





Perceptions, Barriers, and Possibilities: Exploring Creativity in Science Pre-Service Teacher Education

Diniya ^{1,2}, Muslim ^{1,*}, Rika Rafikah Agustin ¹, and Rini Solihat ¹

¹ Universitas Pendidikan Indonesia, Bandung, Indonesia

² Universitas Islam Negeri Sultan Syarif Kasim Riau, Pekanbaru, Indonesia

Email: diniya@upi.edu (D.); muslim@upi.edu (M.); rafikahrika@upi.edu (R.R.A.); rinisolihat@upi.edu (R.S.)

*Corresponding author

Manuscript received November 12, 2025; accepted January 8, 2026; published May 26, 2026.

Abstract—Creativity, widely recognized as one of the most critical 21st-century skills indispensable for navigating uncertainty and complexity, is vital to nurture within higher education systems in developing countries like Indonesia to equip students with the skills needed to thrive in future work environments. This study examines the understanding of creativity definition among Science Pre-Service Teachers (SPST) in Indonesia and explores the challenges they encounter in developing creative skills during their higher education. The research used an online questionnaire to collect data on SPST's understanding of creativity, their engagement in creative tasks, and the obstacles they faced. The findings reveal that while a significant number of students have yet to produce creative works, those who have done so acknowledge the substantial value of creativity in their tasks. Key barriers to creativity include insufficient resources, limited practical experience, and difficulties in generating innovative ideas. Additionally, students emphasized the importance of a supportive learning environment, collaborative opportunities, and adequate facilities as essential for fostering creativity. The results highlight the urgent need for educational interventions that promote creativity, equipping SPST with the necessary tools and opportunities to enhance their creative abilities. This study contributes to the broader understanding of how creativity can be effectively integrated into science education, preparing future educators to address the challenges of the 21st century.

Keywords—creativity, science pre-service teacher, higher education

I. INTRODUCTION

As one study reported, there are seven skills needed in the 21st century: critical thinking, creativity, collaboration, cross-cultural understanding, communication, computing, and career-dependent self-learning [1–4]. Creativity has been considered one of the most important thinking skills in the 21st century [5]. In a post-millennial society, creativity is regarded as highly important for both individuals and society [6]. This is especially true in developing countries, including Indonesia, where fostering creativity is crucial [7]. Creativity is a vital skill as it enables individuals to thrive and adapt to uncertainty [8]. Creativity is vital for individuals for the future of work [6]. Creativity is the top skill of the future and a required life skill in the world of work. The world of work also requires employees who are innovative, creative, initiative, independent, can lead, work in teams, are literate, able to communicate effectively, and able to make decisions and overcome various problems [1, 7]. Creativity is a skill that must be learned by individuals to prepare themselves to face and survive with uncertainty in the present and future both in society and in the work environment.

Higher education is widely recognized for its primary role

in preparing individuals to enter the workforce [9–11]. Educators and researchers emphasize the relevance of fostering creativity in higher education, as it is a critical skill for navigating the complexities of the modern world [12]. In today's rapidly changing and unpredictable times, creativity has become an essential attribute that universities must cultivate to ensure their graduates are work-ready and adaptable [6]. The demands of 21st-century learning require universities to produce graduates who possess not only creativity but also the ability to engage in creative and collaborative processes to solve problems effectively [13, 14].

Higher education play a pivotal role in equipping students with the skills and knowledge needed to thrive as future educators and active contributors to their communities [11, 15]. One of the key strategies to nurture creativity in higher education is through innovative teaching practices. In the context of 21st-century learning, creativity is regarded as a fundamental skill that must be intentionally taught and integrated into curricula [16]. Achieving this creativity should be given significant attention by incorporating it into new teaching methodologies and actively applying it during instruction in higher education [17]. Furthermore, 21st-century skills, including creativity, must be seamlessly integrated into higher education to prepare students for the multifaceted challenges they will face in their professional lives [4, 18].

In Indonesia, creativity is recognized as a crucial skill that must be cultivated in higher education. This is supported by the Minister of Education and Culture Regulation Number 3 of 2020 concerning National Higher Education Standards, which highlights the importance of student-centered learning that fosters creativity, capacity, and independence in acquiring knowledge [19]. Similarly, the Regulation of the Minister of National Education of the Republic of Indonesia Number 16 of 2007 concerning Standards for Academic Qualifications and Teacher Competencies emphasizes that teachers must possess competencies, including the ability to be creative and innovative in applying and developing knowledge. Therefore, integrating creativity into higher education is essential to prepare future teachers who are equipped with creative abilities. In line with these regulations, educational researchers in higher education continue to explore techniques to optimize success and produce creative graduates. These graduates are expected to provide innovative solutions, think broadly, and positively impact society [20]. The incorporation of creativity into learning is vital because it significantly enhances problem-solving and critical thinking skills [21, 22]. Creativity is defined as the

ability to generate, utilize, refine, analyze, and evaluate a wide range of ideas and solutions that are novel, original, or surprising [23].

As facilitators, educators are responsible for unlocking students' potential by providing learning opportunities that nurture creativity. This can be achieved through learner choice, encouraging risk-taking, and developing problem-solving skills [24]. To effectively foster creativity, the learning process must be carefully planned and sustained, as creativity is closely linked to critical thinking skills [25]. For creativity to hold meaningful value in education, it must be grounded in disciplinary knowledge [26]. Additionally, technology-rich learning environments appear to offer structured opportunities for learners to explore questions of personal interest, which are central to creativity [27]. Therefore, there is a need for teaching approaches in higher education that can cultivate the creativity of prospective science teachers during their studies. However, before developing such a program, preliminary research is essential. This initial research should focus on understanding science preservice teachers' conceptualization of creativity and their experiences related to creativity during their college education.

Research on this aspect can provide insight into the extent to which SPST have creative abilities, what are the obstacles they face, and the best methods to enhance their creativity. Identifying pre-service teachers' understanding and experiences is crucial for designing both broad curricula and specific course programs that are effective, focusing not only on content mastery but also on the development of creative skills. Therefore, this study aims to explore the extent to which SPST already have experiences in developing creativity and identify barriers faced by prospective teachers in developing creativity and effective methods to enhance their creativity. By understanding this, it is hoped that future research can design more effective curriculum and course programs for prospective science teachers, so that they can equip students with the creativity needed in the 21st century.

II. LITERATURE REVIEW

Creativity is one of the life skills that can help individuals to thrive and cope with uncertainty [8]. In a post-millennial society, creativity is considered to be vital to individuals and society, valuable to the economy, essential to leadership and vital to the future of work. In these unprecedented times, creativity is a critical attribute that universities must possess to ensure work-ready graduates [6]. Creativity is very important to foster to overcome various problems especially in developing countries. Creativity should be given real attention by including it in new teaching methods and using it during teaching in higher education [28]. Educational researchers in higher education continue to seek an understanding of techniques to optimize success and produce creative graduates. In the future, creative graduates are expected to provide solutions and be broad-minded so that they have a positive impact on society [19].

In general, creativity is defined as an individual's capacity to generate new, original, or surprising ideas and solutions [29]. A creative person has the ability to turn ordinary things into extraordinary [30]. Creativity can also be defined as a set of methods used to become a creative

person [31, 32]. Creativity can also be defined as a skill that makes it possible for individuals to find new opportunities, improve creative thinking skills and accurately assess creativity from an idea [33]. Creativity can be viewed as the production of interesting ideas and valuable solutions to problems [34, 35]. However, creativity can also mean using, creating, improving, analyzing, and evaluating different ideas [23].

Definitions of creativity vary widely depending on one's perspective, scientific field, disciplinary affiliation, and philosophy. From a historical perspective, creativity is likened to a province consisting of several unique individuals endowed with unusual human capacities and intellectual abilities [32]. From a social context perspective, creativity most often emerges when there are conditions that are supportive and conducive to creative action. This is because environment and culture influence the way a person perceives ideas and how to turn those ideas into something brilliant [30, 36]. People living in different cultures, social norms and living standards have different perceptions of creativity [37].

In the field of science education, creativity is a central aspect that can determine the nature of science itself [38]. For learners to be creative, it requires educators who also have the ability to help individuals become creative quickly [30, 39]. Creativity is one of the basic elements of the nature of scientific knowledge [40]. The special domain of creativity in science learning is called scientific creativity [41, 42].

Scientific creativity is a problem-solving process that involves both domain-general and domain-specific skills and knowledge. Scientific creativity depends not only on knowledge, but also on cognitive processes that are the basic tools in scientific discovery [43]. In commonly used knowledge hierarchies such as Bloom's taxonomy, creating is considered the highest cognitive level that learners can perform beyond other types of cognition such as remembering, understanding, applying, and analyzing [44]. Creativity can be shown in the form of performance. Creative performance can be demonstrated in various modalities, including verbal (e.g., written, oral), physical (drawing, photography), and spatial (movement, procedure) [45].

Other research suggests that creativity can also be in the form of products. Scientific creativity as an intellectual trait or ability to produce (or potentially produce) a specific product that is original and has a certain value, designed with a specific purpose and using given information [40]. Creative thinking, often defined as the ability to generate innovative ideas and solutions by breaking away from conventional thought patterns, has become the cornerstone of success in various aspects of life [46]. Scientific creativity is a review of creativity that focuses on scientific knowledge about science, so the development of scientific creativity tests in the context of specific science materials is also very necessary [47].

A scientific creativity model is called The Scientific Structure Creativity Model (SSCM), which is a combination of trait or creativity characteristics, process or creative process, and product or creative product [40]. The characteristics of creativity refer to the Torrance (1990) creativity framework, namely fluency, flexibility, and originality. Creative products can be divided into science problems, science phenomena, science knowledge, and

technical products while the creative process can be divided into two namely thinking and imagination. The illustration of SSCM is depicted in Fig. 1 below.

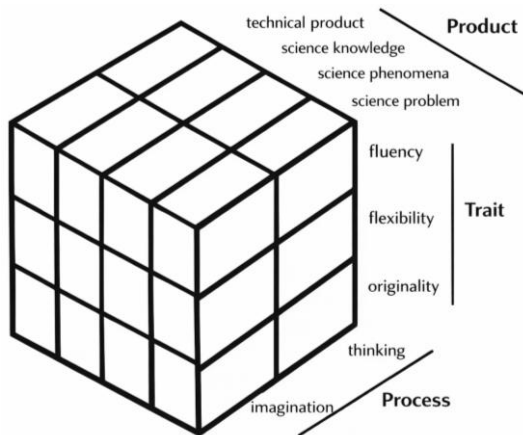


Fig. 1. SSCM illustration.

The indicators of scientific creativity include unusual uses, problem finding, product improvement, creative imagination, problem solving, science experiment and product design. However, there are some notes for the scientific creativity test instrument. The instrument consisted of seven items and was too time-consuming, making the test impractical [40]. There is doubt whether a seven-item test can fully assess the complex aspects of scientific creativity [48].

Product creativity can be subjectively defined as the evaluation of a product as presenting congruence and novelty that arouses passion and pleasure and is consistent with the evaluator's preferences. Products that are considered creative may exhibit a certain degree of novelty and appropriateness [49]. On the other hand, product creativity is defined as the extent to which a product is considered new, and its stance impacts and changes conventional market viewpoints and practices. It refers to the extent to which a new product provides creative ideas for other products, stimulates new thinking, and challenges current ideas about product types [50]. A creative idea or product will be considered original if it is something new or surprising and has never existed before [51]. However, novelty alone does not make something creative. A creative idea or product must also include an underlying value and utility, providing that it is appropriate, functional, correct, and valuable [52]. Therefore, most definitions of creativity identify originality and appropriateness as the key characteristics of creativity outcomes [51, 53].

The most well-known framework for creativity is the Four P's framework of [54], which consists of: First, person (Person) refers to the individual performing the creative act encompassing the various traits and attitudes of the creative individual, as well as creative potential. Second, process refers to the mental processes during creative endeavors involving learning, thinking, and communication of ideas as well as the tools and strategies used. Third, product refers to the tangible results of the creative process (e.g., works of art, writings, computer programs, etc.). Fourth, environment (Press) refers to the environment, the setting, the happening and whether the environment supports the relationship with the individual.

Another opinion about the indicators of creativity is that the product has undergone a transformation. Transformation, which refers to combining "elements in ways that defy tradition and that result in new perspectives," and "forces us to see reality in new ways" [55, 56]. However, it can be grouped with core characteristics. Transformation is only as extreme a form of originality as revolutionary products "that force a shift in the way of looking at reality" [53].

It is important to train students in product creativity. Individuals with creative abilities have a higher likelihood of survival and development than those without [8, 45]. However, most students still learn through methods such as lectures and memorization, which focus more on basic cognitive abilities, such as declarative memory (remembering facts) and conceptual understanding (understanding ideas that have been received). In fact, it is important to develop creative cognitive abilities that encourage innovative ways of understanding science. Creativity will often emerge if there are supportive and conducive conditions for creative action [36, 57]. Thus, it is very important for a teacher to be able to teach creativity to students during lectures.

The relationship between creativity, teaching, and learning can be divided into three parts: teaching for creativity, teaching creatively, and learning. Each part contributes to the belief system and classroom practices of a creative teacher [58]. Teaching for creativity can create a learning environment that encourages a sense of freedom to be creative when opportunities arise [36, 57]. Teaching creativity means providing control, facilitating new connections, and setting the conditions for all learners to engage in an open-ended creative process [43]. Teaching creativity means giving learners the freedom to make new connections, and creating an atmosphere that supports all students to engage in the creative process [57].

III. MATERIALS AND METHODS

A. Participants

This research was conducted at one of the state universities in Pekanbaru City, Indonesia. The participants in this study were third-semester students from the science education study program, who are science pre-service teachers. The third-semester students were selected as participants on the basis that they had already completed two semesters of lectures. This allowed them to provide insights into their experiences related to academic tasks, which might be associated with product creativity, compared to first-year students who had less experience. However, out of 50 students, only 22 were willing to participate and provide information for this study.

B. Data Collection

Data were collected through an online questionnaire administered via Google Form and distributed to the participants. The online survey was designed to identify and provide in-depth insights into individuals' understanding and experiences regarding creativity. For the purposes of this research, a questionnaire instrument was developed to evaluate two domains: creativity understanding, comprising

3 items, and creativity experiences, encompassing 4 items (see Table 1).

Table 1. Survey questions

Aspect	Questions
Creativity product definition understanding	What do you understand about the definition of creativity?
	Name three factors that you think can enhance creativity in product development!
	Write down in detail the name of the product you have developed or are currently developing and during the product development!
Creativity experiences	Were you creative according to the definition you mentioned earlier?
	Tell us about your experience in developing a product (it could be in a lecture you've been through, or an off-campus activity)!
	What was the biggest challenge you faced in applying creativity when developing the product?
	What are your suggestions to improve student creativity in product development?

By gathering this information, the study aims to establish a foundation for developing effective learning strategies or interventions that support the enhancement of creativity. The survey was structured to explore various dimensions of creativity, including participants' perceptions, challenges, and practical experiences in creative endeavors.

C. Data Analysis

The data was analyzed in two main categories: understanding the definition of creativity and creativity-related experiences. Initially, the researchers reviewed the descriptive questionnaire answers collected from and categorized the descriptive answers with specific terms. For example, the data analysis process began by examining the varying understandings of the concept of product creativity among SPST. Observations indicated that some SPST emphasized the generation of new ideas, while others prioritized innovative solutions or original works. To

facilitate systematic analysis, the responses were categorized accordingly.

IV. RESULT AND DISCUSSION

A. Creativity Product Definition Understanding

The first aspect I aimed to explore was understanding how SPST defines creativity. In general, creativity is one of the fundamental elements of scientific knowledge [40]. The specific domain of creativity in science learning is referred to as scientific creativity [59]. Scientific creativity is a problem-solving process that involves both domain-general and domain-specific skills and knowledge. Scientific creativity does not solely depend on knowledge, but also on cognitive processes that serve as fundamental tools in scientific discovery [43]. The findings which are obtained from this exploration are summarized and presented in Table 2 below.

Table 2. Hu and Adey [40] criteria of science creativity

Science creativity aspect	Science Creativity Indicators	Keywords appearing in SPST responses
Unusual uses	Fluency, flexibility, and originality in identifying unconventional or creative uses of specific objects for scientific purposes	1. Innovation, innovative, innovative solutions
Problem finding	Fluency, flexibility, and originality in proposing novel questions not previously considered	2. New ideas, novel concepts, new solutions, idea connection
Product improvement	Fluency, flexibility, and originality in enhancing technical products incorporating multiple scientific principles	3. Original thinking, original ideas, original works, original concepts
Creative imagination	Demonstrating creative imaginative abilities encompassing creative thinking and application of scientific ideas	4. Valuable works, value-added, high-value
Problem solving	Problem-solving skills, cognitive flexibility, idea originality, and applied imagination in addressing scientific challenges creatively	5. Tangible outputs, concrete results
Science experiment	Phenomenon analysis, cognitive flexibility, original thinking, and imagination in conducting scientific experiments	6. Creative thinking
Product design	Flexibility, originality, creative thinking skills, and imaginative application in designing and producing innovative scientific products	7. Unique combinations, uniqueness, unique solutions, unique outcomes
		8. New perspectives
		9. Problem-solving
		10. Cognitive flexibility
		11. Open-mindedness
		12. Adaptability
		13. Creative abilities
		14. Product improvement/enhancement
		15. Imagination
		16. Creation, creative capacity, inventiveness

There are several keywords that emerged which are somewhat different from the scientific creativity as defined by Hu and Adey [40]. Some of these terms include new perspective, tangible work, ability to create, openness, adaptation, and capability. Hu and Adey [40] likely define scientific creativity in terms of problem-solving, originality, and cognitive processes within a structured scientific context. In contrast, the keywords above introduce elements like practical output, mindset, and adaptability, which may extend beyond their original definition.

Keywords were extracted via thematic analysis of SPST responses, then categorized using Hu and Adey's criteria [40].

As shown in Fig. 2 below, the data have been categorized according to the keywords that appeared during the analysis.

Fig. 2 presents a categorization of keywords related to idea and ability, grouped into core themes. The main concept, "idea" and "ability or skill", serves as the central idea, with supporting keywords organized into distinct clusters that highlight different aspects of creativity:

1) Core attributes of creativity: Innovative, originality, uniqueness, and value

At the core of creativity are fundamental attributes: originality, uniqueness, and value. These qualities highlight the necessity of novelty and meaningful contribution in

creative outputs. Original ideas break away from the conventional, while uniqueness ensures they stand apart from existing solutions. Value, on the other hand, grounds creativity in practicality, ensuring that the output is not only novel but also purposeful and impactful. Together, these attributes define what makes a creative work truly innovative.

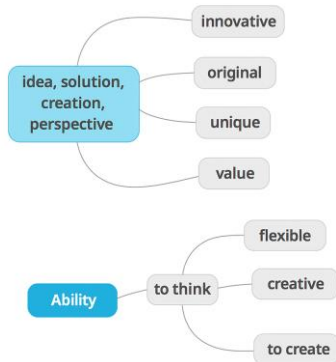


Fig. 2. Categorization based on keywords emerging from SPST responses.

Additionally, creativity thrives on flexibility and the ability to think dynamically. Flexibility allows individuals to adapt their approaches, experiment with different perspectives, and pivot when faced with challenges. The cognitive process of thinking—whether analytical, divergent, or exploratory—fuels the generation of new ideas and refines them into viable solutions. These adaptive and mental processes underscore that creativity is not just about the end product but also about the malleable and iterative journey of innovation.

2) Creative processes

The main keywords, idea, solution, and creation, represent the tangible outcomes of creative thinking—each marking a critical stage in the innovation process. An idea serves as the initial spark, a raw concept that holds potential. When refined and applied, this idea evolves into a solution, addressing specific problems or needs with ingenuity. Finally, creation embodies the materialization of these concepts into concrete results, whether products, artworks, or systems. Together, these terms illustrate how abstract thoughts are transformed into measurable, real-world contributions.

Complementing this progression, the action-oriented verbs to produce and to create emphasize the dynamic effort required to bridge imagination and reality. To produce underscores the practical steps—planning, prototyping, and iterating—that bring ideas to fruition. Similarly, to create implies deliberate craftsmanship, where vision meets execution. These terms remind us that creativity is not passive inspiration but an active process of making, testing, and refining. Without action, even the most brilliant ideas remain unrealized; thus, these keywords celebrate the discipline and persistence behind every innovative achievement.

3) Mindset and approach

The keywords perspective and out of the box encapsulate the essence of unconventional thinking—a hallmark of true innovation. Perspective signifies the ability to see beyond the obvious, to reframe challenges through alternative viewpoints, and to question established norms. Meanwhile,

out-of-the-box thinking pushes boundaries, encouraging solutions that defy conventional logic and embrace bold, uncharted approaches. Together, these concepts highlight how innovation thrives when individuals break free from linear thought patterns and explore ideas from fresh, often unexpected angles.

Equally critical are the terms creative and ability, which underscore the foundational competencies behind innovation. Creative denotes the innate or cultivated capacity to generate original ideas, while ability emphasizes the practical skills needed to execute them—whether technical expertise, problem-solving agility, or collaborative fluency. These keywords remind us that innovation is not just about inspiration; it requires both the vision to imagine new possibilities and the capability to bring them to life. In essence, creativity fuels the what, while ability determines the how, making them inseparable partners in the journey of innovation.

Overall, the categorization illustrates how creativity combines originality, practical execution, and a transformative mindset to generate innovative results. The findings obtained from this exploration are visually summarized and presented in Fig. 3 below, which provides a clear and concise representation of the insights gathered.

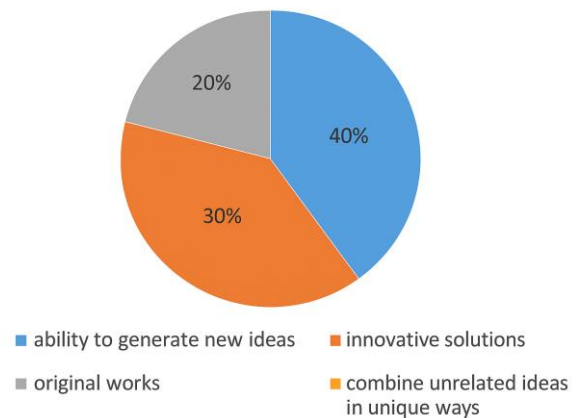


Fig. 3. Creativity definition understanding by SPST.

The findings from the data analysis highlight the diverse perspectives on creativity among respondents. Approximately 40% of respondents emphasized the ability to generate new ideas as a key aspect of creativity, focusing on originality and fresh thinking. Meanwhile, 30% of respondents stressed the importance of innovative solutions, highlighting creativity’s role in problem-solving and addressing challenges in unique ways. Additionally, 20% of respondents pointed to the creation of original works, underscoring the value of producing unique and meaningful outcomes. Finally, 10% of respondents emphasized the unique combination of unrelated ideas, showcasing the importance of connecting diverse concepts to foster innovation. These insights reflect a multifaceted understanding of creativity, encompassing idea generation, problem-solving, originality, and the synthesis of different perspectives. Generally, the SPST already has a solid understanding of the definition of creativity. This indicates that they are familiar with the concept and its fundamental principles, which serve as a good foundation for further exploration or application of creativity in their context.

Having understood the importance of creativity in education, it is now essential to explore its various definitions. Generally, creativity is defined as an individual's ability to generate new, original, or surprising ideas and solutions [23]. A creative person possesses the capacity to transform ordinary things into something extraordinary [24]. Additionally, creativity can be described as a set of methods or practices that help individuals develop their creative potential [25]. Creativity can also be defined as a skill that enables individuals to identify new opportunities, enhance their creative thinking abilities, and accurately evaluate the potential of an idea [60]. It is often seen as the ability to generate innovative ideas and develop valuable solutions to problems [27]. Furthermore, creativity involves the processes of utilizing, generating, refining, analyzing, and assessing diverse ideas [22].

The SPST stated that there are three factors that can enhance a person's creativity. The data (see Fig. 4) reveals that 40% of respondents consider a supportive and open work environment essential for fostering creativity, as it encourages experimentation and risk-taking. Additionally, 35% of respondents emphasized the importance of collaboration and diverse perspectives in driving innovation by bringing together varied expertise and ideas. Finally, 25% of respondents highlighted the role of technology and market trends in enhancing creativity, as staying updated with advancements and trends can inspire fresh and relevant solutions.

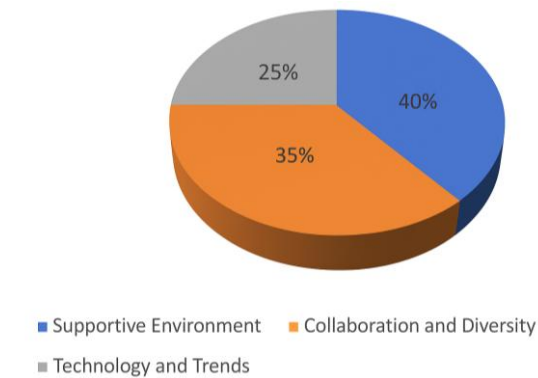


Fig. 4. Three factors that can enhance a Person's creativity.

The data collected from respondents highlights three key factors that can significantly enhance creativity in product development. First, a supportive and open work environment is crucial, as it encourages experimentation and exploration. Many respondents emphasized the importance of creating a space where individuals feel safe to take risks and innovate without fear of failure. Second, collaboration across disciplines and the inclusion of diverse perspectives were identified as vital for fostering creativity. By bringing together individuals with different backgrounds and expertise, teams can exchange unique ideas, leading to more innovative and well-rounded solutions. Third, leveraging technology and staying updated with market trends were also highlighted as essential factors. Exposure to new technologies and emerging trends can inspire fresh ideas and help create products that are not only innovative but also aligned with consumer needs and market demands. Together, these factors such as supportive environments, collaborative diversity, and

technological awareness form a strong foundation for enhancing creativity in the product development process.

B. Creativity Experiences

Based on the questionnaire data on creativity 9 (see Fig. 5), it was found that 64% of students have never developed a product, while 36% have done so. The products developed include facial soap made from papaya extract, facial masks, automatic cars, remote-controlled motors, course assignments on springs and capillarity, food chips, and knitted hats. However, only two of these products were developed during lectures: the assignments on product development involving the concepts of springs and capillarity. Out of the eight students who have developed products, seven (or 85%) stated that their creativity has been very useful. Only one student felt that they lacked creativity, as the products they created were not significantly different from those developed by others. It is important to note that novelty alone does not define creativity. Creative ideas or products must also possess underlying value and usefulness, providing appropriate, functional, correct, and valuable solutions [28].

Based on the distribution of questionnaires about the challenges of applying creativity in product development, 31.82% of SPST stated that they were unaware of the challenges they faced because they had never developed a creative product. Meanwhile, 27.27% of students identified limited tools, materials, and costs as significant challenges. Additionally, a lack of facilities was cited as one of the obstacles hindering creative teaching and learning among students in higher education [61, 62].

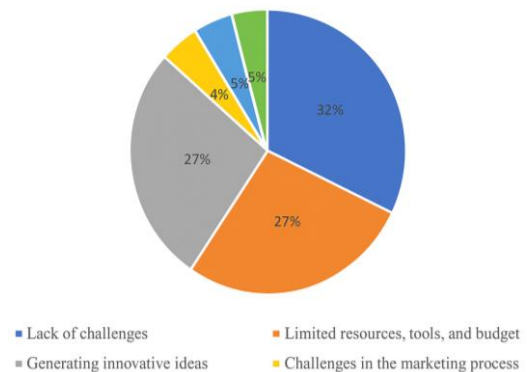


Fig. 5. Challenges in developing products.

Difficulties in generating new ideas were experienced by 27.27% of students, indicating barriers to innovative thinking. This challenge may stem from a lack of inspiration or limited experience in brainstorming and exploring ideas. Creativity, which involves the ability to generate, use, improve, analyze, and evaluate new, original, or surprising ideas and solutions, is essential for overcoming such obstacles [23, 29]. Difficulty in identifying the marketing process was cited by 4.55% of students as a challenge. This suggests that students may feel more confident in the product development aspect than in marketing. However, this low percentage could also indicate a lack of understanding of how marketing strategies contribute to product success. Additionally, 4.55% of students recognized product competition as a challenge, while another 4.55% mentioned a lack of time as a barrier to developing products.

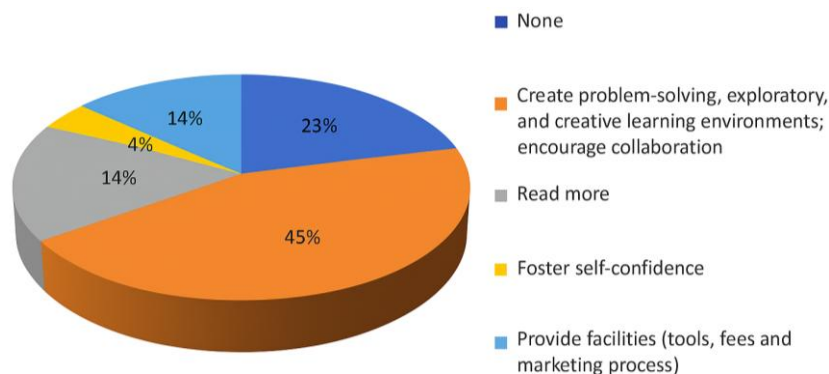


Fig. 6. Suggestions for developing product creativity from SPST.

Students provided several suggestions on ways to develop creativity (see Fig. 6). The majority, 45%, emphasized the importance of creating a learning environment that supports collaboration and exploration as a key factor in fostering creativity. However, 23% of students felt that no changes were needed to the current approach for enhancing creativity. It is worth noting that the role of creativity in education is often unclear and varies significantly depending on the school and program. For creativity efforts to be meaningful in education, they must be grounded in disciplinary knowledge [26]. Additionally, 14% of students highlighted the importance of reading, while another 14% stressed the need for adequate facilities. A smaller percentage, 4%, mentioned the importance of self-confidence. Ultimately, focusing on a positive learning environment and providing supportive resources is essential for students to effectively develop their creativity.

To enhance creativity and innovation within organizations, it is essential to foster a supportive culture that encourages experimentation and risk-taking. By creating an environment where employees feel safe to explore new ideas without fear of failure, organizations can unlock their team's creative potential. Additionally, promoting cross-disciplinary collaboration is crucial, as bringing together individuals with diverse perspectives and expertise can lead to more innovative and well-rounded solutions. Finally, organizations should invest in technology and market research to stay updated with the latest advancements and trends. This not only inspires fresh ideas but also ensures that products remain competitive and aligned with evolving consumer needs. Together, these strategies create a strong foundation for sustained creativity and innovation.

In future research, it is crucial to identify a learning environment that can nurture and enhance the creativity of SPST. In line with the findings of the Systematic Literature Review (SLR), it is evident that there is still limited understanding regarding the dynamics of the creative process, particularly in the context of teaching. Specifically, little is known about what occurs during this process, how teachers generate creative ideas, how they nurture and develop their creativity over time, and what factors or experiences trigger their creative thinking [17]. Given this gap in knowledge, there is a pressing need for a more naturalistic and in-depth exploration of these phenomena. A qualitative research approach, utilizing methods such as in-depth interviews, classroom observations, and reflection diaries, would be highly beneficial. Such an approach would provide valuable insights into the everyday creative practices of teachers,

shedding light on the nuanced and often subtle processes that underlie their creativity. This deeper understanding could ultimately inform strategies to support and enhance creativity in educational settings.

From a social context perspective, creativity often emerges when supportive and conducive conditions are present, enabling creative actions. This is because the environment and culture significantly influence how individuals perceive ideas and transform them into innovative outcomes [36, 63]. In the field of science education, creativity is a fundamental aspect that shapes the nature of science itself [32]. It is considered one of the core elements of scientific knowledge. Specifically, in science learning, this domain of creativity is referred to as scientific creativity (59). Creativity can be manifested through various forms of performance, including verbal (e.g., written or oral), physical (e.g., drawing or photography), and spatial (e.g., movement or procedural) modalities [45]. To foster creativity in learners, it is essential for educators to possess the skills and abilities to guide individuals in becoming creative effectively [63, 64].

Despite providing valuable insights into science pre-service teachers' perceptions and experiences related to creativity, this study has several limitations that should be acknowledged. First, the number of participants was relatively small, with only 22 respondents out of a potential population of 50 students. This limited sample size may restrict the generalizability of the findings to a broader population of science pre-service teachers. Nevertheless, the study was intended as an exploratory investigation, aiming to capture in-depth perspectives rather than to make broad statistical generalizations. Second, the data were collected through a self-reported online questionnaire, which may be subject to response bias, including participants' tendencies to provide socially desirable answers or to overestimate their creative abilities. Future studies may benefit from triangulating self-report data with other sources, such as classroom observations, interviews, or assessments of actual creative products.

Finally, this study focused on students from a single higher education institution, which may limit the transferability of the findings to different institutional or cultural contexts. Future research involving multiple institutions and diverse educational settings is recommended to provide a more comprehensive understanding of creativity development among science pre-service teachers.

V. CONCLUSION

This study highlights the critical role of creativity in preparing SPST in Indonesia for the demands of 21st-century education. The findings reveal that while a significant proportion of SPST have yet to develop creative products, those who have done so recognize the substantial value of creativity in their academic and professional tasks. Key barriers to creativity include insufficient resources, limited practical experience, and challenges in generating innovative ideas. Additionally, students emphasized the importance of a supportive learning environment, collaboration, and adequate facilities as essential factors for fostering creativity. These insights underscore the urgent need for educational interventions that integrate creativity into science education curricula, equipping SPST with the tools and opportunities to enhance their creative abilities. By addressing these challenges and leveraging supportive learning environments, higher education institutions can better prepare future educators to navigate the complexities of the modern world. This study contributes to the broader understanding of how creativity can be effectively nurtured in science education, ultimately empowering SPST to become innovative and adaptable educators capable of meeting the evolving needs of society.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Diniya was primarily responsible for conducting the investigation and preparing the original draft of the manuscript, including data collection and initial analysis. Muslim contributed to the development of the original draft and provided overall academic supervision, offering critical guidance throughout the research design, implementation, and manuscript preparation. Rika Rafikah Agustin and Rini Solihat were responsible for developing the research methodology and contributed substantially to the critical review, revision, and editing of the manuscript to ensure its scholarly rigor and clarity.

ACKNOWLEDGMENT

We gratefully acknowledge the Indonesia Endowment Fund for Education (LPDP), Ministry of Finance of the Republic of Indonesia, for providing the scholarship and funding the publication of this article.

REFERENCES

- [1] B. Trilling and C. Fadel, *21st Century Skills: Learning for Life in Our Times*. Hoboken, NJ, USA: John Wiley & Sons, 2009.
- [2] K. F. Geisinger, "21st century skills: What are they and how do we assess them?" *Appl. Meas. Educ.*, vol. 29, no. 4, pp. 245–249, 2016.
- [3] T. J. Kennedy and C. W. Sundberg, "21st century skills," in *Proc. Science Education in Theory and Practice: An Introductory Guide to Learning Theory*, Cham, Switzerland: Springer, 2020, pp. 479–496.
- [4] A. Imam, S. S. Z. Zaidi, and A. A. Qureshi, "Skill set required for 21st century student: Case study of university level student," *Voyage J. Educ. Stud.*, vol. 3, no. 2, pp. 69–91, 2023.
- [5] N. Ahmadi, L. Peter, T. Lubart, and M. Besançon, "School environments: Friend or foe for creativity education and research?" in *Proc. Creativity Under Duress in Education? Resistive Theories, Practices, and Actions*, C. A. Mullen, Ed. Cham, Switzerland: Springer, 2019, pp. 255–266. doi: 10.1007/978-3-319-90272-2_14
- [6] J. Fox and B. Smith, "Creativity: An unsolved enigma," *Innov. Educ. Teach. Int.*, vol. 61, no. 5, pp. 1075–1087, 2024.
- [7] M. Leasa, J. R. Batlolona, and M. Talakua, "Elementary students' creative thinking skills in science in the Maluku Islands, Indonesia," *Creat. Stud.*, vol. 14, no. 1, pp. 74–89, 2021.
- [8] T. Cremin, "Teaching creatively and teaching for creativity," in *Proc. Essential Competencies for English-Medium University Teaching*, Cham, Switzerland: Springer, 2017, pp. 99–110.
- [9] H. Silva, J. Lopes, C. Dominguez, and E. Morais, "Lecture, cooperative learning and concept mapping: Any differences on critical and creative thinking development," *Int. J. Instr.*, vol. 15, no. 1, pp. 765–780, Jan. 2022. doi: 10.29333/iji.2022.15144a
- [10] G. Tholen, "The limits of higher education institutions as sites of work skill development, the cases of software engineers, laboratory scientists, financial analysts and press officers," *Stud. High. Educ.*, vol. 44, no. 11, pp. 2041–2052, Nov. 2019. doi: 10.1080/03075079.2018.1490894
- [11] Q. Zhang, H. Tang, and X. Xu, "Analyzing collegiate critical thinking course effectiveness: Evidence from a quasi-experimental study in China," *Think. Ski. Creat.*, vol. 45, 101105, Sep. 2022. doi: 10.1016/j.tsc.2022.101105
- [12] I. Jahnke and J. Liebscher, "Three types of integrated course designs for using mobile technologies to support creativity in higher education," *Comput. Educ.*, vol. 146, 103782, Mar. 2020. doi: 10.1016/j.compedu.2019.103782
- [13] Ş. S. Anagün, "Teachers' perceptions about the relationship between 21st century skills and managing constructivist learning environments," *Int. J. Instr.*, vol. 11, no. 4, pp. 825–840, 2018. <https://www.e-iji.net/>
- [14] V. Roey *et al.*, "21st century skills development and assessment in higher education: A systematic review," *Vrije Univ. Brussel, Brussels, Belgium, Tech. Rep.*, 2020. <http://static.battelleforkids.org/>
- [15] B. Uçar and Y. Demiraslan Çevik, "The effect of argument mapping supported with peer feedback on pre-service teachers' argumentation skills," *J. Digit. Learn. Teach. Educ.*, vol. 37, no. 1, pp. 6–29, 2020. doi: 10.1080/21532974.2020.1815107
- [16] A. Thanaraj, P. Durston, and S. Elkington, "A blueprint for designing creativity into learning design," in *Proc. Teaching Legal Education in the Digital Age*, London, UK: Routledge, 2022, pp. 82–107.
- [17] W. Han and N. A. Abdrahim, "The role of teachers' creativity in higher education: A systematic literature review and guidance for future research," *Think. Ski. Creat.*, vol. 48, 101302, Jun. 2023. doi: 10.1016/j.tsc.2023.101302.
- [18] I. Celik, E. Gedrimiene, S. Siklander, and H. Muukkonen, "The affordances of artificial intelligence-based tools for supporting 21st-century skills: A systematic review of empirical research in higher education," *Australas. J. Educ. Technol.*, vol. 40, no. 3, pp. 1–20, 2024.
- [19] Kementerian Pendidikan dan Kebudayaan Republik Indonesia, "Peraturan menteri pendidikan dan kebudayaan nomor 3 tahun 2020 tentang standar nasional pendidikan tinggi," *Berita Negara Republik Indonesia Tahun 2020 Nomor 47*, 2020.
- [20] J. Shreffler *et al.*, "Measuring faculty viewpoints to optimize success for faculty researchers: Does creativity matter?" *Creat. Res. J.*, vol. 33, no. 3, pp. 321–329, 2021.
- [21] O. Kocak, M. Coban, A. Aydin, and N. Cakmak, "The mediating role of critical thinking and cooperativity in the 21st century skills of higher education students," *Think. Ski. Creat.*, vol. 42, 100967, Dec. 2021.
- [22] J. W. Willison, "Research skill development spanning higher education: Curricula, critiques and connections," *J. Univ. Teach. Learn. Pract.*, vol. 15, no. 4, pp. 1–17, 2018. <https://ro.uow.edu.au/jutlp/vol15/iss4/1>
- [23] E. Sharma and S. Sharma, "Creativity nurturing behaviour scale for teachers," *Int. J. Educ. Manag.*, vol. 32, no. 6, pp. 1016–1028, Aug. 2018. doi: 10.1108/IJEM-10-2017-0294
- [24] Gallup, "Creativity in learning," Gallup, Washington, DC, USA, Rep., 2019.
- [25] S. Zubaidah, E. Rosba, S. Mahanal, J. Suliseti, and A. Bin Jamaluddin, "Students' critical thinking skills during the pandemic through online GI-DMM," *Pegem J. Educ. Instr.*, vol. 14, no. 4, pp. 201–212, May 2024. doi: 10.47750/pegegog.14.04.21
- [26] M. Koehler and D. Henriksen, "The 7 trans-disciplinary habits of mind: Extending the TPACK framework towards 21st century learning," *Educ. Technol.*, vol. 51, no. 2, pp. 10–16, Mar. 2011.
- [27] P. Mishra and D. Henriksen, *Creativity, Technology & Education: Exploring their Convergence*. Cham, Switzerland: Springer, 2018. doi: 10.1007/978-3-319-70275-9
- [28] M. Mohammadi, "Creativity in higher education: A way to achieve sustainable development in Afghanistan," *Shanlax Int. J. Educ.*, vol. 9, no. 1, pp. 51–55, 2020.
- [29] N. D. A. C. Alves, C. G. von Wangenheim, and L. H. Martins-Pacheco, "Assessing product creativity in computing education: A systematic mapping study," *Inform. Educ.*, vol. 20, no. 1, pp. 19–45, 2021.

- [30] Y. Mazeh, "What is creativity and why it is so important?" *Open Access Libr. J.*, vol. 7, no. 3, pp. 1–32, 2020.
- [31] C. Walia, "A dynamic definition of creativity," *Creat. Res. J.*, vol. 31, no. 3, pp. 237–247, 2019.
- [32] V. P. Glăveanu and R. A. Beghetto, "Creative experience: A non-standard definition of creativity," *Creat. Res. J.*, vol. 33, no. 2, pp. 75–80, 2021.
- [33] A. Setiamurti and F. Kurniawati, "Fostering creativity in higher education institution: A systematic review (2018–2022)," *Open Educ. Stud.*, vol. 6, no. 1, pp. 1–18, 2024.
- [34] C. Tang, S. Mao, S. E. Naumann, and Z. Xing, "Improving student creativity through digital technology products: A literature review," *Think. Ski. Creat.*, vol. 44, 101032, Jun. 2022.
- [35] Z. Shao, X. Li, and Q. Wang, "From ambidextrous learning to digital creativity: An integrative theoretical framework," *Inf. Syst. J.*, vol. 32, no. 3, pp. 544–572, 2022.
- [36] A. W. Oliveira, A. O. Brown, W. S. Zhang, P. LeBrun, L. Eaton, and S. Yemen, "Fostering creativity in science learning: The potential of open-ended student drawing," *Teach. Teach. Educ.*, vol. 105, 103416, Sep. 2021. doi: 10.1016/j.tate.2021.103416
- [37] T. P. Vo, M. D. Tran, and T. M. C. Ly, "The relationship between new product creativity components and purchase intention and the mediating impact of perceived values: A study of consumers in Ho Chi Minh City," *Cogent Bus. Manag.*, vol. 9, no. 1, 2112357, 2022.
- [38] W. F. McComas, "Seeking historical examples to illustrate key aspects of the nature of science," *Sci. Educ.*, vol. 17, no. 2, pp. 249–263, 2008.
- [39] B. Shermukhammadov, "Creativity of a teacher in an innovative educational environment," *J. High. Educ. Theory Pract.*, vol. 22, no. 12, pp. 56–64, 2022.
- [40] W. Hu and P. Adey, "A scientific creativity test for secondary school students," *Int. J. Sci. Educ.*, vol. 24, no. 4, pp. 389–403, 2002.
- [41] M. Safitri, N. Fadiawati, and C. Diawati, "What do chemistry teachers say about scientific creativity and the development of rosella flower extract indicators as a learning medium for acid–base titration?" *J. Penelit. Pendidik. IPA*, vol. 10, no. 10, pp. 7960–7967, 2024.
- [42] Z. Smyrniou, E. Georgakopoulou, and S. Sotiriou, "Promoting a mixed-design model of scientific creativity through digital storytelling—The CCQ model for creativity," *Int. J. STEM Educ.*, vol. 7, no. 1, 2020.
- [43] N. N. Atesgoz and U. Sak, "Test of scientific creativity animations for children: Development and validity study," *Think. Ski. Creat.*, vol. 40, 100818, Jun. 2021. doi: 10.1016/j.tsc.2021.100818
- [44] P. K. Agarwal, "Retrieval practice and Bloom's taxonomy: Do students need fact knowledge before higher order learning?" *J. Educ. Psychol.*, vol. 111, no. 2, pp. 189–209, 2019.
- [45] S. W. Kleibeuker, C. K. W. De Dreu, and E. A. Crone, "The development of creative cognition across adolescence: Distinct trajectories for insight and divergent thinking," *Dev. Sci.*, vol. 16, no. 1, pp. 2–12, Jan. 2013. doi: 10.1111/j.1467-7687.2012.01176.x
- [46] A. Cropley, "Definitions of creativity," in *Proc. Encyclopedia of Creativity*, 3rd ed., J. C. Kaufman and R. J. Sternberg, Eds. Amsterdam, The Netherlands: Academic Press, 2019, pp. 275–282.
- [47] H. E. Sisman, N. Aydogan, and O. Cankaya, "A scientific creativity scale development process for science teacher candidates," *Int. J. Soc. Educ. Sci.*, vol. 6, no. 1, pp. 37–63, 2024. doi: 10.46328/ijonses.587
- [48] W. Aschauer, K. Haim, and C. Weber, "A contribution to scientific creativity: A validation study measuring divergent problem solving ability," *Creat. Res. J.*, vol. 34, no. 2, pp. 195–212, 2022. doi: 10.1080/10400419.2021.1968656
- [49] D. Horn and G. Salvendy, "Consumer-based assessment of product creativity: A review and reappraisal," *Hum. Factors Ergon. Manuf.*, vol. 16, no. 2, pp. 155–175, 2006.
- [50] A. E. Akgün, M. Dayan, and A. Di Benedetto, "New product development team intelligence: Antecedents and consequences," *Inf. Manag.*, vol. 45, no. 4, pp. 221–226, 2008.
- [51] M. A. Runco and G. J. Jaeger, "The standard definition of creativity," *Creat. Res. J.*, vol. 24, no. 1, pp. 92–96, 2012.
- [52] D. Cropley and A. Cropley, "Functional creativity," in *Proc. The Cambridge Handbook of Creativity*, J. C. Kaufman and R. J. Sternberg, Eds. Cambridge, UK: Cambridge Univ. Press, 2010, pp. 301–318.
- [53] S. P. Besemer and D. J. Treffinger, "Analysis of creative products: Review and synthesis," *J. Creat. Behav.*, vol. 15, no. 3, pp. 158–178, 1981.
- [54] M. Rhodes, "An analysis of creativity," *Phi Delta Kappan*, vol. 42, no. 7, pp. 305–310, 1961.
- [55] M. Krausz, D. Dutton, and K. Bardsley, "Creativity and self-transformation," *Philos. Hist. Cult.*, vol. 28, pp. 191–203, 2009.
- [56] H. Djulius, "How to transform creative ideas into creative products: Learning from the success of batik fractal," *Int. J. Bus. Global.*, vol. 19, no. 2, pp. 183–190, 2017.
- [57] R. C. Anderson, J. Katz-Buonincontro, M. Livie, J. Land, N. Beard, and T. Boussetol, "Reinvigorating the desire to teach: Teacher professional development for creativity, agency, stress reduction, and wellbeing," *Front. Educ.*, vol. 7, 848005, Mar. 2022.
- [58] S. C. Liu and H. S. Lin, "Primary teachers' beliefs about scientific creativity in the classroom context," *Int. J. Sci. Educ.*, vol. 36, no. 10, pp. 1551–1567, 2014.
- [59] A. H. Setyadin, R. Efendi, and A. Samsudin, "Adaptasi instrumen tes kreativitas ilmiah Hu dan Adey sebagai alternatif untuk mengukur kreativitas dalam konteks sains," in *Proc. Pros. Semin. Nas. Fis.*, Bandung, Indonesia, Mar. 2019, vol. 5, pp. 123–130.
- [60] B. Thornhill-Miller *et al.*, "Creativity, critical thinking, communication, and collaboration: Assessment, certification, and promotion of 21st century skills for the future of work and education," *J. Intell.*, vol. 11, no. 3, Mar. 2023.
- [61] Z. Moula, "Academic perceptions of barriers and facilitators of creative pedagogies in higher education: A cross-cultural study between the UK and China," *Think. Ski. Creat.*, vol. 41, 100923, Sep. 2021.
- [62] M. Qahl and O. Sohaib, "Key factors for a creative environment in Saudi Arabian higher education institutions," *J. Inf. Technol. Educ. Innov. Pract.*, vol. 22, pp. 1–18, 2023.
- [63] M. Méndez, J. Cantero, and N. P. Giménez, "Enseñanza de las ciencias y aulas creativas: un diálogo necesario y posible," *Bio-grafta*, vol. 15, no. 29, pp. 45–58, 2022.
- [64] E. O. Bereczki and A. Kárpáti, "Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices," *Think. Ski. Creat.*, vol. 39, 100791, Mar. 2021.

Copyright © 2026 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).