

# Ph.D. Students' Perceptions of Creativity during Doctorate in Science and Technology at NOVA Lisbon University

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*Received July 12, 2023; Revised September 29, 2023; Accepted October 24, 2023*

## **Cite This Paper in the Following Citation Styles**

(a): [1] Isabel Ribau, "Ph.D. Students' Perceptions of Creativity during Doctorate in Science and Technology at NOVA Lisbon University," *Universal Journal of Educational Research*, Vol. 11, No. 11, pp. 193 - 206, 2023. DOI: 10.13189/ujer.2023.111101.

(b): Isabel Ribau (2023). *Ph.D. Students' Perceptions of Creativity during Doctorate in Science and Technology at NOVA Lisbon University*. *Universal Journal of Educational Research*, 11(11), 193 – 206. DOI: 10.13189/ujer.2023.111101.

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**Abstract** To perform research, researchers must have scientific skills, communication skills, teamwork and collaboration, organization and time management, attention to detail, problem-solving, data organization and analysis, as well as leadership and interpersonal skills. However, to develop new and cutting-edge knowledge, they should be creative. Creativity is critical for developing original project research in the Ph.D. journey and is a requirement to have a doctoral degree. Ph.D. students in science often apply for scholarships that are connected to their supervisor's project as they may not have sufficient knowledge to construct their own research project at the beginning of their doctorate. They also need time to be integrated into the research work, to create a sense of belonging, and most of the time this implies "fitting the mold" and at the same time forging scholarly identity. So, the development of creativity, originality, and novelty in this context is difficult, as students are "encapsulated" in the supervisor's project or research team project, and achieving doctorateness in these conditions is challenging. This study explores creativity development among doctoral students in a Portuguese higher education institution. An exploratory case study was conducted where doctoral students completed a survey at the Science and Technology School of NOVA Lisbon University. The survey focused on supervisors' and students' attitudes toward creativity development, teaching and learning methodologies, and types of tasks that can foster creativity

at the doctoral level. Ph.D. students don't see themselves as capable of "pushing the boundaries" of scientific knowledge, and they don't recognize their supervisors as creative persons. Nevertheless, they recognize the supervisor's effort to develop creativity during the doctorate, and the necessity of participating in scientific meetings and conferences to trigger and foster creativity. The research limitation is the number of participants.

**Keywords** Creativity, Scientific Creativity, Scholar Identity, Doctoral Education

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## 1. Introduction

Creativity plays an important role in science as it helps to generate new ideas, theories, and approaches to solving problems. Scientists need to be creative to identify interesting research questions, develop hypotheses, design experiments, and interpret data. Creativity in science can also lead to the development of innovative technologies and solutions to complex problems. This is evident in fields such as medicine, engineering, and environmental science where creativity has led to new inventions, therapies, and sustainable practices. Moreover, creativity is essential in science communication as it allows researchers to convey complex ideas and findings to diverse audiences using

engaging and relatable methods. This helps to inspire interest in science and promote public understanding of the importance of scientific research. Creativity is also an essential component of scientific thinking and practice. Scientists must think critically and creatively to develop new knowledge, solve complex problems, and communicate their findings effectively to others.

In this context, this research work will look, through the lens of PhD students, at creativity, immersed in the natural sciences and engineering field.

### 1.1. Creativity

What is the meaning of creativity? The answer to this question relies on education and life experience, as well as the perception of each science field. But for all societies, there are common meanings. Creativity means creating something new (original) and innovative with novelty. It must be useful and meaningful for someone and should imply well-being. Their significance is personal and is related to the experiences and the area of formation of each person. Creativity is a complex and multidimensional construct, and various models, theories, and frameworks were proposed to understand and explain it [1]. In 2012, Runco and Jaeger [2] published a paper entitled “The Standard Definition of Creativity” as they saw the necessity to clarify it. Creative work must be novel, accepted by the field stakeholders, and must be a step ahead regarding previous knowledge and that depends on the problem nature and work field [2,3]. As Stein refers “The creative work is a novel work that is accepted as tenable or useful (...) by a group (...). By “novel” I mean that the creative product did not exist previously (...). The extent to which a work is a novel depends on the extent to which it deviates from the traditional or the status quo.” [4].

In the lens of Guilford creativity implies fluidity, flexibility, originality, and elaboration. Fluidity is related to the capability to express ideas about a topic, item, or theme at a certain time. Flexibility is connected to the quality production of knowledge. Originality implies unique and unusual ideas & solutions and a gap between that proposal and existing solutions or ideas. Elaboration implies not only communication skills, reasoning, interconnecting ideas, facts, and knowledge, but also procedural, field, and epistemological knowledge of the working area [5]. The Model of Creativity, developed by Paul Torrance [6], and grounded in Guilford’s work, emphasizes the importance of dimensions of creativity, such as fluency, flexibility, originality, and elaboration, in generating innovative ideas and solutions. Fluency refers to the ability to generate ideas or responses and is focused on producing a high volume of ideas without concern for their quality or viability. Flexibility is the ability to adapt and shift perspectives, approaches, and strategies when generating ideas or solving problems, not framed in previous ones. It involves thinking beyond traditional

methods and considering alternative viewpoints and possibilities. Originality refers to the uniqueness and novelty of the ideas or solutions generated that are different from conventional or common. Elaboration is the process of expanding and developing ideas in detail. It involves adding depth, complexity, and refinement to original ideas or solutions. Originality implies producing unique or novel ideas [6].

Rhodes’ Four Ps Model of Creativity (1961) suggests that creativity arises from the dynamic interaction between four components of creativity: person, process, product, and press. It highlights the importance of considering both individual characteristics and the surrounding environment in fostering creativity. The person is the component that emphasizes the individual's characteristics, abilities, and traits that contribute to their creative potential. It includes knowledge, expertise, openness to experience, originality, and problem-solving skills. The process component refers to the cognitive and psychological processes involved in generating creative ideas. It encompasses activities like problem-finding, ideation, evaluation, and synthesis of ideas. The product component focuses on the outcomes or creative outputs of the individual's efforts. It includes the originality, novelty, and value of the ideas or artifacts created. The press component refers to the environmental factors that influence creativity. It includes aspects such as social norms, organizational culture, resources, and support systems that can either facilitate or hinder creative expression [7].

The Componential Model of Creativity (1982), developed by Teresa Amabile [8], suggests that creativity is influenced by a combination and interactions of three components: domain-relevant skills, creativity-relevant skills, and task motivation. The domain-relevant skills are the foundational knowledge, expertise, and technical skills specific to a particular domain or field. It provides the necessary foundation for creative thinking and problem-solving within that domain. The Creativity-Relevant Skills involve the cognitive abilities and processes that facilitate the generation of novel and valuable ideas. It includes cognitive flexibility, associative thinking, analogical reasoning, and the ability to reframe problems. Intrinsic motivation is a driving force for creative expression and the key to engagement. When individuals find a task intrinsically interesting, enjoyable, or personally meaningful, they are more likely to demonstrate higher levels of creativity [8].

The Four C Model of creativity, proposed by Kaufman and Beghetto [9], suggests that creativity involves four components: mini-c creativity, Little-C creativity, Pro-C creativity, and Big-C creativity. Mini-C creativity refers to everyday creative thinking that occurs in individuals' daily lives. It involves generating novel and useful ideas in various domains. The Little-C creativity involves more developed creative abilities. It refers to creativity within a specific domain or discipline, such as a specific field of study within a PhD program. Little C’s creativity requires

expertise and domain-specific knowledge, along with the ability to generate new ideas or solutions within that field. Pro-C creativity refers to professional-level creativity and involves individuals who are considered creatives within their field of expertise. Finally, Big-C creativity represents the highest level of creativity and is associated with individuals who have made groundbreaking and transformative contributions to a discipline or society. It involves producing creative work that has a significant impact and is revolutionary [9].

The Creative Problem Solving (CPS) Model developed by Alex Osborn [10], is a widely used framework for understanding and enhancing creative thinking and a structured approach to generating and evaluating creative ideas. It involves several stages, including clarifying the problem, generating ideas, developing solutions, and implementing and evaluating the best ideas. It consists of several steps, carefully informed by both divergent and convergent thinking, and includes problem-finding, fact-finding, idea-finding, solution-finding, and acceptance-finding [10, 11].

The Investment Theory of Creativity developed by Sternberg and Lubart [12] proposes that creativity is the result of three interacting components: intellectual abilities, knowledge, and personality traits. According to this theory, creativity develops through a process of investing time and effort into a particular domain and can be enhanced by developing these components. There are 6 resources for creativity: intellectual processes, knowledge, intellectual style, personality, motivation, and environmental context. Creative performance results from a confluence of these elements [12,13].

Csikszentmihalyi's Systems Model of Creativity [14-16] highlights the interaction between three elements: the individual, the field (domain or domain-specific knowledge), and the domain (sociocultural context).

All these models can inform curriculum design, instructional strategies, and assessment methods in doctoral education. They provide a theoretical foundation for cultivating creativity among doctoral students and guiding their research and scholarly activities. Applying these models can help doctoral students develop innovative thinking skills, solve complex problems, and make original contributions to their fields of study.

## 1.2. Scientific Creativity

Science creativity is Creativity in the science domain and is viewed as having some attributes due to their background (science) being related to the skills of creativity. Scientific creativity, or creativity in the context of scientific research and discovery, has also been the subject of various models, theories, and frameworks [17,18].

Mihaly Csikszentmihalyi [19] proposed a model of scientific creativity that emphasizes the interaction between personal passion (individual), the scientific

community (domain), and society (field). According to this model, scientists engage in intrinsically motivated, passionate pursuits within a community that provides recognition and validation. He states "For creativity to occur, a set of rules and practices must be transmitted from the domain to the individual. The individual must then produce a novel variation in the content of the domain. The variation then must be selected by the field for inclusion in the domain" [15].

The Consensual Assessment Technique (CAT) developed by Dean Keith Simonton [21], assesses scientific creativity. It involves having a group of experts evaluate the creativity of scientific products (such as research articles or patents) based on established criteria. Simonton defined creativity based on three criteria: novelty, utility, and surprise. In Simonton's words "This three-criterion definition then leads to four implications regarding (a) the limitations to domain-specific expertise, (b) the varieties of comparable creativities, (c) the contrast between subjective and objective evaluations, and (d) the place of blind variation and selective retention in the creative process." [20,21].

The Baer Domain-Specificity Theory (1993) suggests that creativity in scientific domains is domain-specific, meaning that individuals may be more creative within certain areas of science due to their expertise, knowledge, and skills in those domains. The theory emphasizes the role of domain-specific knowledge and problem-solving strategies in scientific creativity [22].

Cognitive Flexibility Theory, developed by Rand Spiro and Paul J. Feltovich [23], focuses on the cognitive processes involved in scientific creativity. It suggests that scientific creativity involves shifting between different problem-solving strategies, thinking flexibly, and restructuring knowledge to generate innovative solutions.

The Theory of Creative Insight proposed by Mark A. Runco [3], emphasizes the role of insight in scientific creativity. It suggests that scientific breakthroughs often occur through sudden moments of insight, where connections between previously unrelated ideas or information are made.

The Knowledge-Based Theory of Scientific Creativity, proposed by Robert J. Sternberg [24], emphasizes the role of domain-specific knowledge and expertise in scientific creativity. It suggests that scientific creativity arises from the ability to identify important problems, generate novel hypotheses, and apply knowledge effectively in research [13, 24, 25].

Hu and Adey [26] define "scientific creativity as a kind of intellectual trait or ability producing or potentially producing a certain product that is original and has social or personal value, designed with a certain purpose in mind, using given information" or can be related to "an answer which is rare, which occurs only occasionally in a given population". They proposed the scientific structure creativity model, where they consider, fluency, flexibility, and original thinking as key personal traits for being

creative [26,27].

### 1.3. Creativity in the Portuguese Curriculum in Higher Education

Regarding higher education, it is found that in the “Framework of qualifications for higher education area” (Bologna process, Jun 1999), the competencies at the end of the 1<sup>st</sup> and 2<sup>nd</sup> cycles do not explicitly refer to creativity or creative thinking, and even in the third cycle, it is not an explicit attribute. It refers to the competencies of the second cycle that it is attributed to students who “have demonstrated knowledge and understanding (...) and that provide a basis or opportunity for originality in developing and /or applying ideas, often within a research context “. The Dublin descriptors for the 3 cycle (2004) assign that “Qualifications that signify completion of the third cycle are awarded to students who: have demonstrated a systematic understanding of a field of study and mastery of the skills and methods of research associated with that field; have demonstrated the ability to conceive, design, implement and adapt a substantial process of research with scholarly integrity; have made a contribution through original research that extends the frontier of knowledge by developing a substantial body of work, some of which merits national or international refereed publication; are capable of critical analysis, evaluation and synthesis of new and complex ideas; can communicate with their peers, the larger scholarly community and with society in general about their areas of expertise; can be expected to be able to promote, within academic and professional contexts, technological, social or cultural advancement in a knowledge-based society” ([dublin\\_descriptors.doc \(fibaa.org\) \[28,29\]](#)). So, creativity is not explicitly named being a ghost/shadow in the higher education curriculum. In this context, Lovitts [30] and Trafford [31] argue, that creativity in doctoral education is not only undefined but also not operationalized, and the ambiguity that emerges from it, casts a shadow over it- creativity in doctoral education remains an enigma [32]. But it should be noted that to achieve ‘doctorateness’ is necessary to have creativity, originality, innovation (that implies the utility of the research object), and novelty as a component of it [31].

### 1.4. Doctoral Education and Scientific Creativity

Creativity plays a significant role in doctoral education, fostering innovation, critical thinking, and problem-solving skills among doctoral students [33-35]. It encourages individuals to think beyond traditional boundaries and explore new ideas, methodologies, and perspectives within their respective fields of study, it allows students to push the boundaries of knowledge and make original contributions to their fields. Doctoral research often involves exploring uncharted territory and addressing complex problems, and creativity enables students to develop novel approaches, theories, or

methodologies to tackle these challenges. It encourages PhD students to think independently, challenge existing paradigms, and come up with innovative solutions. Furthermore, creativity in doctoral education nurtures critical thinking skills. By encouraging students to question established theories, assumptions, and practices, creativity helps them develop a deeper understanding of their research area [33-35]. It promotes a mindset of curiosity, exploration, and intellectual risk-taking, enabling students to analyze problems from different angles and evaluate multiple perspectives. This ability to think critically is vital in producing high-quality research and advancing knowledge within a field. Creativity also has personal and professional benefits for doctoral students. It enhances their problem-solving skills, adaptability, and resilience in the face of challenges. By nurturing creativity, students learn to approach setbacks as opportunities for growth and develop the ability to generate innovative solutions to overcome obstacles. Additionally, creativity can improve communication and presentation skills, as it encourages students to articulate their ideas in compelling and engaging ways, both in writing and oral presentations. Creativity is a fundamental theme in doctoral education. It involves fostering a mindset of curiosity, critical thinking, adaptability, and collaboration. By emphasizing scientific creativity, doctoral education can empower students to make original contributions, address complex research challenges, and drive scientific progress. Through the support of universities and supervisors, doctoral students can develop the necessary skills and mindset to think creatively, push the boundaries of scientific knowledge, and shape the future of their respective fields.

Research is considered a Creative Endeavour, as Dewett, Shin, Toh, and Semadeni [35], state “Creativity is most often defined as the production of novel and useful ideas or products” and “research products are the ultimate creative outcomes for students – and that they are predicated on creative efforts (i.e., research activity)” so, creativity is defined “as the process of engagement in creative acts”. In this context three variables are important in the context of creative work in doctoral education, intrinsic motivation for research (persistence and engagement in the research goals and achieving research outcomes), information seeking (reduces uncertainty, allows deeper understanding, prediction, and control of the environment, and is framed by domain skills) and research-related goals. These three variables are connected to the research products by the research activity [35]. So, research activities are the nurture of the creative process during the Ph.D.

To be creative, the Ph.D. students must know their research field deeply, but also be independent, and autonomous, and have a sense of belonging deeply rooted in their person and an unwavering sense of belonging to the academic community (feeling confident in your identity as a researcher). They must feel confident in their peers when they propose a new perspective /idea /object/strategy to resolve an issue. In this sense, it is important to perceive

what is the relationship between scholarly identity formation during the Ph.D. and the development of the creative process, and also how “fitting the mold” blocks creativity during the Ph.D.

To foster creativity in doctoral education, universities and supervisors play a crucial role [33-35]. They can create an environment that supports and encourages creative thinking by providing opportunities for interdisciplinary collaboration, offering access to resources and research facilities, and promoting a culture of open-mindedness and intellectual exploration. Universities can also organize workshops, seminars, and conferences that focus on creativity and innovation, allowing doctoral students to learn from experts and engage in discussions with peers from diverse disciplines.

#### 1.4.1. Scholarly Identity Formation During Ph.D.: The Challenges of Being Creative and Fitting the Mold

During the PhD journey, doctorates implement a research plan and enculturate themselves in the research field and the academy but, simultaneously doctorates construct their academic identity [36-39]. The research must be original, have novelty, and be innovative, but at the same time, a doctorate must become a responsible scholar which implies doing research (that is accepted by stakeholders) and publishing. Academic identity formation implies being accepted by peers and stakeholders and this way, belonging to a group and fitting the mold pre-defined by them. And in this context being different, innovative, or original may not be well accepted by the other members of the research field [36, 39, and 40]. It is important to highlight that fit for Ph.D. students means a congruence between individual personal values and those of the social structure (peers, stakeholders, and supervisor) or/and organization (academy). That fit may be an obstacle to being creative as academic identity implies the adoption of academic rules. In this context, Brodin and Frick's [39] research revealed “three links between creativity and academic identity formation in doctoral education: “Becoming a responsible scholar” (connected to social identity), “acting with the informed agency” (connected to role identity), and “Expressing the individual voice” (connected to personal identity)”.

Usually, in science and technologies, students enroll in Ph.D. research projects, previously constructed by their supervisors, and accomplish the doctoral research in 3 or 4 years [40, 41]. To do so, they must accomplish the research plan and, when there are difficulties to do it, usually they follow the supervisors' instructions. This frames and restricts new insights into the research project. Another obstacle to fostering creativity during the doctorate is the environment in academies and within the research group, which are directly guided by political issues that give relevance to productivity and the number of published papers (normal science in the sense of Khun) and not original and novelty knowledge that can lead to a paradigm shift. So, the main restrictions on doctoral education to

allow creativity are time, institutions' policies, and stakeholders [42, 43]. It is worth mentioning, that Brodin's research [43] found that “students' scholarly creativity was essentially encapsulated in silence”, which was from their point of view a consequence of “controlling intellectual, political, and economic agendas that enables stifling conditions of students' scholarly creativity, where it was as follows: restricted by scholarly traditions, embodying supervisors' power and unrequested in practice.” [43]. Supervisors play a role in doctoral integration in the academy, fostering the doctorate sense of belonging, and explaining the research process rules and the reactive/active process that leads to an original contribution [36, 37, and 43-45]. In research developed by Frick [44] regarding supervisors' understanding of creativity in doctoral education, “The data suggested that creativity could be conceptualized as a student attribute, but that it also has epistemological and methodological foundations in doctoral Education. Creativity needs to transform students so that aspects of self, knowledge and action interact (Parker, 2003)”. In this sense, creativity is understood as a key concept in doctoral education. As Frick refers [44] “(...) creativity can be conceptualized as a multi-faceted concept developed in various facets, including ontological (how to position themselves as scholars), axiological (how students integrate themselves into the values and ethics underlying the discipline), epistemological (how students negotiate their understanding of and contribution to the discipline), and methodological facets (...)”.

#### 1.4.2. How can Creativity be Developed during the Ph.D.?

“What is the purpose of a doctorate?” asked by Wellington in their paper entitled “Searching for ‘doctorateness’ [46]. Wellington states “Taking intrinsic and extrinsic aspects along with insider and outsider perspectives, the range of purposes for the doctoral study could include: (1) Preparing for a future role or a future career (...); (2) Those already working might see it as career development or continuing professional development; or it might be seen as a way of researching one's practice, to improve (...); (3) Some outsiders might regard a doctorate as a vehicle for a person to develop certain generic skills which might then be transferable to other contexts, not least employment. These skills might include problem-solving, researching, writing, and communicating; they might be grouped in a cluster that some like to call ‘employability’. (...); (4) The doctorate could be seen largely in terms of a student's personal development and her/his achievement; similarly, it might be viewed in terms of satisfying someone's personal and deeply felt curiosity and intellectual interest in an area or a need to ‘prove oneself’ (...). (5) Finally, the purpose of the doctorate might be seen in terms of its product: (...) knowledge production; pushing forward the boundaries of knowledge; adding new or ‘original knowledge; creating a novel position (i.e. a thesis) on an area of research; or

generating knowledge which can be ‘transferred’, to industry perhaps, or at least disseminated” [46]. These utilities don’t always involve new and original Knowledge but sometimes the generalization of it to new fields - normal Science [47]. As Brodin [48] mentions regarding “what is held to be a creative research contribution, it is not only novel but “has the very important characteristic of being relevant (valuable)” as well”. In this sense, a Ph.D. thesis may not indicate novelty but that the knowledge constructed during the Ph.D. can be applied (generalized) to other research areas/objects (for instance, a technique used in research can help and be applied to achieve goals in other fields) and is focused in the process (personal development, preparing a person for a career, inculcating certain ‘transferable’ skills, providing an apprenticeship, giving personal satisfaction and pride) and not in the product (Ph.D. thesis or a body of knowledge, adding to existing work) [49]. So, taking a Ph.D. can be training to be a researcher.

To develop creativity during the doctorate, it is important to expand the scope of the research beyond academic boundaries and engage in interdisciplinary research as it provides a broader perspective for research and brings together diverse fields of study [33]. Engaging in interdisciplinary research helps in integrating different contexts, theories, and methodologies, thus fostering creativity. In this context, it is also relevant to encourage brainstorming and discussions with peers, mentors, and supervisors allowing an exchange of ideas and experiences. These discussions help in advancing the thinking process and generating innovative and creative ideas. Participating in workshops and seminars related to research and other academic pursuits provides an opportunity to learn new techniques, methodologies, and approaches.

Practicing creative communication is also a way to develop creativity in doctoral education. Communicating the research and findings in innovative ways can help in developing creativity. Presenting the research in the form of videos, animations, visual art forms, and other forms of creative communication helps in engagingly conveying the information, thus providing a platform for developing creativity [45, 50]. Taking risks and experimenting with different ideas and approaches helps in developing creative solutions. It is important to be open to new ideas, to approach problems with a fresh perspective, and to test out new theories and concepts. The process of experimentation can lead to innovative and creative solutions.

### 1.5. Research Context and Goals

At NOVA Lisbon University each year, a reward named “Prémio Agir Diferente na NOVA “(ADN) intends to stimulate innovation at the NOVA University of Lisbon and is given to the ones who recognize the good practices implemented. The announcement and presentation of the ADN awards takes place annually at nova’s Organizational Innovation Gala, taking place, whenever possible, on April

21 of each year (World Day of Creativity and Innovation).([O Novo ADN da NOVA: um prémio para estimular a inovação e reconhecer as boas práticas. Candidaturas abertas! | Universidade NOVA de Lisboa \(unl.pt\)](#)). In this context, it is important to understand the perception of Ph.D. students regarding creativity.

## 2. Methodology

The research method used was a study case with exploratory characteristics and a quantitative profile. The phenomenon study is creativity in doctoral research and its influence from the students’ lens. To maximize our in-depth understanding of students’ perceptions of creativity during doctoral supervision, a quantitative research approach was adopted. The research was conducted with a convenience sample of PhD students at NOVA School of Science and Technology | FCT NOVA. Participants in this research project were informed of their aim and participated voluntarily. To collect data an anonymous survey was applied and disseminated, via PhD students’ institutional email. The survey is based on others [51, 52] and adopted whenever necessary to the PhD population. The survey had two parts, the first one allows a characterization of the sample (gender, age, attendance year), and the second explores the meaning of creativity, the tasks proposed by supervisors or advisors during the doctorate, and the degree of creativity in the supervision practice/ supervision tasks. In some questions, a four-point Likert scale ranging from strongly disagree (1) to strongly agree (4), was used to measure confidence in their skills regarding creativity. In other questions, doctorates had to choose the most adequate statement. The survey was applied to PhD students in NOVA School of Science and Technology | FCT NOVA, in June 2022.

## 3. Results and Discussion

The results and discussion are presented in the next sections.

### 3.1. Sample Characterization

The sample population gender was 52% female, 46% male, and 2% didn’t want to answer. Fifty-two percent (52%) of the respondents were between 25 and 30 years old, 23% were between 31 and 35 years old, 6,5% were between 36 and 40 years old and the rest (18,5%) were more than 41 years old.

Eighty percent (80%) of the respondents are full-time enrolled and 20% attended part-time. 16% are enrolled in the first year of the Ph.D., 31% in the second year, 21% in the 3rd year of the doctoral course, 2% are enrolled in the 3rd and final year of the doctoral course, and, 30% are attending the 4th year of the doctoral course.

### 3.2. The Mean of Creativity to Ph.D. Students

To perceive the meaning of creativity among doctoral students, they selected the five most important statements to complete the declaration “Creativity means...” For more than half of these respondents, being creative means thinking “outside the box” (70% of the respondents choose this option), “seeing unusual links/connections between existing concepts, ideas, or things” (69% of the respondents choose this option), “seeing the world in different ways” (66% of the respondents choose this option), “be curious” (56% of the respondents choose this option), “generate new ideas” (54% of the respondents choose this option) and “inventing, innovating, and producing new things.” (54% of the respondents choose this option) (Table 1).

**Table 1.** Doctoral students’ perception regarding the mean of creativity

Creativity means...	% of respondents
Think "outside the box".	70%
See unusual links/connections between existing concepts, ideas, or things.	69%
Seeing the world in different ways.	66%
Be curious.	56%
Generate new ideas.	54%
Invent, innovate, and produce new things.	54%
Do things that others have done before, but in a different way or by combining different ideas.	48%
Search for originality/innovation/novelty.	38%
Reflect critically on the current world.	38%
Do things that nobody has done before.	36%
Search beyond the obvious.	34%
Adaptation of the things that someone else invented.	30%
Take the risk.	30%
Adapt to the existing frameworks.	26%
Explore and discover new and unknown products.	21%
Be agile or nimble to find solutions.	18%
Experiments.	11%
Analyse.	5%
Safety.	3%
Synthesize/resume.	2%

Creativity is not associated with experiments (only 11% of the respondents choose this option), analysis (only 5% of the respondents choose this option), safety (only 3% of

the respondents choose this option) synthesizing or resume (only 2% of the respondents choose this option).

Doctoral education programs by promoting a culture of curiosity, interdisciplinary collaboration, risk-taking, and ethical conduct, can empower students to become creative thinkers and make significant contributions to their fields. Providing support, mentorship, and access to resources further enriches the doctoral experience, fostering doctorates who are prepared to address complex challenges and shape the future of scientific inquiry. It should be noted that the mean of creativity found in this research encompasses the ability to think innovatively, question existing knowledge, and generate novel ideas within the scientific realm. It refers to the capacity of doctoral students to push the boundaries of scientific understanding, explore uncharted territories, and make original contributions to their fields.

A four-point Likert scale ranging from, undeveloped (1), passing to underdeveloped (2), developed (3) and very developed (4), was used to measure Doctoral students’ perception regarding the degree of development of some characteristics that are meaningful regarding creativity (Table 2).

The qualities in the table range from most to least developed, and the average score was 3.0 on a four-Likert scale. The three qualities most developed are “Openness to new experiences/ideas” (score 3.4), and "Open-Mindedness" (score 3.4), and this can be connected to personal characteristics. “The ability to notice and highlight problems, contradictions, or inconsistencies in a project or knowledge.” (Score 3.3) is related to field knowledge. The other two qualities assigned as the most developed are related to scientific skills “The ability to analyze, synthesize and decision making. (Score 3.2), and “The ability to develop and elaborate ideas.” (Score 3.2).

The two least developed qualities are “The risk appetite.” (Score 2.6) and “The ability to produce a variety of original ideas and strategies that are radically different from the obvious, common and stereotypical.” (Score 2.6). The evaluation of the first statement indicates that Ph.D. students are not encouraged to take risks during their research work. But to foster scientific creativity, doctoral education should provide an environment where students feel supported in taking intellectual risks. Failure is a natural part of the research process, and students should be encouraged to learn from setbacks and persevere in the face of challenges, ultimately enhancing their resilience as researchers. On the other hand, the last statement is related to breaking paradigms and/or being framed/ caged in normal science. It can signify that Ph.D. students are trained to work in a certain way that doesn’t allow boundary-breaking fields and that supervisors play the role of Gatekeeping.

**Table 2.** Doctoral students' perception of the degree of development of some characteristics related to creativity

Evaluation of the degree of development of the following qualities...	average	SD
Openness to new experiences/ideas.	3.4	0.6
"Open-Mindedness".	3.4	0.6
The ability to notice and highlight problems, contradictions, or inconsistencies in a project or knowledge.	3.3	0.6
The ability to analyze, synthesize, and decisions making.	3.2	0.6
The ability to develop and elaborate ideas.	3.2	0.6
The ability to work as a team.	3.2	0.8
The ability to notice unusual details, contradictions, and uncertainties.	3.1	0.7
The ability to design new paths/solutions to realize projects that have encountered difficulties.	3.1	0.7
The ability to predict results.	3.0	0.8
The ability to monitor project development.	3.0	0.8
Tolerance for uncertainty, and rapidly changing circumstances.	3.0	0.7
The ability to solve problems /impasses/difficulties in research projects	3.0	0.7
The ability to produce new ideas and propose original strategies based on common materials	2.9	0.8
Individualism.	2.9	0.9
The ability to abandon stereotypical ways of solving problems.	2.8	0.9
The willingness to work in an unusual context.	2.8	1.0
The propensity for symbolic and associative thinking	2.7	1.1
The risk appetite.	2.6	0.8
The ability to produce a variety of original ideas and strategies that are radically different from the obvious, common, and stereotypical.	2.6	0.7
Average	3.0	0.8

### 3.3. The supervision Practice Regarding Creativity from the Students' Lens

Scientific creativity involves the development of a mindset that encourages curiosity and intellectual exploration. Doctoral students need to cultivate a sense of wonder and intrinsic motivation to explore new avenues of inquiry. This mindset entails questioning established theories or/and methodologies and being open to alternative perspectives and approaches. Scientific creativity also involves the ability to think critically and analytically. In this sense, doctoral students should be able to evaluate existing research critically, identify gaps in knowledge, and propose innovative hypotheses or research questions. They need to be skilled in synthesizing information from diverse sources, identifying patterns, and generating new insights. The critical thinking capacity enables students to develop creative research designs and methodologies that can address complex scientific

problems effectively. Collaboration and interdisciplinary approaches are also integral to scientific creativity in doctoral education. By engaging with peers and experts from different disciplines, doctorates can broaden their perspectives, gain new insights, and integrate diverse ideas into their research. Interdisciplinary collaboration encourages the transfer of knowledge across fields, fosters creative problem-solving, and enhances the potential for groundbreaking discoveries. Furthermore, scientific creativity involves the ability to adapt and embrace uncertainty. Doctoral research often involves encountering unexpected challenges and setbacks. Creative doctoral students are resilient and view these obstacles as opportunities for growth and learning. They are flexible in adjusting their research plans, exploring alternative paths, and experimenting with different methodologies or techniques. This adaptability allows them to overcome hurdles and make valuable contributions to their fields.

In this context, doctorate students had to assign the five more frequently proposed tasks or frequent attitudes, during the meetings with the PhD supervisors (Table 3).

Concerning Ph.D. research methodologies, 46% assign the statement "The advisors/supervisors show the doctoral students that their ideas (ideas of doctoral students) have value." and 41% the assertion "The advisors/supervisors show possible paths but give doctoral candidates the freedom of choice to do the Ph.D. research." Only 38% of the PhD students assign that "During the meeting with the supervisors/advisers, they encourage doctoral students to develop self-confidence to work in unpredictable situations." This statement is related to uncertainty that characterizes something new and to the researcher's resilience to mobilize creativity to remove/pass the obstacles /problems that emerge. The lowest assigned statement is related to the supervisor's responsibility, regarding the research project "The advisors/supervisors are linked/connected to the assessment of the causes and consequences of the design of the research project."

Analyzing the PhD research environment, more than half of the Ph.D. students who answered the survey point that "The advisors/supervisors promote autonomy during the development of the doctoral project." (59%); "Advisors/supervisors allow doctoral students to express their thoughts." (52%) and "Advisors/supervisors allow doctoral students to express their creativity" (51%).

The lowest assigned assertions were related to the Supervisor's Characteristics and are "The advisors/supervisors show their creativity" (only 20% of Ph.D. students choose this statement), and "Advisors/supervisors appreciate the unusual questions" (only 16% of Ph.D. students choose this statement).

A four-point Likert scale ranging from Disagree (1), passing to Partially disagree (2), partially agree (3), and agree (4), was used to measure doctoral students' perception regarding their attitudes toward the development of creativity during their Ph.D. (Table 4).

Less than half of the respondent population agree with

these statements: “Each problem has a unique solution” (Score 1.9), “Doctoral students may have their opinion on a problem, but they should only value what is referenced in the literature” (Score 1.9) and “To successfully pass the thesis defense, the doctoral student needs to answer the question(s) exactly as it is stated in the literature.” (Score 1.8), and finally “For advisors/supervisors to accept the thesis, doctoral students should write only what advisors/supervisors consider correct, even if there is literature in another sense.” (Score 1.5). It should be emphasized that these statements are negatively formulated, so students disagree or partially disagree with them.

On the other hand, the statements with a high agreement

are all related to Ph.D. students’ autonomy and where “Doctoral students should be encouraged to be creative.” (Score 3.9), “In a doctoral thesis, the "thesis" (idea) defended may be different from the view accepted by the scientific community, provided that its arguments are valid.” (Score 3.7), “The doctoral thesis should have the traits /perceptions of the doctoral student” (Score 3.6), “Doctoral students can have their opinion on a problem that is completely different from the opinion of the advisors/supervisor.” (Score 3.5). It is also important to nurture the freedom for Independent Thinking (autonomy), which is highlighted in the degree of agreement shown in Table 4.

**Table 3.** Doctoral students’ perception of the doctoral supervisor/advisor regarding their attitudes toward the development of creativity during their Ph.D.

Considering your Doctoral Advisors/supervisor, select the statements that occur most frequently...		Percentage of respondents (%)
PhD research methodologies	The advisors/supervisors show the doctoral students that their ideas (ideas of doctoral students) have value.	46%
	The advisors/supervisors show possible paths but give doctoral candidates the freedom of choice to do the Ph.D. research.	41%
	During the meeting with the supervisors/advisors, they encourage doctoral students to develop self-confidence to work in unpredictable situations.	38%
	The advisors/supervisors engage in a more detailed discussion of others’ ideas (other advisors, authors of articles, and other students...).	31%
	Advisors/supervisors use real-world case studies, as learning tools.	23%
	Advisors/supervisors build research projects for doctoral students to perform. ;	23%
	Advisors/supervisors provide learning situations in which there are no correct answers.	15%
	The advisors/supervisors are linked/connected to the assessment of the causes and consequences of the design of the research project.	13%
PhD research environment	The advisors/supervisors promote autonomy during the development of the doctoral project.	<b>59%</b>
	Advisors/supervisors allow doctoral students to express their thoughts/opinions.	<b>52%</b>
	Advisors/supervisors allow doctoral students to express their creativity.	<b>51%</b>
	The advisors are open (friendly) to different new solutions and accept new or different solutions.	46%
	Advisors/supervisors encourage communication between and with doctoral students’ peers.	43%
	Advisors/supervisors appreciate imaginative and unusual ideas/solutions.	41%
	The advisors/supervisors accept that doctoral candidates want to develop their projects.	36%
	The advisors/supervisors accept well different opinions.	34%
	Advisors/supervisors question everything that is known in theory to encourage doctoral students to think.	23%
Supervisor’s Characteristics	The advisors/supervisors show their creativity.	20%
	Advisors/supervisors appreciate the unusual questions.	16%
	Advisors/supervisors suggest that doctoral students think like them (like the advisors/supervision).	15%

**Table 4.** Doctoral students' perception regarding the development of creativity and autonomy during their Ph.D.

Assign the degree of agreement on the following statements...	Average	SD
Doctoral students should be encouraged to be creative.	3.9	0.3
In a doctoral thesis, the "thesis" (idea) defended may be different from the view accepted by the scientific community, provided that its arguments are valid.	3.7	0.7
The doctoral thesis should have the traits /perceptions of the doctoral student.	3.6	0.8
Doctoral students can have their opinion on a problem that is completely different from the opinion of the advisors/supervisor.	3.5	1.0
It is more important to communicate with doctoral students and review the planning of the doctoral project than to comply initial plan.	3.4	0.9
All doctoral students' perceptions/experiences/ideas about a problem should be considered for the development of their doctoral project	3.3	1.0
Doctoral students can guide/drive the running meetings with the supervisor.	3.2	0.9
To be creative it is necessary to know well the area in which a task / a project is developed.	3.2	1.0
Doctoral guidance/supervision should be oriented towards new learning methods.	3.1	1.0
The advisors/supervisors are the main instigators of doctoral candidates' creativity.	2.5	1.0
The creativity of doctoral students depends on the characteristics of the advisors.	2.5	1.1
To successfully do the PhD, doctoral candidates must strictly follow the instructions of the supervisor.	2.4	0.8
Each problem has a unique solution.	1.9	1.0
Doctoral students may have their opinion on a problem, but they should only value what is referenced in the literature.	1.9	0.8
To successfully pass the thesis defense, the doctoral student needs to answer the question(s) exactly as it is stated in the literature.	1.8	0.8
For advisors/supervisors to accept the thesis, doctoral students should write only what advisors/supervisors consider correct, even if there is literature in another sense.	1.5	0.7
Average	2.8	0.9

Doctoral students should have the autonomy to pursue their research interests and explore unconventional ideas and supervisors should encourage independent thinking allowing students to develop their unique research paths, promoting creativity and originality in their work.

The respondents also had to respond, "Which forms of work at the university are most conducive to the

development of creativity?" PhD students had to select the 6 most important for them (Table 5).

**Table 5.** Doctoral students' perception of the doctoral supervisor/advisor regarding the tasks and who may develop creativity during doctoral research

Which forms of work at the university are most conducive to the development of creativity?"	Percentage of respondents (%)
Participate in seminars/ conferences /debates /study cycles.	80%
Carry out research activities (laboratory or not) in a research group.	79%
Participate in meetings with peers and supervisors or advisors.	64%
Develop projects throughout the course (project activities in doctorate)	62%
Carry out laboratory/research work within the course (project activities).	51%
Review the literature/ read papers.	49%
Academic practice (academic experiences).	49%
Perform oral presentations.	43%
Attend curricular activities (classes/lectures).	39%
Write monographs, projects, scientific papers, and theses /written communication.	39%
Educational games.	23%

The most assigned tasks were "Participate in seminars/ lectures / round tables /debates /study cycles." (80% of the respondents assigned), "Carry out research activities (laboratory or not) in a research group." (79% of the respondents assigned), "Participate in meetings with peers and supervisors or advisors" (assign by 64% of the respondents), "Develop projects throughout the course (project activities in doctorate)" (assign by 62% of the respondents) and the one only referred by 51% of the respondents were "Carry out laboratory/research work within the course (project activities)". Educational games were the task with lower approval (only 23% assigned it).

To assess what tasks or who could foster creativity, PhD students had to respond to the question "What or who is more conducive to the development of creativity in the learning process at the university?" selecting the seven most important for them (Table 6).

The tasks assigned were "Participation in scientific events organized by students." (75%), "Reading papers and doing a literature review." (66%), and "Meetings with the members of the research team." (61%), "Participate in seminars / Colloquia/ Round tables." (61%), "Meetings with the Advisor(s) / supervisor(s)." (59%), "Practical training (hands-on training) in specific techniques." (56%) and "Meet doctoral students from various and different areas." (52%). Lectures, laboratory work, content training, or end-of-cycle design work, which are used in educational contexts, were not evaluated by students as effective for the

development of creativity.

**Table 6.** Doctoral students' perception of the doctoral supervisor/advisor regarding the tasks and who may develop creativity during doctoral education

What or who is more conducive to the development of creativity in the learning process at the university?"	Percentage of respondents (%)
Participation in scientific events organized by students.	75%
Read papers and do a literature review.	66%
Meetings with the members of the research team.	61%
Participate in seminars / Colloquia/ Round tables.	61%
Meetings with the Advisor(s) / supervisor(s).	59%
Practical training (hands-on training) in specific techniques.	56%
Meet doctoral students from various and different areas.	52%
Know well the research field where you work (techniques and knowledge).	48%
Research activities in the research group.	44%
Participation in courses at the Doctoral School.	39%
Observe more experienced researchers at work.	38%
Participation in national and/or international scientific events.	30%
Meetings with representatives of companies and industry.	21%
Laboratory works.	20%
Curriculum classes taught/content training/lectures.	13%
End-of-cycle design work.	8%

Doctorates had to select among tasks, the five most common they experienced during the research project (Table 7).

The type of tasks that more than half of them assign, as the tasks, they were encouraged to do during the Ph.D. research project, are “present evidence of their arguments.” (66% appoint), “write papers” (62% appoint), “give new solutions to problems.” (54% appoint) and express their point of view/ their opinion (appointed by 51%). These results show the importance of the ability to communicate ideas effectively, which is essential for scientific creativity. Doctoral education should offer opportunities for students to present their research to peers, and faculty, and at conferences, enabling them to refine their ideas through collaboration and feedback.

Supervisors, as mentors and guides, can encourage scientific creativity by promoting intellectual independence, supporting students in taking risks, and providing constructive feedback. They can create a safe space for students to explore unconventional ideas, challenge existing knowledge, and experiment with different research methodologies. Supervisors should also

facilitate opportunities for students to present their work and engage in scholarly discussions to enhance their communication and critical thinking skills. Moreover, supervisors can actively promote creativity by encouraging students to think independently, providing constructive feedback that stimulates innovative thinking, and supporting them in taking calculated risks in their research. They can guide students in identifying gaps in existing knowledge, exploring alternative research methodologies, and experimenting with different approaches. By fostering a nurturing and supportive environment, supervisors can help students develop the confidence and skills necessary to express their creative ideas.

**Table 7.** Doctoral students' perception of the doctoral supervisor/advisor regarding the tasks and who may develop creativity during the doctoral research project

During the preparation and development of the doctoral research project, doctoral students are encouraged to...	Percentage of respondents (%)
Present evidence of their arguments.	66%
Write papers.	62%
Give new solutions to problems.	54%
Express their point of view/ their opinion.	51%
Conduct meetings with the advisors/supervisors, explaining what they did and saying what it proposes to do.	46%
Develop new methodologies.	46%
Participate in constructive discussions.	43%
Use the resources creatively.	36%
Give constructive suggestions.	34%
Listen to the elements of the research group with more experience.	26%
Do what the advisors want.	23%
Strictly comply with what was planned at the beginning of the doctoral project.	5%

Universities and supervisors play a significant role in fostering scientific creativity in doctoral education. They can create an environment that supports and nurtures creativity by providing access to cutting-edge research facilities, resources, and interdisciplinary collaborations. Universities can also organize workshops, seminars, and conferences that expose students to diverse research perspectives and stimulate innovative thinking.

## 4. Conclusions

Creativity is a vital component of doctoral education. It enables students to think critically, generate innovative solutions, and make original contributions to their fields. By fostering creativity, universities and supervisors can empower doctoral students to develop the necessary skills and mindset for successful research and scholarly

endeavors. By embracing creativity, doctoral education can drive intellectual progress, inspire breakthroughs, and shape the future of academic scholarship.

In the present research, the mean of creativity presented by students encompasses: nurturing creative thinking and problem-solving abilities (this involves encouraging students to ask innovative research questions, think critically, and explore new ideas within their respective domains); conducting independent and original research, contributing to the existing body of knowledge (this involves identifying gaps in the literature, designing and implementing studies or experiments, analyzing data, and drawing novel conclusions); encouraging non-linear thinking, taking risks, and being open to new ideas or unconventional methodologies; receive feedback from faculty members and peers, which helps them refine their research and validate their ideas in meetings.

It is worth noting that creativity is often an inherent attribute or disposition of individuals (Table 1. “Be curious”), and doctoral education provides an environment to further develop and enhance creative thinking skills. In this sense, the tasks that may develop creativity during doctoral research are related to exposing students to diverse perspectives, methods, and approaches (participating in seminars/conferences/debates/study cycles), interacting with peers and experts in a collaborative environment (carrying out research activities (laboratory or not) in a research group). This implies effective mentorship (supervisors should serve as mentors who encourage students to think critically, provide constructive feedback, and inspire them to their full creative potential) and offering opportunities for students to present their research to peers and experts, at conferences and meetings enabling them to refine their ideas through collaboration and feedback.

The process of obtaining a PhD involves much more than producing scholarly research. It includes the formation of a scholarly identity, which refers to the development and construction of one's personal and professional identity as a researcher, thinker, and writer in the academic community. The scholarly identity formation during a Ph.D. is a complex process that comes with several challenges. One of these challenges is balancing creativity with fitting the mold of academic expectations. Academia demands a certain level of rigor and adherence to specific formats, and this can restrict one's creative freedom and originality. The pressure to conform to a particular academic culture can stifle individual thinking and hinder the development of new ideas. As such, Ph.D. students often struggle with the tension between expressing their creativity and adhering to the established academic norms and standards. To overcome these challenges, Ph.D. students must learn to balance innovation with fulfilling the academic requirements of their discipline. This requires developing a deep understanding of the expectations, norms, and traditions in their field while also identifying and pursuing unique and innovative research interests, and

supervisor and institutional support. Ultimately, the formation of a scholarly identity requires both creativity and a commitment to excellence. Ph.D. students must learn to push the boundaries of their field while also demonstrating a mastery of the established academic standards. This balance is crucial to successful scholarly identity formation and long-term success in academia.

Although it is an exploratory study case, the number of participants was a limitation of this research work.

## Acknowledgements

This work is financed by national funds through FCT - Foundation for Science and Technology, I.P., within the scope of the project «UIDB / 04647/2020» of CICS.NOVA - Centro Interdisciplinar de Ciências Sociais da Universidade Nova de Lisboa.

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