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COLLABORATIVE ETHNO-STEAM ENRICHED PROJECT-BASED LEARNING (COE-STEAM-PJBL): ITS IMPACT ON PROSPECTIVE SCIENCE TEACHERS' COLLABORATION AND CREATIVE THINKING SKILLS

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ABSTRACT

Students' 21st-century skills, particularly collaboration and creative thinking, remain underdeveloped. Previous studies have introduced the Collaborative Ethno-STEAM Enriched Project-Based Learning (CoE-STEAM-PjBL) model, but its implementation and effects in teacher education settings have not been thoroughly investigated. This study aims to analyze the impact of CoE-STEAM-PjBL on prospective science teachers' collaboration and creative thinking skills. Using a pre-experimental One-Shot Case Study design, the research was conducted at a teacher education institution. Data were collected through creative thinking tests and collaboration observation sheets. Learning was conducted using the CoE-STEAM-PjBL syntax with product-based projects rooted in local wisdom. The data were analyzed descriptively. Results showed that 29% of participants are highly creative, 48% are creative, and 23% are fairly creative. For collaboration, 17% were in the very good category, 58% good, and 25% moderate. The most prominent indicator of creative thinking was fluency, while social interdependence was dominant in collaboration. Thus, it can be concluded that the implementation of CoE-STEAM-PjBL has an impact on increasing collaboration and creative thinking of prospective teachers. This study contributes to the development of science education by providing empirical evidence on the integration of local wisdom and ethnoscience in STEAM-based project learning to enhance essential 21st-century skills among prospective teachers.

Keywords: collaboration; creative thinking; ethno-STEAM; project-based learning

INTRODUCTION

Teacher education institutions have a vital role in preparing future educators who are not only pedagogically competent but also equipped with essential 21st-century skills. These include creative thinking, collaboration, and problem-solving, which are increasingly relevant in responding to global challenges (Nakano & Wechsler, 2018) such as environmental degradation, technological disruption, and education inequality. These issues are closely linked to the Sustainable Development Goals, particularly Goal 4 on Quality Education, Goal 9 on Innovation, and Goal 12 on Responsible Consumption and Production.

Despite the growing importance of these competencies, studies show that many prospective teachers have not yet developed them adequately. Julianto et al. (2018) and Rahman et al.

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(2023) reveal that learning in many institutions still emphasizes memorization and single-answer thinking, which inhibits students' creative potential. Similarly, Firman et al. (2023), Hidayati (2019), and Mu'arifah et al. (2023) showed that collaboration is also rarely taught explicitly, making it difficult for students to work productively in teams. These problems are not limited to Indonesia. In Malaysia, for instance, Ismail et al. (2019) reported that many science teachers, including those in Chemistry, Physics, Biology, and Science, in Selangor, Kedah, Penang, and Johor, still face challenges in implementing STEM education effectively.

To address this issue, there has been a growing interest in integrating STEAM education (e.g., Liliawati et al., 2018; Yulianti et al., 2020) with local cultural wisdom. Sumarni et al. (2022) argue that culturally responsive STEAM learning optimizes local intelligence, wisdom, and excellence, as adopted by local communities. It has the potential to foster deeper engagement, contextual understanding, and creative problem-solving. The Project-Based Learning model is effective in this context, especially when designed around community-based projects that reflect local values. This is also supported by a review that highlights the advantage of PjBL, which can improve students' creative thinking (Sumarni, 2013; Wiyanto et al., 2020). Projects are also carried out in groups, so this learning model has the potential to improve collaboration skills. Again, previous research supports the idea that this model can enhance both creative thinking and collaboration (Guo et al., 2020; Ningsih et al., 2020; Permana et al., 2023; Sabrina & Jatmiko, 2025; Widiyono & Ghufron, 2024).

Creative thinking skills are an individual's mental process for generating new ideas, insights, approaches, perspectives, and solutions when facing a problem (Wijayati et al., 2019). Therefore, it is necessary to develop (Gu et al., 2023). Someone skilled in creative thinking has a faster and more effective way of finding solutions to problems. In addition to creative thinking, real-life problems can be successfully solved when they involve multiple parties with solid collaboration (Ayyildiz & Yilmaz, 2021; Avoyan, 2023). Collaboration skills are needed for all components of society to overcome problems (De Prada et al., 2022).

Unfortunately, these two important skills are considered underdeveloped because they are rarely trained and receive little attention at all levels of education. Important skills in the 21st century are very relevant to the four pillars of education: learning to know, learning to do, learning to be, and learning to live together. Each of these four principles contains specific skills that need to be empowered in learning activities, such as critical thinking and problem-solving, communication, collaboration, innovation, and creativity (Nambiar et al., 2019; Gu et al., 2023). Therefore, the learning process at Teacher Education Institutions must consider these elements (Abosalem, 2016).

Most studies to date have only explored limited classroom practices. There is still a lack of empirical research on how a combined approach, such as Collaborative Ethno-STEAM Enriched Project-Based Learning (CoE-STEAM-PjBL), works in real teacher education settings. This lack of implementation and testing indicates a clear gap in the literature, both in national and international contexts. Studies published in reputable journals have not yet focused on how this approach can be scaled or validated in broader teacher training programs.

This study aims to fill that gap by implementing CoE-STEAM-PjBL in a science teacher education program and analyzing its impact on prospective teachers' creative thinking and collaboration skills. The model includes learning projects such as chemical batik, leaf bone crafts, and eco-printing using local plants, providing both scientific grounding and cultural relevance.

This research has several contributions. First, it supports the advancement of SDG-related education by integrating science learning with local wisdom and 21st-century skills. Second, it offers empirical evidence that collaborative and culturally enriched project-based learning can significantly enhance creative thinking and teamwork among future teachers. Third, it provides a validated and applicable model for science teacher education institutions seeking innovative, locally grounded approaches to improve learning outcomes.

This study is designed to support and extend previous findings by offering practical implementation data. It contributes to the development of science education through an innovative pedagogical approach that bridges global educational goals with local educational realities.

METHODS

The method used should be accompanied by references, and the relevant modification should be clearly explained. The procedure and data analysis technique should be emphasized in a literature review article.

This study employs a pre-experimental design with a one-shot case study approach. This method was chosen because it aligns with the research objectives of analyzing creative thinking and collaboration skills after implementing CoE-STEAM-PjBL with prospective teachers at teacher education institutions. The CoE-STEAM-PjBL model was tested for validity and practicality before being implemented. The CoE-STEAM-PjBL was implemented in Applied Science courses in the chemistry education study program at teacher education institutions to test its effects. Learning took place over eight meetings. Creative thinking skills were assessed at the end of the learning process using a creative thinking skills essay test, which was declared valid by experts and subsequently tested. In comparison, collaborative observations were carried out during the project work.

The participants in this study were 90 prospective science teachers from a teacher education institution in Central Java, Indonesia, who were enrolled in Applied Science courses. There were also experts in STEM education and instructional design.

To collect data, researchers used qualitative and quantitative approaches. Data were collected through interviews, tests, observations, and Focus Group Discussions. The research instrument used was a creative thinking test developed in previous studies with an Aiken V value of 0.65.

To assess the impact of the CoE-STEAM-PjBL model on creative thinking skills, essay questions were used based on Torrance's creative thinking skill indicators: a) fluency, b) flexibility, c) Originality, and d) Elaboration. Before being tested, the test was first validated for content and construct by material and evaluation experts. After being declared valid, the test was piloted to assess the validity of the items and the reliability of the test questions. To assess the impact of the CoE-STEAM-PjBL model on collaboration skills, an observation sheet was used, which included a) introduction of new ideas, b) cooperation, c) conflict resolution, d) productive work, e) show respect, f) compromise, g) responsibility, h) social interdependence, adapting and modifying (Evans, 2020). Experts validated the observation sheet to assess the suitability of the statements in relation to collaboration skill indicators.

CoE-STEAM-PjBL was developed through research and development, which was validated by experts and tested to measure its practicality. The implementation of the model was designed as a pre-experimental study with the implementation of CoE-STEAM-PjBL on prospective teachers at Universitas Negeri Semarang, followed by an analysis of prospective chemistry teachers' collaboration and creative thinking skills.

The problem-solving approach in this study follows a sequence of stages, including initial coordination, implementation, evaluation, reflection, and final coordination. The following are the details of the problem-solving approach: (a) Coordination and discussion regarding the distribution of tasks and responsibilities between research teams for the implementation of CoE-STEAM-PjBL through Focus Group Discussion while finding agreement on the schedule, learning tools for CoE-STEAM-PjBL, research instruments, and ethno-STEAM products or projects created; (b) Implementation of CoE-STEAM-PjBL at Universitas Negeri Semarang according to schedule; (c) Evaluation of implementation results related to the learning process and prospective teachers' collaboration and creative thinking skills; (d) Reflection of activities based on evaluation results.

The data were analyzed descriptively using the percentage of creative thinking skills test scores and observation scores of students' collaboration skills. The scores were obtained based on the following calculations.

Score = Obtained Score / Maximum Score x 100

Students' creative thinking skill levels were calculated based on their scores. The criteria are listed in Table 1.

Table 1. Achievement Criteria of Creative Thinking and Collaboration Skills

Score	Criteria	
	Creative Thinking	**Collaboration**
81 – 100	Highly Creative	Very Good
61 – 80	Creative	Good
41 – 60	Fairly Creative	Moderate
21 – 40	Less Creative	Poor
0 – 20	Uncreative	Very Poor

RESULTS AND DISCUSSION

The CoE-STEAM-PjBL model combines problem-based projects with local cultural contexts or ethnoscience and STEAM knowledge. This model offers opportunities for prospective teachers, especially in science, to integrate science, technology, engineering, art, and mathematics with local wisdom, making learning more contextual and relevant to real life. The CoE-

STEAM-PjBL model is a learning approach that merges problem-based projects with local cultural or ethnoscience knowledge and STEAM. It provides prospective teacher students, particularly in chemistry, the opportunity to integrate scientific knowledge, technology, engineering, art, and mathematics with local wisdom, making learning more meaningful and applicable to real-world situations. The following explains the validity and practicality of the CoE-STEAM-PjBL model in enhancing the collaboration and creative thinking skills of prospective science teachers.

The validity of the CoE-STEAM-PjBL model was established through expert judgment involving three specialists in science education and ethno-STEAM. Their assessment confirmed that the model aligns well with expected learning outcomes and instructional design principles. The integration of ethnoscience into STEAM learning was considered a strength, as it creates a more contextualized and meaningful learning environment that connects theoretical knowledge with real-life cultural practices.

This model is built upon a strong theoretical foundation, particularly the constructivist learning paradigm, which emphasizes learning through direct experience and interaction with the surrounding environment. Ethno-STEAM adds another layer to this by linking scientific understanding with traditional knowledge systems that have long been practiced and valued within local communities. Such integration fosters a learning experience that is not only relevant and engaging but also reflective of students' cultural backgrounds.

To ensure its applicability in real classroom settings, the model was tested through a series of trials. These trials aimed to evaluate whether ethno-STEAM-based projects are feasible, relevant, and aligned with the goals of science education. Initial implementation in the classroom showed promising results. The model was well-received by both students and instructors, and its structure proved to be adaptable to various learning conditions.

Beyond validity, the practicality of the CoE-STEAM-PjBL model was also examined. Practicality here refers to how easily the model can be implemented using available resources and how effectively it functions in typical teaching environments. The findings suggest that the model is highly practical. It supports flexible learning arrangements through project-based activities that allow prospective teachers to engage in hands-on exploration, such as field studies, interviews with community members, and experiments using locally sourced materials.

Collaboration is an integral part of the model. Prospective teachers work together to complete real-world, problem-based projects. These collaborative efforts often extend beyond the classroom, involving interactions with the local community. This not only strengthens teamwork but also exposes students to diverse perspectives and lived experiences that enrich the learning process.

Moreover, the model offers a realistic context for learning chemistry. Prospective teachers have the opportunity to directly observe and apply chemical concepts in everyday life, bridging abstract scientific principles with cultural practices. These authentic experiences stimulate creative thinking, as students are challenged to find innovative solutions that are relevant to their cultural settings.

Field implementation revealed that the CoE-STEAM-PjBL model was positively received. Students demonstrated increased motivation and engagement, while lecturers reported a deeper understanding of scientific content among participants. Ethnoscience-based projects encouraged students to explore their cultural identity while simultaneously building essential scientific skills, showing the potential of this model to transform the way chemistry is taught in teacher education programs.

The CoE-STEAM-PjBL model in this study was implemented in applied science courses attended by 90 prospective teachers, divided into three classes. Learning was conducted in parallel according to the lecture schedule. CoE-STEAM-PjBL, especially in the learning sub-achievements of the Applied Science course in the fields of Agriculture, Plantations, and Forestry, was carried out through project assignments that included creating chemical batik with natural dyes, bioplastics, leaf bone crafts, and ecoprints. The chemical batik project, in addition to teaching about various compound structures, also addresses the issue of the extensive use of synthetic dyes by the textile industry, which has the potential to pollute the environment. The leaf bone craft project used abundant dry leaf waste around the campus. In contrast, ecoprints involved fresh leaves and flowers. Bioplastics were made from tapioca flour, and trees were widely planted around the campus.

The profile of collaboration skills based on data from the observation sheet is presented in Figures 1 and Table 1. It appears that the implemented CoE-STEAM PjBL can train students to be skilled at collaborating, as it is facilitated by group activities such as discussions, exploratory activities, inquiry-based learning, project completion, and presentations. In CoE-STEM PjBL, it is implemented by giving problems to students who collaboratively solve problems by producing products based on local wisdom. They submit the results of discussions or reports in groups (Putri et al., 2021).

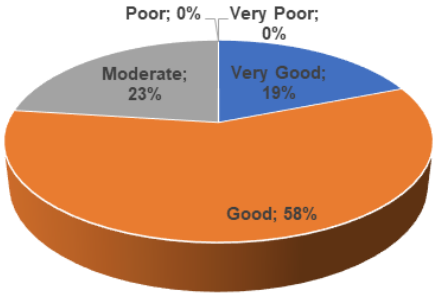

Figure 1. Profile of Prospective Teacher Collaboration Skills

When viewed, the average score for each aspect of collaboration skills is presented in Table 1.

Table 1. Average Score for Each Aspect of Collaboration Skills

No	Aspects	Average Score
1	Social Interdependence	4.3
2	Show respect	4.2
3	Responsibility	3.8
4	Communication	3.7
5	Compromise	3.6
6	Productive work	3.5
7	Introduction of new ideas	3.5
8	Cooperation/ Task division	3.4
9	Conflict resolution	2.5

The results showed an average score of 3.70 for the collaboration skills indicator. This score indicates that students' collaboration skills after implementing CoE-STEAM-PjBL are in a good category. This good collaboration ability may stem from the fact that in PjBL, each group is assigned to create a project, allowing students to discuss, exchange ideas, and collaborate with their peers on their assignments (Hidayat et al., 2020). The stages of creating ecoprint and batik writing projects are collaborative activities undertaken by students. The success of each group in completing a project is closely tied to the discovery of solutions to the problems they face together. For example, when creating an ecoprint project with the theme of alkaloid compounds, students discuss and study literature to choose leaves or flowers that contain alkaloid compounds for medicinal purposes (Science). In addition, student groups also discuss determining the tools used (technology), seeking information, and testing techniques to obtain good leaf/flower traces that do not fade easily (engineering). To obtain a good leaf/flower trace appearance, student groups creatively design and select leaves/flowers/twigs, and arrange them well on the cloth. Student groups also choose a combination of fabric colors with natural dyes (Art). From a mathematical perspective, the student group performs calculations to determine the composition of the dye and water used, the optimum time to produce the dye, the optimum steaming time to obtain good leaf/flower traces, and the concentration of mordant, alum, and lime solutions for fixation.

According to Table 1, social interdependence is the highest indicator of student achievement after implementing CoE-STEAM-PjBL. This result is inextricably linked to several contributing factors. Project learning involves solving complex problems that individuals cannot solve alone. In the context of ethnoscience, these problems are often tied to local issues or challenges that are relevant to the community. These problems motivate students to support each other, share information, and develop strategies to solve them. This condition indirectly triggers students' collaboration, interdependence, responsibility, and active participation.

The integration of the STEM approach in learning allows students to share knowledge, experience, responsibility, and creativity in solving problems (Triana et al., 2020). In CoE-STEM PjbL learning, teachers create conditions for students to collaboratively discuss and exchange opinions and provide the right learning environment in exploring and encouraging investigative attitudes (Guo et al., 2020; Hairida et al., 2021), such as teachers facilitating students to be more active and build their own understanding based on experiences during group activities. The problems assigned to each group are also more complex, requiring intensive group work to find solutions to existing problems. This can build trust in group members, so that they can provide new experiences for each group member and have tolerance for the ideas and thoughts of group members (Fajra & Novalinda, 2020)

Collaboration skills on this indicator contribute to making decisions for common goals, resulting in an increase in the N-gain score and value. The problems solved in discussion activities may be more complex and always related to science, technology, engineering, and mathematics. This demonstrates that the implementation of CoE-STEAM PjBL offers students opportunities to explore knowledge through group activities, where group members exchange ideas and assist one another in solving the given problems (Chen et al., 2019; Hanif et al., 2019). In addition, this model enables more intensive interaction between students, teachers, and learning resources. This rarely happens in conventional classes.

By design, CoE-STEAM-PjBL is an ethno-STEAM-based project that involves students in tasks requiring them to work in groups. In this process, each group member plays a crucial role, feels involved, and is interdependent in achieving common goals (Muliadi et al., 2025). The lecturer's facilities in this situation encourage students to communicate more actively, share ideas, and solve problems collaboratively (Engeness, 2020). In CoE-STEAM-PjBL, positive interdependence occurs when students realize that the project's success depends on each member's contribution. This statement follows Johnson and Johnson (2018), who suggest that this positive dependency increases the sense of responsibility because students realize their actions will affect the group's final results. Project-based learning that integrates ethnoscience enhances conceptual understanding, fosters collaborative skills, and is relevant to students' lives (Rahayu et al., 2023). Another contributing factor is the ethno-STEM content. This project allows students to explore, appreciate, and apply local wisdom in learning. This follows the findings that PjBL can improve collaboration skills. Students become more open to different perspectives and ideas, enriching discussions and group collaboration (Andriyatno et al., 2024). During project learning, students are invited to understand and appreciate the cultural and social context in which local science knowledge is developed. This activity enhances social and communication skills, fostering empathy and appreciation for local values. Students learn to work with people from diverse cultural backgrounds, strengthening mutual respect and cooperation.

Participation in ethnoscience projects also fosters stronger emotional bonds between students, as they feel the project is relevant to their real lives. A stronger group identity increases social interdependence because they work for academic grades and a greater purpose (Sulistyowati et al., 2020). These factors place students' social interdependence in the high category when ethno-STEM-based project learning is applied, as they learn to depend on each other in a meaningful and relevant context that relates to their culture and life.

According to Table 1, conflict resolution is the lowest indicator that students achieve after implementing CoE-STEAM-PjBL. Conflict resolution is the process of resolving disputes or differences of opinion constructively to achieve a solution that is fair and mutually satisfactory to all parties involved. Several studies support this result (Smith et al., 2005; Johnson & Johnson, 2018). Conflict resolution, or the ability to resolve conflicts, is often lower than other collaboration indicators in collaborative learning due to several factors.

Students generally lack the specific skills to resolve conflicts effectively in groups. Often, they are more focused on academic tasks than on developing interpersonal skills, such as mediation, negotiation, and conflict resolution.

In collaborative learning, poor communication can lead to conflict, while effective conflict resolution requires open and honest communication. Students who are not accustomed to assertive communication or are uncomfortable expressing their disagreements tend to avoid conflict rather than resolve it. In groups, there are often members who are more dominant and make other members feel intimidated or uncomfortable expressing their opinions. This dominance leads to unresolved or avoided conflicts, resulting in less developed conflict resolution skills compared to other collaboration indicators.

Students are not typically taught how to manage conflict directly in collaborative learning settings. Most learning models emphasize the achievement of group tasks or objectives rather than how groups manage conflict during the process (Kreijns et al., 2002). In some cultures, students tend to avoid conflict to maintain group harmony. They prefer to give in or avoid discussions that trigger tension. As a result, conflicts are not resolved constructively but are suppressed, resulting in the lack of skill development in this aspect (Buchs & Butera, 2015). Lecturers often fail to provide sufficient attention or guidance on resolving group conflicts. Their focus is more on the project's result than the group's dynamic processes, including how students resolve conflicts or differences of opinion. Most students come from diverse backgrounds, values, and perspectives, which can lead to conflict. However, conflict tends to be ignored or resolved ineffectively without training or learning how to understand and work through these differences. Conflict resolution requires time for reflection, discussion, and deep understanding. In collaborative learning, students are often under pressure to meet project deadlines, so they tend to focus more on completing tasks than resolving conflicts effectively.

Effective communication and understanding between group members is lacking, especially during online learning. These conflicts are often overlooked and not handled properly (Donelan & Kear, 2024). Direct interventions, such as conflict resolution training, improved lecturer guidance, and an emphasis on effective group communication, are needed to enhance these skills (Azeharie et al., 2024). The conflict resolution is still low compared to other indicators of collaboration skills, indicating that in working together to solve problems, students are not yet optimal in building better relationships. This is understandable, because this skill must emerge from each student's personality, where students are not yet accustomed to building good relationships with everyone, not just avoiding or suppressing conflict. The development of conflict resolution skills requires habituation, which takes a relatively long time and must always be instilled by teachers through the learning process (Yulianti & Anjani, 2019).

To improve these skills, direct interventions are needed, such as conflict resolution training, better facilitation by teachers, and an emphasis on the importance of effective communication in groups (Azeharie et al., 2024). To minimize conflict resolution issues in collaboration, several solutions can be offered, including:

(1) Avoid harmful debates: Unresolved conflicts can damage collaborative relationships and hinder the achievement of common goals.

(2) Create a safe environment: A collaborative approach to conflict resolution emphasizes mutual respect, openness, and empathy, ensuring all parties feel comfortable sharing their opinions.

(3) Focus on shared interests: Solutions in conflict resolution should consider the needs and interests of all parties involved, not just select individuals or groups.

(4) Build trust: An effective conflict resolution process can enhance trust among team members and strengthen collaborative bonds.

(5) Improve relationships: Constructive conflict resolution helps repair damaged relationships and fosters stronger ones in the future.

Thus, conflict resolution in collaboration is not just about solving problems, but also about building stronger relationships, improving cooperation, and achieving common goals more effectively.

Data on creative thinking skills were measured after the implementation of CoE-STEAM-PjBL. The average score data for the creative thinking skills profile are presented in Figure 2 and Table 2.

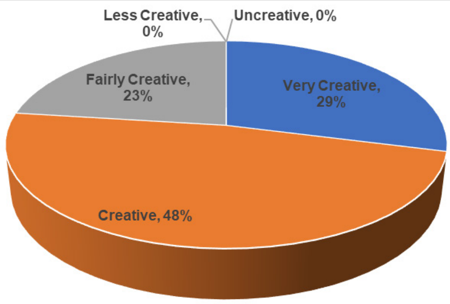

Figure 2. Profile of Prospective Science Teachers' Creative Thinking Skills

Figure 2 shows that students' average creative thinking skills profile is generally in the creative category, with none falling into the less creative or uncreative categories. However, there are many students in the fairly creative category. Table 2 shows the results reviewed for each indicator of creative thinking. When viewed from each indicator of creative thinking, the results are as presented in Table 2.

Table 2. Average Score for Creative Thinking Skills Indicators

No	Aspects	Average Score
1	Fluency	3.8
2	Elaboration	3.6
3	Originality	3.5
4	Flexibility	2.5

According to Table 2, fluency is the highest indicator that students achieve after implementing CoE-STEAM-PjBL. In implementing ethnoscience-integrated project learning, creative thinking skills, especially fluency, often achieve the highest category compared to other indicators. This achievement is possible because students are stimulated to generate many ideas in a context that supports and motivates them culturally and socially.

Ethnoscience-integrated learning encourages students to explore diverse local knowledge and practices (Beghetto & Kaufman, 2014). This knowledge comes not only from textbooks but also from direct observation, interviews with local figures, and cultural exploration. These activities enrich students with numerous ideas that can be developed, thereby increasing their fluency in creative thinking and the ability to generate multiple ideas or solutions (Fontes & Rodrigues, 2025). Additionally, ethnoscience-based projects offer a context that is both relevant and close to students' daily lives. This relevance motivates students to put forward as many ideas as possible because they feel more connected and interested in the learning material. When students feel an emotional or personal connection to the project, they find it easier to express many ideas spontaneously. Ethnoscience project learning typically provides students with more space to explore their ideas without many restrictions (Hanif et al., 2019). The stimulation of more fluent idea production (fluency) is triggered by students continuously being exposed to diverse ways of thinking and perspectives, which broaden their horizons and enrich their ideas.

Ethnoscience learning often employs contextual and problem-based approaches that prompt students to think critically and respond to real-world situations (Hidayati & Julianto, 2025). Because ethnoscience combines elements of familiar cultures and traditions, students tend to generate many ideas more easily and quickly, especially in the early stages of creative thinking. In ethnoscience projects, the support of a collaborative and supportive learning environment enables students to express a broader range of ideas more comfortably. Support from classmates and teachers who appreciate every idea strengthens fluency because students feel their ideas are accepted and appreciated.

In-depth interviews with five participants revealed varying approaches to creative thinking regarding the problems faced. Although most admitted to having a limited understanding, some students were able to convey more than one idea in solving the problem (flexibility) and expressed it clearly, coherently, and completely (fluency), as well as in detail (elaboration). For example, when presented with synthetic dyes in batik, students fluently explained several acid dyes that batik artisans commonly use because they provide bright, long-lasting colors, do not fade quickly, are readily available, and are affordable. The following are examples of several student interview transcripts.

Q1: What do you think about the change in the color of your well water due to the batik industry waste around your residence? What solutions can you offer to minimize water pollution?

A1: The discoloration of well water is likely due to the infiltration of textile dyes into soil pores. Every textile industry should have an effective wastewater treatment plant to treat waste before it is discharged into the waters.

A2: Bioreactors, anaerobic treatment systems, or phytoremediation can be used to reduce pollutants in waste.

A3: Textile industry owners and the community must be trained to process waste and use environmentally friendly chemicals.

A4: Engage the public or involve local communities in monitoring and reporting water pollution and providing solutions tailored to local needs.

Participants flexibly conveyed the negative environmental impacts of a large amount of unmanaged batik dye waste. Several participants shared their creative ideas about natural dyes derived from plants in the surrounding area, including turmeric, mango leaves, mangosteen peel, mahogany bark, and others.

Q2: However, the rapidly growing batik industry must be preserved. Share your ideas to help the batik industry remain sustainable while minimizing environmental pollution.

A5: Replacing synthetic dyes with natural dyes, such as leaves, flowers, and bark.

A6: Increasing the efficiency of fuel, dye, and water use in the batik production process to reduce waste.

A7: Reducing the use of water and synthetic chemicals and developing technology to increase natural dyes' durability and color variation.

In addition, several respondents demonstrated knowledge of cultural practices that reflect local wisdom related to ceramic making, such as the tradition of making bricks, pottery, and roof tiles, which are widely associated with colloidal chemistry. Respondents also agreed on integrating local wisdom in creating contextual learning.

Table 2 displays that elaboration is the lowest creative thinking skill indicator students achieve after implementing CoE-STEAM-PjBL. Elaboration often falls into the lowest category because students focus more on exploring and developing ideas rather than deepening and refining the details of existing ideas. There are several other causes for the low elaboration aspect. Students tend to focus more on exploring initial ideas (fluency) rather than developing them further (elaboration) (Frenzel et al., 2021). In CoE-STEAM-PjBL, students are encouraged to generate numerous ideas by exploring local culture (fluency) or creating new, unique concepts (originality). As a result, attention to further development or detailing these ideas becomes less because they consider the initial phase more (Runco & Acar, 2012).

Elaboration requires more time and effort to develop and elaborate ideas into more detail and structure. In learning, students often face deadlines, causing them to focus more on completing the primary assignment rather than refining or elaborating on their ideas (Beghetto & Kaufman, 2014; Treffinger et al., 2023). Learning also tends to emphasize cultural exploration and the introduction of unique local concepts (Meyer & Crawford, 2011; Ernawati et al., 2024). Lecturers do not provide sufficient facilities to elaborate on ideas in more detail. Students are also less skilled in developing in-depth ideas due to a lack of understanding or specific training in elaborating them, especially if the project learning syntax has a structure that directs students to follow a particular flow or procedure. This structure can limit further development or detailing of ideas because students feel they must follow specific rules in the project.

Fluency and originality are more appreciated because they are easier to see and assess in projects. Elaboration involves developing existing ideas into more complex and structured ones, often hidden in the creative process and receiving less attention. Project-based learning tends to focus on the more open and unrestricted aspects of ideas (fluency and originality) but often fails to deepen and develop ideas into more complex ones (elaboration) (Jaber & Hammer, 2016).

CONCLUSION

This study concludes that the implementation of Collaborative Ethno-STEAM Enriched Project-Based Learning (CoE-STEAM-PjBL) effectively enhances prospective chemistry teachers' collaboration and creative thinking skills. By engaging in team-based projects rooted in local culture, students learn to communicate, negotiate, and solve problems together, thereby strengthening their capacity for meaningful collaboration. The involvement of local communities further enriches the process, encouraging cross-cultural dialogue and expanding students' social perspectives. Ethno-STEAM, as integrated in this model, also plays a critical role in fostering creativity. Exposure to traditional knowledge and local practices inspires students to generate original ideas and explore alternative solutions by connecting scientific concepts with culturally embedded experiences. This not only improves the fluency and flexibility of their thinking but also nurtures a deeper appreciation for the relevance of science in everyday life. The findings of this research contribute to the development of science education by offering a pedagogical model that aligns with the goals of culturally responsive teaching and the demands of 21st-century skills. This model provides a concrete example of how science learning can be transformed through the integration of local wisdom, making it more inclusive, engaging, and socially relevant.

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REFERENCES

Abosalem, Y. (2016). Assessment techniques and students' higher-order thinking skills. *International Journal of Secondary Education*, *4*(1), 1.

Andriyatno, I., Purwianingsih, W., Solihat, R., Gusti, U. A., & Yusni, D. (2024). Improving students' collaboration skills through project-based learning on environmental change material. *The Eurasia Proceedings of Educational and Social Sciences*, 71–79.

Avoyan, E. (2023). Collaborative Governance for Innovative Environmental Solutions: Qualitative Comparative Analysis of Cases from Around the World. *Environmental Management*, *71*(3), 670–684.

Ayyildiz, P., & Yilmaz, A. (2021). 'Moving the Kaleidoscope' to see the effect of creative personality traits on creative thinking dispositions of preservice teachers: The mediating effect of creative learning environments and teachers' creativity fostering behavior. *Thinking Skills and Creativity*, *41*, 100879.

Azeharie, S., Sari, W. P., & Yoedtadi, M. G. (2024). Women in Conflict Communication Perspective (Case Study of the Role of Women in Maintaining Harmony in Manado). *Jurnal Komunikasi*, *16*(1), 288–299.

Beghetto, R. A., & Kaufman, J. C. (2014). Classroom contexts for creativity. *High Ability Studies*, *25*(1), 53–69.

Buchs, C., & Butera, F. (2015). Cooperative learning and social skills development. In *Collaborative Learning: Developments in Research and Practice* (pp. 201–217).

Chen, L., Yoshimatsu, N., Goda, Y., Okubo, F., Taniguchi, Y., Oi, M., Konomi, S., Shimada, A., Ogata, H., & Yamada, M. (2019). Direction of collaborative problem solving-based STEM learning by learning analytics approach. *Research and Practice in Technology Enhanced Learning*, *14*(1), 24.

De Prada, E., Mareque, M., & Pino-Juste, M. (2022). Teamwork skills in higher education: Is university training contributing to their mastery? *Psicologia: Reflexão e Crítica*, *35*(1), 5.

Donelan, H.& Kear, K.(2024). Online group projects in higher education: persistent challenges and implications for practice. *J Comput High Educ* **36**, 435–468.

Engeness, I. (2020). Teacher facilitating of group learning in science with digital technology and insights into students' agency in learning to learn. *Research in Science & Technological Education*, *38*(1), 42–62.

Ernawati, T., Rosana, D., Atun, S., & . S. (2024). Exploration of Culturally Responsive Teaching and Problem-Based Learning in The Diverse Learning of Prospective Science Teachers. *International Journal of Religion*, *5*(3), 353–365.

Evans, C. (2020). *Measuring student success skills: A review of the literature on collaboration*. National Center for the Improvement of Educational Assessment.

Fajra, M., & Novalinda, R. (2020). Project Based Learning: Innovation to improve the suitability of productive competencies in vocational high schools with the needs of the world of work. *International Journal Of Multi Science, 1*(08), 1-11.

Firman, Syamsiara Nur, & Moh. Aldi SL.Taim. (2023). Analysis of Student Collaboration Skills in Biology Learning. *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi*, 82–89.

Fontes, D. T. M., & Rodrigues, A. M. (2025). Science education collaboration network: The case of the cultural-historical activity theory. *Science & Education*, *34*(1), 609–629.

Frenzel, A. C.; Daniels, L.& Burić, I. (2021). Teacher emotions in the classroom and their implications for students. *Educational Psychologist*, *56*(4), 250–264.

Gu, X., Tong, D., Shi, P., Zou, Y., Yuan, H., Chen, C., & Zhao, G. (2023). Incorporating STEAM activities into creativity training in higher education. *Thinking Skills and Creativity*, *50*, 101395.

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*, 101586.

Hairida, H., Marmawi, M., & Kartono, K. (2021). An Analysis of Students' Collaboration Skills in Science Learning Through Inquiry and Project-Based Learning. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *6*(2), 219–228.

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. *Journal of Science Learning*, *2*(2), 50.

Hidayat, R. Y., Hendayana, S., Supriatna, A., & Setiaji, B. (2020). Identification of student's collaborative skills through learning sharing and jumping task on the topic of redox reactions. *Journal of Physics: Conference Series*, *1521*(4), 042056.

Hidayati, F., & Julianto, J. (2025). Integrasi pendekatan etnosains dalam pembelajaran sains untuk meningkatkan keterampilan berpikir kritis siswa. *DIDAKTIKA : Jurnal Pemikiran Pendidikan*, *31*(1), 101.

Hidayati, N. (2019). Collaboration Skill of Biology Students at Universitas Islam Riau, Indonesia. *International Journal of Scientific & Technology Research*, *8*(11), 208-211.

Ismail, M. H. B., Salleh, M. F. M., & Nasir, N. A. M. (2019). The Issues and Challenges in Empowering STEM on Science Teachers in Malaysian Secondary Schools. *International Journal of Academic Research in Business and Social Sciences*, *9*(13), Pages 430-444.

Jaber, L. Z., & Hammer, D. (2016). Learning to Feel Like a Scientist. *Science Education*, *100*(2), 189–220.

Johnson, D. W., & Johnson, R. T. (2018). Cooperative learning: The foundation for active learning. In S. Manuel Brito (Ed.), *Active learning—Beyond the future*. IntechOpen.

Julianto, J., Wasis, W., & Agustini, R. (2018). Profil keterampilan berpikir kreativitas mahasiswa jurusan PGSD FIP Unesa di mata kuliah konsep dasar IPA. *Jurnal Pendidikan Dasar*, *2*(1), 10–15.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2002). The Sociability of Computer-Supported Collaborative Learning Environment. *Educational Technology & Society*, *5*(1), 8–22.

Liliawati, W., Rusnayati, H., Purwanto, & Aristantia, G. (2018). Implementation of STEAM Education to Improve Mastery Concept. *IOP Conference Series: Materials Science and Engineering*, *288*, 012148.

Meyer, X., & Crawford, B. A. (2011). Teaching science as a cultural way of knowing: Merging authentic inquiry, nature of science, and multicultural strategies. *Cultural Studies of Science Education*, *6*(3), 525–547.

Mu'arifah, H., Citraning, R., & Mukaromah, S. (2023). Peningkatan Keterampilan Kolaborasi Siswa dengan Metode TTS (Tutor Teman Sebaya) pada Mata Pelajaran Biologi. *Jurnal Pendidikan Guru Profesional*, *1*(1), 69–72.

Muliadi, A., Rokhmat, J., & Sukarso, Aa. (2025). Ethnoscience integrated project-based learning model for enhancing students' creative thinking skills and cultural literacy: Expert perspectives and preliminary testing. *International Journal of Innovative Research and Scientific Studies*, *8*(3), 3676–3685.

Nakano, T. D. C., & Wechsler, S. M. (2018). Creativity and innovation: Skills for the 21st century. *Estudos de Psicologia (Campinas)*, *35*(3), 237–246.

Nambiar, D., Karki, S., Rahardiani, D., & Singh, K. (2019). *Study on skills for the future in Indonesia*. Oxford Policy Management.

Ningsih, S. R., Disman, D., Ahman, E., Suwatno, S., & Riswanto, A. (2020). Effectiveness of Using the Project-Based Learning Model in Improving Creative-Thinking Ability. *Universal Journal of Educational Research*, *8*(4), 1628–1635.

Permana, N. D., Lestari, I., Susanty Harahap, F. D., Azhar, A., & Defianti, A. (2023). Project Based Learning (PjBL) Model with STEAM Approach: Its Impact on Students Creative Thinking Skills on Energy in Living System Topic. *Journal of Natural Science and Integration*, *6*(2), 186.

Putri, R. K., Bukit, N., & Simanjuntak, M. P. (2021). *The Effect of Project Based Learning Model's on Critical Thinking Skills, Creative Thinking Skills, Collaboration Skills, & Communication Skills (4C) Physics in Senior High School:* 6th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2021), Medan, Indonesia.

Rahayu, R., Sutikno, & Indriyanti, D. R. (2023). An ethnosains based project based learning model with flipped classroom on creative thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 348–355.

Rahman, N., Nizaar, M., & Sabaryati, J. (2023). Profil keterampilan berpikir kreatif mahasiswa dan upaya peningkatannya melalui model project based learning. *Pendekar : Jurnal Pendidikan Berkarakter*, *6*(2), 162–166.

Runco, M. A., & Acar, S. (2012). Divergent Thinking as an Indicator of Creative Potential. *Creativity Research Journal*, *24*(1), 66–75.

Sabrina, N. M. N., & Jatmiko, B. (2025). Implementation of PJBL-Based Worksheet with a STEAM Approach to Improve High School Students' Creative Thinking Abilities: A Synthesis of Empirical Insights. *Journal of Digitalization in Physics Education*, *1*(1), 38997.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, *94*(1), 87–101.

Sulistyowati, S., Reffiane, F., & Handayani, D. E. (2020). Pengaruh model pembelajaran project based learning berbasis etnosains tema ekosistem terhadap aktivitas belajar siswa. *Jurnal Pendidikan Surya Edukasi (JPSE)*, *6*(2), 120–132.

Sumarni, W. (2013). The Strengths and weaknesses of the implementation of project based learning: A review. *International Journal of Science and Research (IJSR)*, *4*(3), 478–484.

Sumarni, W., Rumpaka, D. S., Wardani, S., & Sumarti, S. S. (2022). STEM-PBL-Local Culture: Can It Improve Prospective Teachers' Problem-solving and Creative Thinking Skills? *Journal of Innovation in Educational and Cultural Research*, *3*(2), 70–79.

Treffinger, D. J., Isaksen, S. G., & Stead-Dorval, K. B. (2023). *Creative problem solving: An introduction*. Routledge.

Triana, D., Anggraito, Y. U., & Ridlo, S. (2020). Effectiveness environmental change learning tools based on STEM-PjBL towards students' collaboration and communications skills. *Journal of Innovative Science Education*, *9*(3), 244–249.

Widiyono, A., & Ghufron, A. (2024). Improving Creative Thinking Skills Through the PjBL-STEM Model assisted by LKPD Life Cycle Diology. *Jurnal Pendidikan Dan Pengajaran*, *57*(3), 532–541.

Wijayati, N., Sumarni, W., & Supanti, S. (2019). Improving Student Creative Thinking Skills Through Project Based Learning. *KnE Social Sciences*.

Wiyanto, Sumarni, W., & Sekarini, A. P. (2020). Review of learning strategies to improve creative thinking skills. *Journal of Physics: Conference Series*, *1567*(4), 042050.

Yulianti, D., & Anjani, D. (2019). Implementing physical learning based on momentum and impulse Stem materials to develop collaboration skills. *Jurnal Ilmu Pendidikan*, *25*(1), 27.

Yulianti, D., Wiyanto, Rusilowati, A., & Nugroho, S. E. (2020). Student worksheets based on Science, Technology, Engineering and Mathematics (STEM) to facilitate the development of critical and creative thinking skills. *Journal of Physics: Conference Series*, *1567*(2), 022068.