Science Education International
36(4)_2025,373-380
https://doi.org/10.33828/sei.v36.i4.1

ORIGINAL ARTICLE

Are they Ready? Creative Self-Efficacy in Science and Performance of Pre-service Teachers

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ABSTRACT

Creative thinking is an essential competence that should be fostered at all educational levels, yet for teachers to effectively develop this skill in students, they must possess the necessary abilities, confidence, and pedagogical knowledge. This study examines the creative self-efficacy (CSE) in science of pre-service teachers, their ability to recognize creative activities in the science classroom, and their scientific inquiry skills. The results indicate that the 213 Spanish primary pre-service teachers in the sample perceive themselves as creative in science. However, many participants mistakenly classify non-creative activities as creative and demonstrate low inquiry skills. As a result, no significant correlation was found between their self-perception and actual performance in creative tasks. The study also highlights that prior science training influences both their perception of CSE in science and their ability to distinguish between creative and non-creative activities in the classroom. These findings underscore the importance of integrating creativity into teacher training programs to enable future educators to effectively implement creative practices in the primary education classroom, aligning with societal demands for creativity in education.

KEY WORDS: Inquiry skills, pre-service teachers, scientific creativity, self-efficacy

INTRODUCTION

Creativity is recognized as a crucial competency for the 21st-century society (Henriksen et al., 2016), a view supported by the OECD in its reports (OECD, 2019). Creativity was also incorporated into the PISA tests in 2022, alongside the traditional assessments in reading, mathematics, and science. Furthermore, creativity is increasingly demanded by businesses and social organizations worldwide, as innovation and the creation of new knowledge are essential for addressing everyday challenges (Soulé and Warrick, 2015; Sung, 2015). This growing importance of creativity is reflected in the curricula of many countries (Patston et al., 2021). In Spain, the recent educational law, LOMLOE (Ley Orgánica, 2020), explicitly states that "[...] artistic creation, audiovisual communication, digital competence, the promotion of creativity, and the scientific spirit will be worked on in all areas of Primary Education" (p. 122873).

This positions creativity as a cross-cutting theme throughout the entire curriculum presents in all subjects, with teachers being ultimately responsible for equipping students with creative skills and competencies (Soh, 2017). However, the lack of clear definitions of creativity and the inadequate training many teachers report receiving contribute to uncertainty and hesitation in implementing creativity effectively in the classroom (Mullet et al., 2016; Skiba et al., 2010). Indeed, some empirical studies have shown that early childhood and primary teachers feel unprepared to effectively foster student creativity due to curriculum constraints (Aish, 2014; Cheng, 2010). Similarly, in a review by Bereczki and Kárpáti (2018), while participating teachers expressed positive attitudes toward creativity, they did not integrate creativity-promoting activities into their teaching practices. Gaining a deeper understanding of teachers' beliefs about creativity would offer valuable insights into their teaching approaches and help guide efforts to promote creativity in the classroom.

There is an international consensus that science is inherently creative (Lubart et al., 2022), and that fostering specific aspects of scientific creativity should be a key priority in education (Hetherington et al., 2020). Several factors can influence scientific creativity, including convergent and divergent thinking (Cheung et al., 2016), general creativity versus domain-specific creativity (Qian et al., 2019; Scotney et al., 2019), motivation (Xue et al., 2020), creative self-efficacy (CSE) (Liu et al., 2021), inquiry skills (Yang et al., 2016), metacognitive abilities (Puryear, 2016), and knowledge of science (Huang and Wang, 2019). While intelligence is considered a necessary condition for creative thinking, it is not sufficient on its own (Karwowski et al., 2016).

Inquiry-based learning approaches are known to provide numerous opportunities for fostering creativity (Martins and McCauley, 2021). Aktamis and Ergin (2008) showed that promoting procedural skills in science education enhances scientific creativity, while Yang et al. (2016) found strong and significant correlations between scientific creativity and four key areas of scientific inquiry: Identifying research questions, formulating hypotheses, designing experiments, and drawing conclusions. Newton and Newton (2010) identified three types of activities that can enhance scientific creativity in the classroom: a) Speculative descriptions of situations with tentative or hypothetical explanations and potential alternatives; b) gathering knowledge and evaluating ideas (such as proposing methods to collect reliable, descriptive information or empirical tests to validate a hypothesis); and c) applying scientific knowledge to solve real-world problems. In addition, specific training in divergent thinking has been shown to improve scientific creativity in secondary students (Sun et al., 2020), although domain knowledge plays a significant role in this process.

Despite its recognized importance, several studies highlight a lack of teacher preparation in effectively implementing creativity in the science classroom (Ramnarain, 2018). Newton and Newton (2010) found that some primary education teachers struggled to differentiate between creative and reproductive (non-creative) activities for promoting creativity in science. A meta-analysis by Gralewski and Karwowski (2019) revealed a positive, though weak, and statistically significant relationship between teachers' scores on students' creativity and their performance in divergent thinking tasks. Similarly, in a study by Cruz et al. (2020), primary pre-service teachers were asked to generate questions related to the primary education curriculum for scientific research activities, but it was found that not all the proposed questions were appropriate for initiating scientific inquiry in the classroom.

One of the factors that significantly impacts motivation toward a learning or teaching goal is the perception of self-efficacy in the subject or area of knowledge (Caprara et al., 2006; Ozder, 2011). CSE, which refers to personal beliefs about one's ability to recognize and produce creative outcomes, is considered a key factor in supporting creativity in the classroom (Nemerzitski and Heinla, 2020). According to Kruse et al. (2021), creative self-perception is linked to increased effort, perseverance, enthusiasm, professional commitment, classroom management, and even teachers' attitudes toward their students. Other studies found a positive relationship between teachers' creative self-perception and their beliefs on teaching for creativity (Díaz-Díaz et al., 2025; Izquierdo-Sanchis et al., 2025). Therefore, it is crucial for teachers and pre-service teachers to develop a strong creative self-concept in science, as it fosters optimism and motivation, enabling them to inspire their students with a sense of interest, social relevance, and curiosity about science in a creative manner (Kinskey and Callahan, 2022).

Self-efficacy has a significant influence on both motivation and cognition, particularly on cognitive control, which are two critical constructs in goal-directed behavior. Researchers are increasingly investigating how motivation and cognitive control interact (Yee and Braver, 2018), with dopamine identified as a key neuromodulator in these interactions. The Value-Based Cognitive Control framework, recently proposed by Westbrook and Braver (2015), conceptualizes this interaction as a decision-making process where motivation is weighed against the cognitive effort required to achieve a goal. This framework highlights how individuals make decisions based on the balance between the desire to achieve a goal and the mental resources that they are willing to invest.

The correlation between self-efficacy and teaching practice is not always straightforward, as some researchers encounter discrepancies when using self-reported data, which may not accurately reflect the actual instructional practices teachers implement in the classroom (Kruse et al., 2021). To address this issue, our study aimed to investigate whether the self-perceptions of pre-service teachers are related to more objective evaluations of their creativity in science classrooms. Specifically, we focused on their inquiry skills and their ability to design and conduct activities that foster scientific creativity in students. Based on this general objective, the following research questions were formulated:

1. What is the self-perception of scientific creativity in early childhood and primary school teachers in training?
2. What is their ability to differentiate creative activities from non-creative ones in science?
3. What are their inquiry skills, as a form of scientific creativity?
4. Is there a relationship between their creative self-perception and their performance in the above-mentioned competences?
5. Are there differences according to content domain (branch of studies in secondary school) or gender?

METHODOLOGY

An *ex post facto* descriptive design was used in this study to quantitatively analyze self-perceptions of scientific creativity in teachers in training and their performance in different tasks related to scientific creativity. As a descriptive study, there was no experimental intervention or pre-post comparison of teaching practices.

Participants

Participants were a convenience sample of 213 students belonging to the 2nd year of the Primary Education Teaching degree at the Faculty of Teacher Training of a university located in a large Spanish city. One hundred and eighty identified as female (84.5%) and 31 as male (15.5%), which is in accordance with the total population of sophomore students in this degree (two people identified themselves as non-binary and were not included in the gender analysis). The entire participating sample was studying at least one scientific subject ("Natural Sciences for teachers" with a workload of 90 teaching hours). The branch of previous studies completed in high school by most students was "Social Sciences and Humanities," with 76.5% (n = 163), followed by "Science and Technology," with 18.3% (n = 39).

Instruments

Three validated instruments were used to measure CSE, the ability to differentiate between creative and non-creative incidents in the classroom and inquiry skills. All of them were previously translated to Spanish.

The CSE in science was measured according to Beghetto et al. (2011) with five Likert-type items ranging from 1 (not true) to 5 (very true). Cronbach's alpha of the Spanish translation was 0.812, which indicates a very good reliability.

The ability to differentiate between creative and non-creative incidents in the classroom was measured with the instrument developed by Newton and Newton (2010). Originally, it was comprised of 36 short classroom incidents in three dissimilar science topics: Earth, Space, and Gravity; Electricity; and Plants and Animals. For the present study, only the 24 incidents related to the first two topics were used to not overload the participants. There were eight incidents favoring creative thought in science and eight incidents biased toward non-creative thought in science (four related with descriptive science and four with explanatory science). These 16 items corresponded to Field 1 (constructing notional scientific knowledge such as speculative descriptions of situations, tentative explanations, and hypothesis) and Field 2 (constructing empirical ways of gathering knowledge and evaluating ideas). Four additional items were related to incidents in Field 3 (applying scientific knowledge to solve a practical problem). There were also four items involving creative thought but not related to science. The various categories of items appeared equally for each of the two topics. The degree of stimulation of creativity in each situation is asked to be rated using a 5-level Likert scale, where the lowest level means "no opportunity to develop scientific creativity" and the highest-level means "a very good or great opportunity to develop scientific creativity."

The Inquiry skills test was adapted from the one developed by Cuevas et al. (2005), which was composed of eight items. The adaptation used in this study had four items, one closed question and three open questions (one of them with different sub-sections) to assess the six studied variables (Izquierdo-Sanchis and Solaz-Portolés, 2022). From a given text narrating a daily problematic situation with the phenomenon of evaporation, each person is asked: To formulate the research question; to determine the dependent variable (DV), the independent variables (IVs) and the control variables (CVs); to formulate an appropriate hypothesis; and to describe how the experiment would be carried out (steps, conditions, materials, their use, etc.) to be able to answer the initial research question and thus resolve the problematic situation raised. A specific rubric was created to evaluate responses and was validated through multiple rounds of inter-judge agreement. The rubric categorized responses into three levels: 0 (no response or incorrect one), 1 (partially correct or incomplete), and 2 (correct and complete). To assess the reliability of the scientific inquiry questionnaire, Cronbach's Alpha coefficient was calculated, yielding a value of 0.619. This value is considered satisfactory given the characteristics of the questionnaire, which includes a small number of items, each requiring different types of knowledge.

Data Gathering and Analysis

The pre-service teachers completed the paper-based questionnaires in a typical class session. These included sociodemographic data and the validated questionnaires described in the previous section. All participants received information about the scope of the research and the data anonymization protocol, and they signed an informed consent form to participate in the study.

Descriptive statistical analysis was done using the Statistical Package for the Social Sciences software version 26. Particularly, mean and standard deviation were calculated for each of the variables. To check the normality of the distributions, Kolmogorov–Smirnov test for one sample was used. As all the distributions turned out to be non-normal, non-parametric tests were used for comparisons. Mann–Whitney U-test was used for independent samples (differences according to gender or studies before the degree) and Wilcoxon signed-rank test was used for related samples (ability to differentiate between non-creative and creative activities). The correlation between variables was studied by Pearson's correlation coefficient. In all cases, the significance level was set at 0.05.

FINDINGS

CSE in Science

Total mean scores for CSE in science and those obtained according to gender and branch of prior studies are shown in Table 1. It is apparent that the conception of CSE in this group of pre-service teachers varied significantly among individuals with a minimum of 1.20 and a maximum of 4.80 (from a potential range of 1–5). The mean value was 3.08, similar to the one obtained by Beghetto et al. (2011) for US elementary school students and Hartley et al. (2016) for Chinese elementary school students.

As shown in Table 1, there were no statistically significant differences according to gender, in agreement with previously published studies (Beghetto et al., 2011; Hartley et al., 2016), although He and Wong (2021) recently found gender differences for general CSE in undergraduate students. However, the branch of prior studies proved to be an important

Table 1: Descriptive statistics and Mann–Whitney test results for creative self-efficacy in science

Variable	Mean	Standard deviation	z	p
Prior studies				
Science and technology	3.46	0.46	−4.454	0.000*
Rest	2.99	0.62		
Gender				
Male	3.04	0.64	1.930	0.054
Female	3.27	0.48		
Total	3.08	0.62		

*significant correlation at the 0.05 level variable in the self-perception of CSE in science, since there were statistically significant differences between those students that had studied a baccalaureate in science and technology and the rest, with a large size effect (Cohens' d = 0.86). This result is in line with previous studies that stated that self-efficacy is influenced positively by prior knowledge and prior ability (Ineson et al., 2013; Bandura, 1997).

Ability to Identify Creative Activities in Science

Mean scores for the test items are shown in Table 2 (standard deviations in brackets). The findings indicate that these pre-service teachers generally rate creative incidents slightly higher than non-creative ones. However, the difference in ratings was much smaller than the one observed by Newton and Newton (2010). This disparity may be because the participants in Newton and Newton's study were in-service teachers, whereas our sample consists of pre-service teachers in the early stages of their training. As a result, they may not yet have fully grasped what it means to "be creative in science."

The data also suggest that these pre-service teachers found it more challenging to distinguish between non-creative and creative incidents in Field 2 (empirical methods of gathering knowledge), as both types received very similar scores. Additionally, items in Field 2 (empirical knowledge gathering) and Field 3 (practical problem-solving), regardless of their nature, generally received higher creativity scores than those in Field 1 (constructing theoretical scientific knowledge). This implies that these pre-service teachers perceive greater potential for creative thinking in hands-on and problem-solving tasks than in more theoretical activities.

To determine if the differences in scores between creative and non-creative incidents were statistically significant, a Wilcoxon signed-rank test for paired samples was conducted (Table 3). The results indicate that score differences were statistically significant for descriptive activities in Topic 1 within both Field 1 (constructing theoretical scientific knowledge) and Field 2 (empirical methods of gathering knowledge), with medium effect sizes (Cohen's d = 0.52 and 0.60, respectively). In Topic 2 of Field 1, the effect was even larger (Cohen's d = 1.04), although no significant difference was found in Field 2. For explanation-based activities, students significantly distinguished between creative and non-creative activities in Field 1 for both Topics 1 and 2, with large effect sizes (Cohen's d = 1.35 and 0.80, respectively), but again, not in Field 2. When evaluating problem-solving activities (Field 3), significant differences emerged in both Topic 1 (small effect, d = 0.25) and Topic 2 (medium effect, d = 0.55). Overall, these findings suggest that pre-service teachers are generally able to identify activities that are likely to foster scientific creativity in the classroom.

To provide an overview of the results, we combined the scores for all creative and non-creative activities by topic and overall. These results, presented in Table 4, show that students assigned higher scores to both creative and non-creative activities in Topic 2 than in Topic 1. This may be due, as Jarvis and Pell (2004) noted, to the fact that most primary teachers (including pre-service teachers) are not science specialists, leading to varied levels of understanding across topics, which could affect their ability to assess creativity promotion in different subjects. In addition, some students awarded high scores – even the maximum of 5 points – to non-creative activities across both topics. As shown in Table 4, the high average score for non-creative activities suggests a limited understanding of scientific creativity and how to nurture it. Nevertheless, the analysis revealed that the score difference between creative and non-creative activities was statistically significant across all cases, with a large effect size for Topic 1 (d = 0.87) and for all items combined (d = 0.90), and a medium effect size for Topic 2 (d = 0.75).

Regarding incidents of non-scientific creative thought (Table 5), these activities also received high scores, with items 11 and 23 scoring similarly to creative scientific incidents in both topics. Although items 12 and 24 received scores closer to those given to non-creative scientific items, the results suggest that these pre-service teachers may struggle to clearly differentiate between scientific and non-scientific creativity.

Table 2: Mean scores awarded to the incidents for fields 1, 2, and 3 (the higher the score, the greater the perceived opportunity for creativity)

Field	Kind of science					
	Description		Explanation		Problem-solving	
	Non-creat.	Creat.	Non-creat.	Creat.	Non-creat.	Creat.
			Topic: Earth, space, and gravity			
Field 1	3.10 (1.11)	3.63 (0.91)	2.59 (1.07)	3.92 (0.89)		
Field 2	3.70 (0.97)	4.25 (0.86)	3.67 (0.98)	3.60 (0.93)		
Field 3					3.54 (1.10)	3.80 (0.95)
			Topic: Electricity			
Field 1	2.70 (1.05)	3.73 (0.93)	2.83 (1.10)	3.64 (0.84)		
Field 2	4.26 (0.93)	4.26 (0.69)	3.95 (1.07)	3.93 (0.86)		
Field 3					3.56 (1.11)	4.11 (0.86)

Table 3: Results of the Wilcoxon signed-ranks test for paired samples (creative vs. non-creative) for the different topics and fields

Field	Kind of science					
	Description		Explanation		Problem-solving	
	Z	p	Z	p	Z	p
Topic 1: Earth, space and gravity						
Field 1	−5.840	0.000***	−10.086	0.000***		
Field 2	−5.741	0.000***	1.085	0.398		
Field 3					−2.587	0.010**
Topic 2: Electricity						
Field 1	−9.036	0.000***	−7.665	0.000***		
Field 2	−0.123	0.902	0.575	0.566		
Field 3					−5.186	0.000***

**significant correlation at the 0.01 level. ***significant correlation at the 0.001 level

Table 4: Descriptive statistics and results of the Wilcoxon signed-ranks test for paired samples for the scores awarded to creative and non-creative incidents in the different topics (Topic 1: Earth, space, and gravity; Topic 2: Electricity)

Type of incident	Min	Max	Mean	SD	Z	p
Topic 1 creative	2.67	5.00	3.79	0.51	−9.686	0.000***
Topic 1 non-creative	1.75	5.00	3.27	0.67		
Topic 2 creative	2.60	5.00	3.93	0.51	−7.816	0.000***
Topic 2 non-creative	1.20	5.00	3.45	0.74		
Total creative	2.82	4.91	3.86	0.43	−9.833	0.000***
Total non-creative	1.56	4.78	3.37	0.64		

***significant correlation at the 0.001 level

To evaluate the impact of prior training and gender on pre-service teachers' ability to distinguish between creative and non-creative scientific incidents, a new variable was created by calculating the difference in scores assigned to creative versus non-creative incidents in science (excluding the four items related to non-scientific creative thought). A Mann–Whitney test revealed that neither gender (U = 2239, Z = −0.502, p = 0.616) nor prior studies (U = 2539, Z = −1.422, p = 0.155) had a significant effect.

Inquiry Skills

The third questionnaire assessed competence in scientific inquiry. Figure 1 displays the average scores for each component evaluated: Problem statement, identification of the DV, identification of the IV, identification of CV, hypothesis formulation, and experimental design. The questionnaire's overall mean score was 1.08 (SD = 0.42), with a minimum of 0.00 and a maximum of 2.00.

Given that Cuevas et al. (2005) designed this instrument for 12-year-old students, the scores achieved by this group of pre-service teachers appear low. These results are consistent with findings by Foulds and Rowe (1996), who reported similarly low scores in scientific procedural skills among Australian primary teacher students. This may reflect a generally low level of scientific literacy among future primary teachers. Verdugo-Perona et al. (2019) noted that pre-service primary teachers enter university with a low level of conceptual knowledge in science, which typically reaches a medium level by the end of their studies. However, their procedural knowledge remains low throughout their 4 years of training.

Table 5: Scores awarded to non-scientific creative activities

Item 11	The children look at pictures of planets while listening to the *Planet Suite*, then use a xylophone to make tunes which suit the Earth, Jupiter, and Mercury.	3.75 (1.11)
Item 12	The teacher has the children write a diary about a long journey on a spaceship giving attention to the tensions of living together.	2.71 (1.05)
Item 23	The children draw pictures of thunderstorms to make a storm frieze for the classroom.	3.71 (1.00)
Item 24	The teacher introduces the phrase, "bright spark," and has the children think up five sentences in which they use it.	3.16 (1.14)

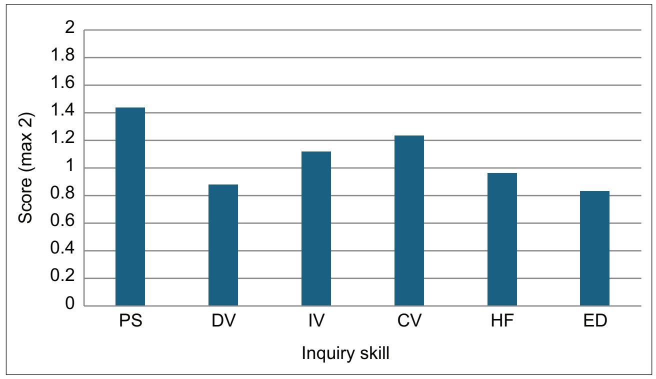

Figure 1: Scores for each element of scientific inquiry

The inquiry skills, ranked from easiest to most challenging, were as follows: 1) Formulating a research question (1.44), 2) identifying CVs (1.23), 3) identifying the IV (1.12), 4) formulating a hypothesis (0.96), 5) identifying the DV (0.88), and 6) designing the experiment (0.82). These rankings and scores align with findings from Chabalengula et al. (2012) for U.S. pre-service teachers and Aydoğdu et al. (2014) for Turkish in-service teachers.

Male (M = 1.06, SD = 0.36) and female (M = 1.08, SD = 0.43) participants showed similar total scores in inquiry skills. As anticipated, a Mann–Whitney test confirmed that this difference was not statistically significant (U = 1778.50, Z = −0.396, p = 0.692). Although students with prior studies in scientific fields scored slightly higher (M = 1.13, SD = 0.40) than those without (M = 1.06, SD = 0.43), a Mann–Whitney test also found this difference to be non-significant (U = 2406, Z = −0.914, p = 0.361). This finding contrasts with a study by Izquierdo-Sanchis and Solaz-Portolés (2022), which reported significant differences in inquiry skills based on prior scientific studies among pre-service teachers.

Table 6: Pearson correlation coefficients and p values (in brackets) between the different variables

Variable	CSE	Ability to differentiate activities	Inquiry skills
CSE	1	0.021 (0.769)	0.091 (0.228)
Ability to differentiate activities		1	0.202 (0.007**)
Inquiry skills			1

**Significant correlation at the 0.01 level

Relationship among Variables

One research objective was to examine the relationship between pre-service teachers' perception of their CSE in science and their actual skills to foster creativity in the classroom – specifically, their ability to distinguish between creative and non-creative science activities and their inquiry skills. To investigate this, Pearson correlations were calculated between CSE scores, the difference between the scores awarded to creative and non-creative incidents in science, and inquiry skills scores, as shown in Table 6.

The results indicate no significant correlation between CSE in science and any of the selected creativity indicators. However, a statistically significant correlation exists between pre-service teachers' ability to differentiate between creative and non-creative activities in primary science and their inquiry skills. This suggests that those with stronger inquiry skills are also better at identifying activities that promote creativity. However, their perceived CSE does not align with either of these abilities, similar to findings from a study on Turkish pre-service elementary teachers, who reported moderate self-efficacy in teaching ability despite limited science knowledge (Cantrell et al., 2003).

DISCUSSION AND CONCLUSION

This study explored the relationship between pre-service teachers' CSE beliefs and their performance in creative tasks. It assessed their ability to differentiate between activities that promote creativity in the science classroom and those of a non-creative nature, as well as their inquiry skills. In addition, the study examined the influence of prior studies and gender on all these variables.

The results from this convenience sample indicated that the participating pre-service teachers displayed a wide range of CSE in science, with the mean value being moderate and comparable to those reported in previous studies (Beghetto et al., 2011; Hartley et al., 2016). Regarding their ability to differentiate between creative and non-creative activities in the science classroom, although there were statistically significant differences between the scores assigned to both types of activities, the outcomes were not entirely satisfactory. The items considered creative yielded results similar to those found in previous studies (Newton and Newton, 2010), showing a clear recognition of these activities as opportunities to foster creativity in students. However, many participants also rated non-creative activities as valuable for developing students' creativity, which was contrary to expectations. This could be attributed to the nature of their training at the teacher education faculty, which emphasized general and cross-disciplinary didactic training with limited focus on disciplinary specialization, particularly in science, both of which are components of pedagogical content knowledge (Gudmundsdottir and Shulman, 1987).

The didactic training received by these pre-service teachers primarily focuses on preparing activities, with greater emphasis placed on the procedure and materials (i.e., what is done and how) rather than on the content (i.e., what must be learned). As a result, when presented with activities that involve manipulation or the use of innovative materials, they often perceive these activities as opportunities to foster creativity, even if the activities themselves are non-creative in nature.

The results indicate that the participants in this study perceive creativity in science as similar to creativity in other school subjects, primarily focusing on "inventing ways of executing actions and proposing novel activities." They do not seem to consider the specific content that needs to be taught and learned, nor the way information is presented – whether it is pre-established or discovered by students. This misunderstanding of creativity in science, from a teaching perspective, may explain the lack of distinction between scores assigned to truly creative activities and those that are non-creative (where all information is provided by the teacher) but placed in novel contexts.

The results from the inquiry skills test were notably low for university students, especially given that the situation presented was appropriate for compulsory education. These results agree with studies in which the scientific creativity of Spanish secondary students is considered moderate/low (Pont-Niclòs et al., 2023; Pont-Niclòs et al., 2024). This raises an important concern for teacher educators, as inquiry skills are considered crucial for fostering scientific and technological literacy, which is essential for the future needs of society.

Interestingly, while pre-service teachers' perceptions of their CSE in science were influenced by prior training, this did not translate into their ability to differentiate between creative and non-creative incidents in science classrooms or into their inquiry skills. These findings suggest that either science training at the secondary education level is insufficient or not focused on promoting scientific creativity. It would be valuable to conduct a similar study in a few years, following the implementation of the PISA creativity test and the new educational law in Spain, which specifically addresses creativity, to examine any potential progress in these areas.

On the other hand, teachers' CSE is believed to be a key factor in fostering creativity in the classroom (Nemerzitski and Heinla, 2020), yet the results of the present study reveal that CSE does not correlate with the actual scientific creativity of pre-service teachers. Other studies have similarly shown that the perception of creativity in pre-service teachers does not align with their performance in creative tasks (Echegoyen-Sanz and Martín-Ezpeleta, 2021). To enhance the real CSE in science for pre-service teachers, targeted actions should be taken since the data from this descriptive study strongly suggest that pre-service teachers lack the requisite skills and knowledge for effective creative science teaching. A vision of science as a creative human activity needs to be promoted. This could be achieved by incorporating research-based learning activities where the creative processes of science, such as proposing research questions and formulating hypotheses, can be applied. In addition, it would be beneficial to integrate specific training programs and activities within the curriculum to help teachers improve their CSE in science. Future intervention studies must be implemented to observe and measure the specific changes that training can produce by analyzing the development of in- and out-of-class activities and the use of material resources aimed at promoting scientific creativity in primary education. This would complement the development of creativity in secondary education, which should also evolve to better foster creativity (Wyse and Ferrari, 2015).

Pre-service teachers need to strengthen their creative self-concept and become more aware of how school science can promote creativity. As part of their training, the non-creative or creative nature of common classroom activities and textbook exercises should be critically analyzed. Although limited, studies on teaching materials suggest that there is room for improvement in the inclusion of activities designed to foster creativity (Trisnayanti et al., 2021). Problem-based or project-based learning, which has been proven to promote creative thinking (Siew et al., 2015), remains underrepresented in Spanish education faculties and should be encouraged.

Studies like the present one (which should be replicated with a larger, more representative sample) highlight the need for teacher training to align with the OECD's emphasis on creativity as a core element of education. It remains clear that if teachers do not cultivate their own creativity, it will be challenging for them to nurture their students' creativity.

ETHICS STATEMENT

The combination of informed consent with anonymity and confidentiality of responses ensures the ethical principles and requirements established by the Ethics Committee of the University of Valencia. Hence, ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements.

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