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Pre-Service Science Teachers' Beliefs About Creativity at School: A Study in the Hispanic Context

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Abstract: The present study examines the beliefs of pre-service science teachers on creativity in science teaching and learning and identifies factors in the school environment that, in their view, can influence students' creativity. A total of 152 Colombian prospective science teachers participated in this study. A questionnaire, with an open and a closed part, was administered to participants. Descriptive and inferential statistical analysis of the qualitative and quantitative data collected was carried out. The results revealed that (a) the concept of creativity held by the participants was incomplete and significantly diverged from expert definitions; (b) they viewed creativity as a universal potential that can be nurtured within the school system; (c) the ability to identify problems and ask challenging questions was rarely selected as a creative personality trait; (d) they demonstrated unclear ideas about the relationship between creativity and intelligence and the role of prior knowledge in students' creativity; and (e) the subject or curricular domain was seen as an important factor influencing students' creativity. From all this, it could be concluded that Colombian future science teachers exhibited flawed concepts of creativity based on poorly articulated beliefs, which is consistent with findings in other international studies.

Keywords: creativity; science education; science teachers; pre-service teachers' beliefs

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1. Introduction

Creativity, particularly within the realm of sciences, has garnered increasing interest in the educational community. UNESCO [1] has emphasized the importance of creativity as a fundamental competency for citizens of today and the future. The PISA program [2] included a specific assessment of creative thinking, manifested in "creative expression" and "knowledge creation and creative problem-solving".

Despite the agreement on their importance [3,4] education in creativity is a new challenge to teachers. Teacher training programs hardly encompass creativity. Moreover, in traditional programs, science is frequently taught as a set of unquestioned truths to be discovered using the infallible scientific method [5]. Consequently, many teachers tend to develop the science curriculum in the way described long time ago by Tobin and McRobbie [6], "*In the enacted curriculum science was represented as a catalogue of facts to be memorised and as algorithmic solutions to problems*". In this conception, there is no room for creativity, and tasks such as problem-posing, deep questioning, or those involving divergent and critical thinking are scarcely considered [7].

As teachers' beliefs and conceptions influence their teaching actions [8,9], it is important to reveal teachers' beliefs about students' creativity in science as the first step to a pedagogical change that entails greater institutional support and new teacher training programs in science education. These new teacher training programs must explicitly include creativity as an important skill to develop. Some studies have obtained evidence of an improvement in teachers' self-efficacy, beliefs, and actions fostering creativity in their students when creativity was explicitly included in teacher training programs [10–12].

The present study aimed at elucidating teachers' beliefs about creativity in science teaching and learning during initial training, and to identify factors that, in their view, can influence classroom practices that enhance creativity. As creativity is scarcely faced in pre-service teacher training programs, teachers' professional thoughts on creativity would depend strongly on their expertise. Therefore, future teachers' thoughts on creativity in science education are probably "beliefs" instead of "conceptions" [13]. Hence, we will refer to teachers' beliefs in the present study.

Since Diakidoy and Kanari's study [14] with student teachers, abundant research has been conducted on teachers' perceptions and actions on creativity in many countries and cultural settings. To the best of our knowledge, only one of these studies included Latin American teachers ([15] included math teachers from Mexico). The current study was conducted in Colombia, within the Latin American context in Colombia, South America, where research on teachers' beliefs about creativity remains scarce.

1.1. Research Questions

The main research questions in current exploratory study focused on the beliefs Colombian future science teachers have on creativity in the school context:

1. What is their concept of creativity in the school context? Does this concept align with those of researchers or with those of other teachers in the international landscape? How do they describe creative behaviors (i.e., students' behaviors teachers consider as creative according with their beliefs)?
2. Do they consider creativity as potentiality in everybody to be educated, or an innate and rare characteristic?
3. How do they conceive creative students?
4. What factors, such as types of tasks proposed, subject domain specificity, curriculum design, instructional and assessment emphasis, or prior knowledge (i.e., students' level of science knowledge) facilitate students' creativity according with future teachers' beliefs?

Experts' conceptions of creativity and its measurable components can provide a foundation for analyzing pre-service teachers' beliefs about creativity in the science classroom. Additionally, reviewing previous studies on teachers' beliefs about creativity can offer valuable insights into how these questions have been addressed in other countries.

1.2. The Concept of Creativity in the Science Classroom

Defining and assessing creativity is inherently challenging [16]. However, experts have reached some consensus on evaluating creativity in educational contexts. In schools, teachers are tasked with fostering "little-c creativity" [17], which focuses on individual and contextual creativity, as opposed to "Big-C Creativity", which is evaluated in the broader context of human history and specialized fields.

A widely accepted definition by Runco and Jaeger [18] describes creativity as the intersection of two key components: originality and usefulness. Simonton [19] further expands on this by adding a third component: non-obviousness (or unexpected nature).

Most experts agree that creativity can be assessed through divergent thinking [20], which includes the components of fluency, flexibility, and originality [21–23]. "Fluency" refers to the number of ideas generated in response to a problem; "flexibility" to the thematic variety of these ideas; and "originality" to how uncommon or frequent the ideas are within a given population. These components have been utilized in recent studies on creativity in science [24] and technology [25] to evaluate the impact of instructional methods on students' creativity [26,27] and to analyze teachers' perceptions of student creativity [28].

In science education, the creativity of an outcome—be it an idea, process, or product—can be evaluated using these components in areas that Newton and Newton [29] identified as crucial for developing key scientific literacy skills: (1) the use and construction of declarative, verbal, theoretical descriptions and explanations; (2) empirical procedures for

describing and explaining entities, their properties, and relationships, and for formulating and testing predictive hypotheses; (3) practical problem-solving.

1.3. Studies on Teachers' Beliefs About Creativity

Various studies on teachers' beliefs about creativity in schools and creative students have been conducted worldwide, with a few examples listed below:

- Cyprus [14,30];
- United Kingdom [31–33];
- USA [4,34–40];
- Canada [41];
- Israel [3];
- Australia [42,43];
- Greece [44–47];
- Finland [48];
- Poland [49];
- Serbia [50,51];
- Kuwait [52,53];
- India [15];
- Pakistan [54];
- Hong Kong [55,56];
- South Korea [57,58];
- Taiwan [59];
- China [60].

Most of these studies are referenced in reviews by Andiliou and Murphy [61], Mullet et al. [62], and Bereczki and Karpati [63]. Other research has explored aspects beyond teachers' beliefs about creativity. For instance, Hetherington et al. [64] recently analyzed the relationship between science and creativity in educators' criteria in an international survey, while Han and Abdrahim [65] reviewed studies on teachers' creativity in higher education.

Main findings in the studies on teachers' beliefs about creativity can be summarized in the following aspects:

1. Teachers universally agree on the importance of fostering creativity in education. Most believe that everyone has the potential to be creative, though some are convinced that creativity has a significant innate component.
2. Teachers and experts hold differing views on creativity, creative products, and creative behaviors. Experts often rely on model-based definitions of creativity, identifying creative behaviors through fluency, flexibility, and originality, and characterizing creative personality traits as open to new experiences, critical, risk-taking, curious, or non-conformist. In contrast, teachers often lack a precise definition of creativity, describing creative products primarily by their novelty or uniqueness and rarely mentioning usefulness or ethical and social implications. Teachers tend to describe creative personalities with adjectives such as imaginative, artistic, original, intellectual, and independent. In controlled studies, most teachers have struggled to associate creative behaviors with divergent thinking, critical thinking, or autonomy, often attributing creative skills to gifted students and conflating creativity with intelligence, talent, and academic achievement.
3. Teachers' practices often contradict their stated commitment to creativity, as noted in reviews by Andiliou and Murphy [61] and Mullet et al. [62]. Many teachers who believed they were effectively teaching for creativity were found, upon expert observation, to misinterpret non-creative activities as creative or lacked a clear understanding of what constitutes a creative activity.
4. Most teachers feel unprepared to teach creative strategies, design creative activities, or foster creativity in their students. Bereczki and Karpati [63] identified several barriers frequently mentioned by teachers, including lack of time, an overloaded curriculum,

inadequate resources, unsupportive school culture, lack of teacher training, difficulties in teaching and assessing creativity, and reliance on traditional teaching methods. Mullet et al. [62] emphasized the lack of teacher training as a critical factor in these challenges, stating that pre-service teacher education must improve to "*enhance their understanding and identification of creative acts and behaviors in students, as well as their ability to design and implement creativity-fostering curricula*" (p. 25).

5. Teachers often equate creativity with the arts. While most acknowledge that creativity can manifest in any discipline, many studies reveal that teachers predominantly associate creativity with visual arts, music, theater, and literature. Although Cropley et al. [66] found no arts bias in teachers' views of creativity, other studies [14,32,37,67] did observe this arts-biased perspective.
6. In the context of science education, teachers widely agree on the inherently creative nature of science. Their responses support ideas such as: "Science requires imagination", "Creativity has a place in the scientific method", "Science should encourage young people to question the world around them", "Science is a creative endeavor", and "Scientific inquiry involves critical questioning" [64]. Newton and Newton [32] found similar agreement among student teachers. However, in Hetherington et al.'s [64] survey, some secondary and higher education teachers argued that a certain level of disciplinary knowledge is necessary for creativity to emerge. Consequently, they believe that science-specific activities like question-asking or problem-posing are unlikely to be creative for most students. This belief often leads to a preference for knowledge-based learning activities over other types of science classroom activities.

All these studies involve teachers and pre-service teachers across primary, secondary, and higher education, as well as various curricular subjects. However, studies like Kettler et al. [68] found no significant differences in most teachers' beliefs based on grade level or subject area.

2. Materials and Methods

2.1. Participants

The sample consisted of 152 future science teachers in their final semesters (8th, 9th, and 10th) at two large universities in prominent Colombian cities. Of these, 52 were enrolled in the Natural Sciences and Chemistry teaching training program (27 women and 25 men), and 100 were in the Physics and Mathematics teaching training program (33 women and 67 men). None of the participants identified as non-binary.

All intact groups from each semester and university were included. While the participants were representative of future science teachers in Colombia, the sampling was not random. Therefore, the results of this study should not be generalized.

2.2. Instrument

Data were collected using the questionnaire developed by Diakidoy and Kanari [14], which consists of two sections: A and B. Section A aims to explore teachers' open conceptualization of creativity within the school context. Section B includes 20 multiple-choice items designed to refine the beliefs expressed in Section A by providing explicit ideas and options for selection. These items can be categorized into the following aspects (the specific wording of the items will be detailed in the Results Section):

1. Concept of creativity: 1A, 5A, 3B, 12B, 13B, 17B, 18B.
2. Distribution of creativity: 1B, 4B, 8B, 15B
3. Creative students: 2A, 5B, 6B, 9B, 10B, 11B, 16B.
4. Facilitation of creativity: 3A, 4A, 6A, 7A, 2B, 7B, 14B, 19B, 20B.

The questionnaire was used in its original form, with no additional validation beyond the translation into Spanish. First, a bilingual expert translated the questionnaire from English to Spanish. Then, three additional bilingual professionals reviewed the translation to identify any discrepancies between the translated and original versions, ensuring equivalence in content and meaning. This process led to some adjustments in the wording

of certain items. A pilot test was subsequently conducted with a group of 20 participants from the fields of natural sciences and physics (not included in the current study's sample) to assess the clarity and comprehension of the translated questionnaire. Based on the feedback, minor modifications were made to the instructions to enhance clarity. The final version was deemed suitable for use with the pre-service teacher sample.

The original questionnaire and the Spanish version used in the current study can be found at https://udeaeduco-my.sharepoint.com/:w:/g/personal/tarcilo_torres_udea_edu_co/EWs6cHwpBWpHrmu-ye_wG34BzS4ychVul3ZkkheZvB-8Eg?e=jOwr4J.

2.3. Data Collection Procedure

Authorization was obtained from the coordinators of the teacher training programs at each university to administer the questionnaire in classrooms on prearranged dates and times. Participants were informed about the study's purpose, and their voluntary participation was requested. Full anonymity was assured and maintained throughout all stages of this study. Written instructions were provided, and any questions were clarified before participants completed the questionnaire. The questionnaire was administered individually through the Google Forms application, accessible via email links and QR codes. Participants were instructed to contextualize and respond to the items in relation to science education.

2.4. Data Analysis

R-Studio and Excel software were used for the descriptive and inferential statistical analysis of the qualitative and quantitative data, respectively. Textual qualitative responses were categorized using codes derived from a text mining technique. Two independent researchers coded a subset of participants' open-ended responses using these codes. Some adjustments were made to enhance clarity and detail in the coding process. After applying the revised codes to a new subset of responses, inter-rater simple agreement reached 91%, which was deemed sufficient. The coded data were then organized in Excel format for descriptive analysis.

3. Results

Items in the questionnaire were analyzed and grouped to cover various aspects of this study: the concept of creativity, its distribution among students, the characteristics of creative students (in terms of personality, intelligence, and academic performance), school environment and teaching factors influencing creativity, and the relationship between prior knowledge and creativity.

3.1. The Concept of Creativity

Student teachers provided a variety of definitions of creativity in item 1A. Most conceived creativity as a capability or ability (63.2% of participants). For example (examples will be shown in their original Spanish and translated into English):

> Participant #4, "*La capacidad para crear algo nuevo o encontrar distintas soluciones de problemas (. . .) basta con que sea novedoso para la persona que lo ha ingeniado* [*The ability to create something new or find different solutions to a problem (...) it's enough for it to be novel to the person who has devised it*]".

Others (24.3%) defined creativity as a process or a way or manner to do things. For example:

> Participant #32, "*La creatividad es el proceso inherente al ser humano que consiste en unir ideas de cualquier índole y crear algo con base en ellas* [*Creativity is the inherent human process that involves connecting ideas of any kind and creating something based on them*]".

Terms such as "generation", "invention", and "construction" (ideas, representations, and procedures) were frequent (72.4%).

Among the products mentioned in the free definitions, "problem solving" was explicitly mentioned in only 18.4% of the sample, although different outcomes of creativity (i.e., "creativity as a product") were mentioned by 33.6% of participants.

Some participants associated creativity with imagination and inventiveness (18.4%).

Originality was explicitly mentioned by most participants (66.4%), but usefulness was not (0%). Usefulness or appropriateness as a component of creativity was reexamined in item 18B, "*A creative product does not necessarily have to be appropriate: A child who discovers a new strategy for performing a three-digit addition is creative, even if the strategy leads to an incorrect solution*". Only 53.3% of participants agreed with the statement. Fluency, flexibility, and ethical considerations were not mentioned at all.

Item 5A asked future teachers to provide examples of how creativity manifests in schools. Table 1 presents the examples collected in the current study.

Table 1. Selected examples of situations and activities considered as creative by the participants.

Manifestations of Creativity (Item 5A)
Teaching physics through science fiction or cinema.
An 11-year-old student, in fifth grade, needed to create a story that demonstrated the importance of numbers. The story she wrote included sentences like "Ramón woke up and heard the news saying it's '#$%$#' (sic) in the morning". The student substituted numbers with "scribbles", and reading them produced unintelligible but amusing sounds. The entire story followed this dynamic, and we could understand her intention to highlight the importance of numbers in everyday life, and how they suddenly disappeared.
Creating an educational game for teaching mathematics using recycled materials.
Developing video games that explain physical phenomena.
Programming a physical system on the Microbit platform.
In an exercise to determine the area of an irregular shape, the teacher suggested drawing lines from the vertices of the figure. However, a student, without consulting the teacher, used a method of correspondences and proportions to achieve the same result.
Moments when the student solves a problem correctly without following the process shown by the teacher or a previous one by the student.
By recreating a discrepant experiment using available materials.
When students create representations of phenomena that are different from the usual ones in textbooks.
When students ask questions, when they conduct experiments, or when it comes to arguing a response.

Only 4.6% of student teachers gave examples related to divergent thinking. Surprisingly, only 9.9% of future science teachers mentioned problem-solving as an opportunity to manifest creativity and only 2.6% mentioned asking questions as related to creativity. In the collected examples, no mention was made of science-specific activities, such as defining, explaining, predicting, measuring, or interpreting. Experimenting was mentioned by 5.9% of the participants and modelling by only one participant.

Items 3B (general or domain-specific ability), 12B (individual or social relevance of creative outcomes), and 13B (personal dimension of school creativity) complemented the participants' visions of creativity. A large percentage of participants, 94.1%, agreed with the statement of item 3B, "*Creative children manifest their creativity in a variety of domains and in a variety of ways.*" In item 12B, only 28.9% of participants chose the option, "*Creative outcomes are considered creative if they are novel to the social group in which the person producing them belongs*". Item 13B presented a concrete example of a student's behavior at school and asked for their creative or reproductive character, "*Children who discover on their own how to use a paper clip are creative*". In the present study, 77.0% of future teachers agreed with the statement.

Finally, in item 17B, "*The extent to which people manifest creativity depends on (environment, knowledge, domain, personality, tasks, intelligence)*", future teachers selected Environment (84.2%), personality (80.9%), and knowledge (68.4%) as the most influential factors, and task as the least influential.

3.2. The Distribution of Creativity

In item 1B, "*Some children are more creative than others*", 70.4% student teachers agreed; only 13.8% agreed with item 8B, "*Creativity is not a characteristic of all individuals*"; and 46.1% declared that creativity is not common in the school population (item 4B).

Complementarily, a large percentage of future science teachers, 83.6%, believe that creativity can be facilitated in everybody (item 15B), and more still believe that teachers can facilitate creativity in their students (item 4A).

3.3. Creative Students

Table 2 shows the participants' selection of personality traits that they believe to be associated with creative students (item 5B).

Table 2. Selection of personal traits associated with creativity identified by different percentages of participants in the present study.

Personal Traits (Item 5B)	Percentage of Participants
Imagination	98.7
Self-confidence	90.1
Autonomy	84.9
Ability to set own goals	75.0
Critical thinking	75.0
Many interests	67.1
Artistic inclinations	60.5
Independence	57.9
Ability to set own rules	52.0
Intelligence	52.0
Willingness to accept guidance	52.0
Divergent thinking ability	51.3
Innate talent	34.9
Convergent thinking ability	28.3
Need for recognition and acceptance	23.7
Need for praise and reinforcement	18.4
Problem finding ability	15.8
Fear of failure	9.9
Need to avoid mistakes	8.6
Analogical reasoning ability	0.0
Obedience to rules and expectations	7.9

In Table 2, intelligence was selected as a trait of creative personality by 52.0% of the sample. However, in item 2A, "*What do you think is the relationship between creativity and intelligence?*" 84.2% of the future science teachers described creativity as positively related, usually considering creativity as a form of intelligence.

> Participant #13, "*La creatividad es una manera especial de desarrollar la inteligencia* [*Creativity is a special way of developing intelligence*]".

Nevertheless, the relationship between intelligence and creativity does not imply equivalence, as 53.3% of participants answered positively in item 11B, "*Do you think it is possible for a very intelligent person not to be creative?*"

A positive answer on item 9B, "*Is creative thinking different from the thinking required to solve problems at school?*", was obtained in almost a half of the sample, 44.7%. These future teachers believe that problems posed to students at school are mostly reproductive, as expressed by some of them:

> Participant #3, "*Casi nunca se requiere creatividad en la escuela, ya que nuestro sistema está planteado de forma que se enseña rígidamente como solucionar los problemas* [*Creativity is almost never required in school because our system is designed in such a way that problems are rigidly taught how to be solved*]".

The other 55.3% of the sample associated problem-solving in school with creative thinking:

> Participant #53, "*No existe una sola manera de resolver un problema escolar, por lo que la creatividad puede permitir encontrar diferentes maneras de resolver dichos problemas* [*There is not just one way to solve a school problem; creativity can allow for finding different ways to solve these problems*]".

On the other hand, item 10B, "*Is creative thinking different from the thinking used to solve problems in everyday life?*", obtained a negative answer in 70.5% of the sample. This suggests that, in opinion of most future science teachers, everyday life proposes mainly challenging, creative problems to solve:

> Participant #2, "*Para la vida misma se requieren inteligencias que cubran las necesidades de solución de problemas. de formas creativas* [*For life itself, intelligences are required that address problem-solving needs in creative ways*]".

Good students were conflated with creative ones by a significant percentage of participants, as only 61.2% agreed to Item 6B, "*Good students do not have greater chances of being creative than average students.*"

Academic performance was not considered in general as a good index of students' creativity, as only 24.3% of participants agreed with item 16B, "*Academic performance is a good indicator of creativity*".

3.4. Facilitation of Creativity

This dissociation between academic performance and creativity could be caused by inappropriate programs, as asked in items 6A, "*The national curriculum allows for the manifestation of creativity in the school*", or by unsupportive school environment, as asked in item 19B, "*Pupils have a lot of opportunities in school to manifest their creativity*". The ideas were agreed with by 51.3% and 73.0% of student teachers, respectively.

Table 3 details the environmental factors that, according to the participants selection, facilitate the manifestation of creativity (item 20B).

Table 3. Selected environmental aspects facilitating creativity in the classroom.

Environmental Aspects (Item 20B)	Percentage of Participants
Opportunities to correct one's own mistakes	80.9
Emphasis on autonomy and independence	79.6
Emphasis on discovery learning	79.6
Emphasis on collaborative learning	75.7
Emphasis on intrinsic motivation	74.3
Opportunities to question theories and assumptions	74.3
Acceptance of all work outcomes	48.0
Emphasis on knowledge	42.1
Frequent and detailed feedback	41.4
Choice in tasks	34.2
Use of external rewards	32.9
Emphasis on competition	32.2
Frequent praise	29.6
Frequent evaluation of outcomes	28.9
Emphasis on following instructions	12.5

These facilitating aspects can be accommodated to varying degrees in different school subjects. Item 7A asked, "*Please list ten (10) subjects or domains in which you consider it likely for a person to manifest his/her creativity*". Table 4 shows the more frequent domains and subject-areas proposed by the participants.

Table 4. Selected examples of ways to promote creativity in students, as proposed by the participants.

Domains and Subject Areas Facilitating Creativity (Item 7A)	Percentage of Participants
Arts	33.6%
Music	32.9%
Games	19.7%
Science	15.8%
Literature	9.2%
Dancing	7.9%
Technology	7.2%
History	6.6%
Cooking	2.0%
Social interactions	1.3%

The domain of history was specifically addressed in item 14B, "*Could someone manifest creativity in the domain of history*?" When asked specifically, 40.1% if future science teachers showed conceptions of history allowing for creativity. This percentage was higher than 6.6% of mentions to history, observed in item 7A.

In item 4A, "*Can teachers facilitate creativity in pupils? If yes, in what way? If no, why not?*", all future teachers but two (98.7%) responded 'yes'. Justifications contained different arguments, usually unspecific, as can be seen in Table 5:

Table 5. Selected examples of ways to promote creativity in students, as proposed by the participants.

Teachers Can Facilitate Creativity in Pupils. . . **(Item 4A):**
Implementing practices that awaken students' curiosity.
Using a variety of classroom resources that pique students' curiosity, stimulate their thinking, and guide their methodology towards knowledge creation, whether through experimentation, inquiry, art, or other methods that can enhance students' creativity.
Through teaching strategies that include reading and writing components, for example, the works of Jules Verne could foster creativity in physics education.
Through literature, which invites readers to create scenarios based on what they read, whether fantastical or realistic stories, compelling the brain to imagine and see things differently.
When they are allowed to solve problems using various tools instead of being limited to a single one.
Creating images, characters, activities, readings, dynamics, and situations in which students can choose academic, intellectual, and imaginative tools, among others.
Providing activities open to discussion that can be solved in multiple ways.
Children are more creative when taught through emotions and play, when they are allowed to interact with their peers, and when they are listened to.
When they are given a leading role, presented with challenges, invited to create strategies, and given the opportunity to express their ideas to solve problems, considering the diversity of approaches.

Item 2B proposed different types of tasks and asked the participants, "*Indicate which of the following tasks you consider likely to elicit or facilitate creativity*". Future science teachers globally agreed on their preferences for open-ended questions (91.4%) over closed-ended questions (3.9%), for questions and problems that take multiple responses (85.5%) over single correct response (7.2%) or well-defined problems (0%), and for questions and problems for which pupils have relevant prior knowledge (71.1%), although questions and problems for which pupils have little or no relevant prior knowledge were also selected for 46.7% of student teachers. The familiarity with the questions asked or problems posed were considered not a clear factor, as 51.3% preferred unfamiliar and 55.9%, familiar problems.

The relationship between prior knowledge (i.e., the level of science knowledge) and creativity was explored in items 3A and 7B. A significant 84.2% of responses to item 3A, "*What do you think is the role of prior knowledge in creativity?*" emphasized the importance of prior knowledge for students to exhibit creative behaviors. For instance:

Participant #28, "*El conocimiento previo sirve como base para la creatividad, ya que se debe de partir de algo que se conoce para generar nuevas formas de éste* [*Prior knowledge serves as a foundation for creativity, as one must start from something known to generate new forms of it*]".

However, few student teachers (6.6%) also mentioned prior knowledge as a possible limiting factor for creativity, when it is "frozen knowledge":

Participant #150, " *(. . .) a veces, tener demasiado conocimiento puede limitar la creatividad. Puede hacer que las personas se sientan atrapadas en las formas convencionales de pensar o les impida ver más allá de lo que ya saben* [*(. . .) sometimes having too much knowledge can limit creativity. It can make people feel trapped in conventional ways of thinking or prevent them from seeing beyond what they already know*]".

Some other participants (5.3%) declared than prior knowledge is not necessary or even a disadvantage for creativity:

Participant #36, "*Considero que la creatividad es espontánea y surge sin necesidad de un conocimiento previo* [*I believe that creativity is spontaneous and arises without the need for prior knowledge*]".

In addition, 61.8% of the sample disagreed with item 7B, "*When a person has a high degree of knowledge in an area, then it is difficult for the person to be creative when working in that area*".

4. Discussion

This study aimed to examine the beliefs of prospective science teachers in a Hispanic context (Colombia) regarding creativity, using the questionnaire developed by Diakidoy and Kanari [14]. Four key areas were identified: the concept of creativity; its distribution among students; characteristics of creative students—including personality, academic performance, and intelligence; the relevance of prior knowledge; and the teaching and school environment factors that influence creativity.

4.1. The Concept of Creativity

The concept of creativity held by the participants was incomplete and significantly diverged from expert definitions, such as those reported in several previous studies [63]. The analysis of the free definitions provided by the participants revealed that most prospective teachers primarily perceive creativity as a human ability or capacity (67.1% of participants) to solve problems (78.3%) or to generate ideas and products (57.3%) in an original or novel manner (66.4%), leveraging prior knowledge and past experiences (68.4%). Some international reports have identified teachers' conception of creativity as an ability [30,48], but in others, this seems to be an inference made by the authors from implicit information, rather than a concept explicitly used by the participants (as noted by Andilou and Murphy [61] in their review). Additionally, in some studies, participants were provided with pre-formulated statements, including terms like "skill" or "ability", as options in multiple-choice questions [15,52,67].

Although only 21.1% of participants in the current study defined creativity as a "process", this conception has been prevalent in a significant portion of participants in most international studies: 86.7% in Rubinstein et al. [40], 65.3% in Diakidoy and Kanari [14], 50% in Daskolia et al. [44], and 37% in Pavlovic and Maksic's [69] study with university teachers. Similarly, studies by Kampylis et al. [45], Liu and Lin [59], and Park et al. [58], among others, reported that teachers conceptualized creativity as a mental or physical "activity" or "action".

Originality is widely recognized as a key component of creativity by experts [18,19] and is consistently mentioned in studies on the subject. In the present study, 66.4% of student teachers associated creativity with generating original or novel products, ideas, or procedures. This percentage aligns closely with those reported in other studies, such as 63.3% in Diakidoy and Kanari [14] and 64.8% in Rubinstein et al. [40]. It is lower than the

88.2% reported by Aljughaiman and Mowrer-Reynolds [35] but higher than the 25% found in Daskolia et al. [44].

Usefulness or appropriateness was not mentioned by participants in this study when defining creativity, a pattern consistent with most studies on teachers' definitions of creativity (see reviews by Mullet et al. [62] and Han and Abdrahim [65]). In some studies, usefulness was explicitly mentioned by teachers, though less frequently than originality (20.6% in Rubinstein et al. [40]; 10.2% in Diakidoy and Kanari [14]). Despite this common omission, 46.7% of student teachers in the current study considered a specific procedure (the example given in item 18B) that was original but inappropriate as non-creative. This percentage is higher than the 24.5% reported by Diakidoy and Kanari [14]. This suggests that the appropriateness of outcomes is significant for nearly half of the participants in this study, but only when creativity is contextualized within specific classroom tasks that teachers typically assess as correct or incorrect.

When asked to provide examples of activities that foster creativity, student teachers primarily linked creativity to the type of activity (e.g., hands-on, artistic), the teaching methods used (e.g., student-centered, active), and the resources employed (e.g., new technologies, games, video games), regardless of how these activities were actually implemented or the opportunities they provided for creative processes and outcomes. The reasoning behind why these activities were considered creative was never articulated. Thus, in the participants' beliefs, creativity appears to be tied to student motivation, similar to findings in other studies. For example, chemistry teachers in Tomasevic et al. [51] associated laboratory practice with creative activities, while experienced science teachers in Liu and Lin [59] justified the use of fun and inquiry-based activities to promote creativity. This emphasis on fun, hands-on activities was also noted by Huang and Lee [56] and Rubenstein et al. [40].

In this study, 77.0% of future teachers considered the example in item 13B to be creative, which is similar to the 69.4% reported in Diakidoy and Kanari's [14] study. This suggests that participants view creativity as an individual trait rather than a social or collective one, consistent with their responses to item 12B, where only 28.9% chose the option stating that "*creative outcomes are considered creative if they are novel to the social group to which the person belongs*". Thus, the collective and social aspects of creativity were not deemed important, unlike in the views of many Eastern teachers.

4.2. The Distribution of Creativity

As observed in many similar studies with teachers [4,33,36,41,53,57,67], Colombian future science teachers view creativity as a universal potential that can be nurtured within the school system. In this study, 83.6% of participants believed that creativity can be developed in everyone (item 4A), which is close to the 93.9% reported in Diakidoy and Kanari's [14] study. Additionally, 98.7% of participants believed that teachers play a role in this development (item 15B).

However, the comparison of responses reveals some inconsistencies. While 70.4% agreed with the statement "*Some children are more creative than others*" (item 1B), 86.2% disagreed with "*Creativity is not a characteristic of all individuals*" (item 8B), suggesting that participants believe every child is creative, but some are more so than others. Yet, 46.1% indicated that creativity is not common in the school population (item 4B, "*How often do you think an educator encounters creative children?*"). This could suggest that participants believe environmental factors in schools inhibit the expression of creativity. However, this is inconsistent with the 73.0% agreement on item 19B, "*Pupils have a lot of opportunities in school to manifest their creativity*". Therefore, it is also possible that some student teachers believe in an innate factor influencing creativity, as reported in other studies [34,46,47,51].

4.3. Creative Students

Previous studies have examined teachers' beliefs about the traits of creative students in depth [39,49,55,70]. The results of the present study align with these findings. Imagination, self-confidence, autonomy, the ability to set one's own goals, lack of obedience to rules, and

critical thinking were the most commonly identified traits of a creative personality (selected by over 75% of the sample). In contrast, traits such as convergent thinking were selected by only about half of the participants. Additionally, a large majority of future teachers (over 90%) did not associate creativity with a need to avoid mistakes or a fear of failure.

Remarkably, and contrary to the emphasis in other studies [64], the ability to identify problems and ask challenging questions was rarely selected by participants. This is notable given that creativity in science and engineering has historically been demonstrated through asking insightful questions and identifying new problems. This suggests that future science teachers may be more focused on problem-solving than problem-posing, likely because they have not been exposed to such tasks during their education.

The lack of expert knowledge about creativity among the sample is evident in the fact that half of the participants did not select divergent thinking as an important trait of a creative personality. This finding aligns with Aljughaiman and Mowrer-Reynolds [35] but contrasts with results from other studies [14,59].

The relationship between creativity and intelligence among future science teachers was generally unclear, likely due to a lack of understanding of expert concepts of both creativity and intelligence. Most participants (84.2%) believed that creativity is a form of intelligence (compared to 73.5% in Diakidoy and Kanari [1]). This confusion between intelligence and creativity has also been observed in other studies [34,41,46,50,54]. However, half of the current study's participants did not conflate the two, agreeing that a person can be very intelligent but not creative (item 11B).

The concept of a creative student was also not conflated with that of a "good student" or one with high academic achievement.

4.4. Facilitation of Creativity

About half of the participants viewed school programs as inhibiting the proper manifestation of creativity, despite most believing that schools provide ample opportunities for students to express their creativity—an apparent contradiction. Participants' suggestions for fostering creativity (item 4A) focused primarily on surface and motivational factors, such as novel teaching methods involving literature and the arts, hands-on activities, or "active" teaching strategies like brainstorming or debating. However, these suggestions did not address activities that genuinely develop creativity in students, such as problem-solving, question-asking, or tasks involving scientific inquiry. Creativity was indirectly associated with concepts like imagination, curiosity, emotions, or freedom, and there were no solid arguments linking teaching actions to key creativity components like originality, usefulness, flexibility, or fluency.

Motivational factors also guided U.S. teachers' beliefs in Hong and Kang's [57] study, where teachers believed fostering creativity primarily required providing environmental and emotional support. The superficial association of certain activities with fostering creativity may stem from a lack of informed criteria on creativity and its pedagogy. Previous studies have found that teachers often perceived non-creative activities as creative [47,52]. In science education, Al-Abdali and Al-Balushi [71] and Newton and Newton [29] reported that teachers lacked clear ideas about what constitutes a creative activity and struggled to differentiate creative tasks from reproductive ones. Similarly, Meyer and Lederman [38] conducted a study with secondary science teachers who believed they were fostering creativity in their students, but careful observation of their classroom practices revealed that the tasks were neither creative nor conducive to promoting students' creativity.

The subject or curricular domain was also seen as an important factor influencing students' creativity according to Colombian student teachers' beliefs. As in several studies conducted in various countries [14,31,34,35,42,45], creativity was strongly associated with the arts. In this study, Colombian future science teachers were asked in item 7A to identify subjects or domains where creativity is most likely to be manifested. "Arts", in general, and "Music", specifically, were mentioned twice as often as "Science" and four times more

than "Technology", despite the participants being future science teachers. This aligns with the findings of the aforementioned studies.

However, when asked directly, the percentages shifted, as seen in Cachia and Ferrari's [67] survey, where most European teachers (86%) disagreed with the statement, "*Creativity is only relevant to visual arts, music, drama, and artistic performance*". In the current study, item 2B presented participants with non-artistic tasks as potential avenues for creativity. A high percentage of student teachers selected open-ended questions and multiple-answer problems—tasks closely associated with science and math education—mirroring the results of Diakidoy and Kanari [14].

In addition, tasks like discovery learning or collaborative learning, which were seldom mentioned in other items, were frequently identified in item 20B, "*Which of the following environmental aspects do you consider necessary for the facilitation of creativity?*", when explicitly offered. The opportunity to correct one's own mistakes was the most frequently selected factor for facilitating creativity, underscoring the importance of developing metacognitive and self-regulation skills—areas previously unmentioned.

To complete this diffuse picture of creativity, creative students, and how to facilitate creativity in schools, participants attributed the extent to which creativity can be manifested primarily to environmental and personality factors, with knowledge playing a moderate role (item 17B). Tasks were generally seen as the least important factor, suggesting that prospective teachers believe creativity depends less on classroom activities and more on innate traits (like personality) and the environment. This view is not entirely consistent with the belief that creativity is universal and can be developed in school.

Participants in this study demonstrated unclear ideas about the role of prior knowledge in creativity within the school context. Although 84.2% of future science teachers considered prior knowledge a prerequisite for developing creativity (item 3A), their beliefs were similar to those of most science teachers in the international survey by Hetherington et al. [64].

Moreover, 61.8% of participants did not associate a high level of knowledge with a lack of creativity (item 7B). Comparing responses to items 3A and 7B, only 66.1% of future science teachers were consistent, indicating that the relationship between prior knowledge and creativity remained unclear for most participants.

Other studies, such as Liu and Lin's [59], observed that science teachers neglected the importance of convergent thinking in creativity, and thus the relevance of prior knowledge.

The training that primary or secondary education teachers receive influences whether they develop domain-specific or domain-general conceptions of creativity, as observed by Leikin et al. [15] in Mexico. Primary teachers often associate creativity with creating fun, game-based activities, particularly in arts-related subjects. Liu and Lin [59] found that primary science teachers in Taiwan tended to overlook the importance of convergent thinking, and then, of prior knowledge in fostering creativity. In contrast, secondary teachers are more likely to connect creativity with deep thinking and the ability to perform specific disciplinary tasks, such as problem-posing, problem-solving, and asking challenging questions in science and mathematics—areas where prior knowledge is crucial, as seen in Romanian math teachers [15].

In the present study, a large percentage of participants (94.1%; similar to the 81.6% reported by Diakidoy and Kanari [14] viewed creativity as general-domain—independent of any specific domain (item 3B). This suggests that Colombian future science teachers hold beliefs about the relevance of prior knowledge in creativity similar to those of primary school teachers. This suggests that these future science teachers do not yet know how to integrate their beliefs about creativity with their specialized pedagogical knowledge in science.

5. Conclusions

Colombian pre-service science teachers demonstrated flawed and poorly articulated concepts of creativity, mirroring findings from other international studies. Their definitions of creativity often omitted essential components of creative processes and products, such as

fluency, flexibility, and appropriateness, as well as the teaching strategies necessary to foster creativity in students. Additionally, aspects such as the ethics of creative processes, their collective and social dimensions—important to teachers in some Eastern countries—were also absent. When describing creative activities in the classroom, participants primarily emphasized activities where students engage physically, remain active, or use ICTs. These findings address the first research question by highlighting that Colombian pre-service teachers' conceptions of creativity align with international tendencies but are also characterized by notable gaps, particularly in their understanding of students' creative behaviors.

Most participants believed that creativity can be cultivated in all students, emphasizing the teacher's role in this development. However, a significant portion also suggested that they perceive creativity as being influenced by innate factors, indicating that they do not entirely reject the notion of creativity as an inherent characteristic. This insight provides a nuanced answer to the second research question, suggesting that participants hold a dual perspective on whether creativity is developed or innate.

Regarding the third research question, which explored the traits of creative students, the trainee teachers emphasized imagination, self-confidence, autonomy, goal-setting abilities, non-conformity to rules, and critical thinking. However, they appeared to undervalue the importance of convergent thinking and problem identification and exhibited some confusion between the concepts of intelligence and creativity.

The fourth research question addressed factors that promote student creativity in the classroom. The future science teachers in this study primarily focused on superficial and motivational factors, such as manipulative activities and teaching strategies where students take an active role. In contrast, they overlooked genuinely creative activities like open problem-solving, inquiry tasks, and question-asking. Furthermore, these teachers demonstrated unclear ideas about the role of prior knowledge in creativity, resulting in a vague understanding of the relationship between domain-general and domain-specific creativity.

In conclusion, Colombian pre-service science teachers display a clear lack of professional preparation to effectively nurture creativity in the classroom. This deficiency likely stems from an absence of targeted training on creativity within teacher education programs. Therefore, the findings of this study underscore the urgent need to address this gap in pre-service teacher education by integrating more comprehensive training on fostering creativity in school settings.

This study has clear limitations. First, the sample was not representative of all Colombian science teachers, as it was not randomly selected and only included participants from two major universities in two principal cities. Second, a specific questionnaire was used, but its reliability was not assessed in this study. Consequently, the findings should be interpreted with caution, and further research in similar contexts is needed before making concrete recommendations for teacher training programs aimed at fostering creativity in the classroom.

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Institutional Review Board Statement: It is important to emphasize that, prior to the administration of any research instrument, formal authorization was requested from the principals of the participating educational institutions, as stipulated by the guidelines from the Medellin Mayor's Office. Furthermore, during each session, participants were presented with an informed consent form, which they were encouraged to review and sign voluntarily, ensuring full transparency regarding the purpose of the study and their autonomy in deciding whether to participate. It is essential to highlight that our research adhered rigorously to the ethical principles required for working with adult participants. First, all participants willingly engaged in the study, and their right to confidentiality and anonymity was upheld throughout the process. No financial, academic, or other forms of compensation were offered, ensuring that their participation was entirely free from external influences. Moreover, since the research did not involve minors, there was no need to seek additional permissions from external authorities. Nevertheless, we have strictly adhered to all relevant bioethical standards and can readily provide you with the ethical protocol for your review and records, assuring that the research process has been conducted according to the highest standards of ethical responsibility.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The datasets presented in this study are available upon request from the corresponding author, in the following link. https://drive.google.com/drive/folders/1emb3rosax7HMIHFaPmO6do0h2G3k5xTg?usp=drive_link.

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