective* (6th ed.). Pearson.

Scrimsher, S., & Tudge, J. R. H. (2003). The teaching/learning relationship in the first years of school: Some revolutionary implications of Vygotsky's theory. *Early Education and Development, 14*(3), 293-312. https://doi.org/10.1207/s15566935eed1403_3

Smith, G. A., & Sobel, D. (2014). *Place- and community-based education in schools*. Routledge. https://doi.org/10.4324/9780203858530

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of problem-based learning (PBL) in STEM education: Using expert wisdom and research to frame educational practice. *Education Sciences, 12*(10), 728, 1-20. https://doi.org/10.3390/educsci12100728

Snively, G., & Corsiglia, J. (2001). Discovering Indigenous science: Implications for science education. *Science Education, 85*(1), 6-34. https://doi.org/10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R

Suastra, I. W. (2006). Perspektif kultural pendidikan sains: Belajar sebagai proses inkulturasi [A cultural perspective on science education: Learning as an enculturation process]. *Jurnal Pendidikan dan Pengajaran Undiksha, 12*(3), 4-16.

Sudarmin. (2014). *Pendidikan Karakter, Etnosains, dan Kearifan Lokal* [Character education, ethnoscience, and local wisdom]. UNNES Press.

Suprijono, A. (2019). *Cooperative learning: Teori dan aplikasi PAIKEM* [Cooperative learning: Theory and application of PAIKEM]. Pustaka Pelajar.

Suyono & Hariyanto. (2015). *Belajar dan pembelajaran: Teori dan konsep dasar* [Learning and instruction: Basic theories and concepts]. Remaja Rosdakarya.

Tarigan, W. P. L., Kuswanto, H., & Tarigan, C. U. (2023). Local potential-integrated augmented reality booklet to facilitate student's curiosity and learning interest. *Anatolian Journal of Education, 8*(2), 195-206. https://doi.org/10.29333/aje.2023.8213a

Tarigan, W. P. L., Paidi, Wiyarsi, A., Handoyo, L. D., Nuryani, H. S., & Dewi, R. P. (2024). Factors associated with computational thinking skills among college students in the university. *Edelweiss Applied Science and Technology, 8*(5), 2167-2183. https://doi.org/10.55214/25768484.v8i5.1968

Tarigan, W. P. L., Paidi, Wiyarsi, A., & Suhartini. (2023). *Field observation data as preliminary observations undertaken in 2023 (Unpublished raw data).* Universitas Negeri Yogyakarta.

Thobroni, M., & Mustofa, A. (2013). *Belajar dan pembelajaran: Pengembangan wacana dan praktik pembelajaran dalam pembangunan nasional* [Learning and instruction: Developing discourse and instructional practices in national development]. Ar-Ruzz Media.

Torrance, E. P. (1966). *Torrance tests of creative thinking: Directions manual and scoring guide.* Personnel Press.

Tröhler, D. (2017). Progressivism. In G. W. Noblit (Ed.), *Oxford Research Encyclopedia of Education.* Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.111

UNESCO. (2006). *UNESCO guidelines on intercultural education*. UNESCO Paris. https://unesdoc.unesco.org/ark:/48223/pf0000147878

von Thienen, J. P. A., Weinstein, T. J., & Meinel, C. (2023). Creative metacognition in design thinking: Exploring theories, educational practices, and their implications for measurement. *Frontiers in Psychology, 14*(1157001), 1-20. https://doi.org/10.3389/fpsyg.2023.1157001

Voogt, J., & Pelgrum, H. (2005). ICT and curriculum change. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments, 1*(2), 157-175. https://doi.org/10.17011/ht/urn.2005356

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Wilson, K. J., Long, T. M., Momsen, J. L., & Bray Speth, E. (2020). Modeling in the classroom: Making relationships and systems visible. CBE - *Life Sciences Education, 19*(1), 1-5. https://doi.org/10.1187/cbe.19-11-0255

Wiyarsi, A., Çalik, M., Priyambodo, E., & Coştu, B. (2024). Indonesian prospective teachers' scientific habits of mind: A cross-grade study in the context of local and global socio-scientific issues. *Science & Education, 33*, 1257–1283. https://doi.org/10.1007/s11191-023-00429-4

Yaumi, M. (2013). *Prinsip-prinsip desain pembelajaran: Disesuaikan dengan Kurikulum 2013* [Principles of instructional design: Aligned with the Curriculum 2013]. Kencana Prenadamedia Group.

AUTHORS

Wenny Pinta Litna Tarigan is an Assistant Professor and Biology Education Lecturer at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta (UNY). Her main research interests are TPACK, science curriculum, learning integrated with technology and local wisdom, particularly in product development, and computational thinking in science education. She has authored educational textbooks, published articles, and delivered notable papers. She is actively involved in educational workshops aimed at enhancing the integration of technology and local knowledge. Email: wennypintalitnatarigan@uny.ac.id

Paidi is a Professor and Biology Education Lecturer at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta (UNY). His primary research interests are learning strategies and development in both school and higher education settings, with a focus on enhancing teaching methodologies and improving educational outcomes. He has contributed to various research projects and educational initiatives aimed at advancing the quality of biology education.
Email: paidi@uny.ac.id

Antuni Wiyarsi is a Professor and Chemistry Education Lecturer at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta (UNY). Her main research interests include socio-scientific issues in education, as well as learning strategies and development in both school and higher education settings. She has been actively involved in research and projects that focus on integrating socio-scientific issues into the curriculum and enhancing teaching strategies to foster critical thinking and problem-solving skills among students and colleges.
Email: antuni_w@uny.ac.id

Suhartini is an Associate Professor and Biology Lecturer at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta (UNY). Her main research interests include environmental science and agriculture, with a particular focus on sustainable agricultural practices and environmental sustainability. She is actively involved in research projects aimed at promoting eco-friendly and sustainable farming practices to support long-term environmental health. Email: suhartini@uny.ac.id