

# The 4Cs as a Process and a Product in Doctoral Education

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**Abstract** Doctoral education is not only the pinnacle of the higher education system but is also the researchers' source nowadays. To achieve the Ph.D. profile (Dublin descriptors framework, 2004), scientific skills are not the only skills that must be developed during the doctoral journey. On the one hand, during the doctorate, a Ph.D. student must develop scientific skills, be trained with technical and theoretical knowledge, develop new knowledge, and be innovative and original, allowing scientific success and the development of science. On the other hand, it must develop soft skills as it should be capable of issuing knowledge in different contexts, but also working with others in different work team contexts (collaborating and/or cooperating) and the awareness of managing emotions and professional relations. During this development, the academic identity is constructed and the integration into the academy and a sense of belonging to a community of practices appears. At NOVA Lisbon University, each year rewards a person inside the university who disseminates innovative practices and contributes to the development of a culture of organizational innovation. In this context, the focus of the present research is the Learning and Innovation Skills of the 21st-century skills proposed by "The Partnership for the 21st Century". This quantitative research aims to capture the Ph.D. students' perception regarding the development of Learning and Innovation Skills (creativity, communication, collaboration, and critical thinking) during the doctorate. This paper draws on the data collected among Ph.D. students in a Portuguese higher education, using a survey, with close questions applied, in July 2022. The results show that Ph.D. students have a positive perception of the

development of all these four skills. Nevertheless, they feel less confident in their ability to use critical thinking.

**Keywords** Critical Thinking, Communication, Collaboration, Creativity, Doctoral Education

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## 1. Introduction

The definition of education milestones holds the foremost importance for society. In recent years, the Organization for Economic Cooperation and Development (OCDE) has developed frameworks to guide societies in achieving their goals. At the beginning of the 21st century, the traditional 3Rs (reading, writing, and arithmetic), which were the key subjects of the 20th century, were reviewed. Although the framework for 21st-century learning skill areas is supported by the 3Rs, the key skills presented in the framework range from life and career skills (Leadership, Flexibility, Productivity, Social skills), to learning and innovation skills (Critical thinking, Communication, Collaboration, Creativity), and Information, Media, and Technology skills (Information literacy, Media literacy, Technology literacy) [1,2].

### 1.1. The 4Cs (Critical Thinking, Creativity, Collaboration, and Communication)

The four learning and innovation skills (Critical thinking, Creativity, Collaboration, and Communication) are pillars

of research and teaching skills. As essential skills, they help individuals integrate into society and become active citizens, which is increasingly important in today's workforce [3-6].

Communication skills include listening, non-verbal communication (including body language), clarity and conciseness, friendliness, confidence, empathy, open-mindedness, respect, feedback, and knowledge to select the medium to diffuse the message [6]. These skills are essential to articulate thoughts and ideas effectively and express themselves [7]. Listening and reading are crucial to understanding the message (knowledge) but speaking and/or writing are fundamental to communicating effectively in different environments and contexts [8].

Collaboration skills include working competently with others to achieve a common goal, respecting others' opinions, and taking equal responsibilities in achieving outcomes [7-10]. It involves individuals or groups in sharing ideas, knowledge, resources, and skills to solve problems, make decisions, or create something new. Collaboration typically requires effective communication, coordination, and cooperation among team members. The main aim of the collaboration is to harness the collective abilities and expertise of individuals, to achieve better outcomes than what could be conducted individually. This skill is essential to work in teams and is related to knowledge, attitudes, and interpersonal skills [7-10].

Critical thinking skills imply cognitive abilities such as remembering, understanding, applying, analyzing, evaluating, and creating, and cognitive activities like interpretation, inference (to predict consequences of the decisions made), explanation, self-regulation, and synthesizing information [9-11]. As Pardede [9] states, critical thinking "is a complex mental process involving a diverse and multidimensional cognitive ability", which only can be understood considering that critical thinking as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, criterion-logical, or contextual considerations upon which that judgment is based" [9]. As Jaswal and Behera [10] mention, "critical thinking refers to one's ability to distinguish relevant information from irrelevant information, relate ideas, infer, and justify whether a particular assumption is acceptable or unacceptable" and is crucial in a world with fake news.

Creativity is associated with innovations, originality, novelty, effectiveness, and ethics [7, 12-14]. It is the ability to generate new ideas, concepts, or solutions that are original, innovative, and valuable. Thinking creatively involves breaking out of conventional boundaries and established norms and discovering original ways to express oneself or tackle a problem. This skill is crucial as it enables individuals to generate innovative and meaningful ideas, leading to personal growth, progress, and innovation in society. As Pardede states [9], "Creativity is the products, processes, or interactions that generate new ideas, thoughts,

and objects". Creativity is not only related and conditioned by individual traits but also by culture society and the knowledge fields [11]. Creative thinking refers to the "thinking skills which enable a person to generate creative original or new ideas, thoughts, and objects" [9], and is one of the key elements needed to develop creativity.

Learning models, like problem-based learning (PBL) [15,16], group work [7], blended learning [10], or the production of critical analysis [17], among others, can foster 4C skills.

## 1.2. The 4Cs Skills during the Doctorate

The doctoral supervision instructional practices are teaching practices adapted to teach the research process to highly qualified students. As an aim to form future researchers, one of the learning outcomes is the acquisition of scientific skills. As Kembara, Rozak, and Hadian [5] state, "Research skills help graduates to critically investigate problems and if appropriate produce and evaluate relevant data, test ideas, theories, and hypotheses, and successfully guide the way for them to navigate the sea of information that characterizes the information age. Writing a scientific work in it involves a process of scientific thinking. To support this, the skills that need to be trained by students are research skills. Research skills are skills in conducting scientific research in the framework of scientific truth-seeking by applying scientific methods that rely on scientifically proven reasoning". But nowadays, learning during the doctorate implies learning and developing scientific skills and soft skills. The development of Critical thinking, Communication, Collaboration, and Creativity competencies is inherent to the supervision process (how to do research in a certain field? how to disseminate the knowledge? and how to work in research teams?) and they are interconnected with research skills. In this sense, supervision practices should promote the Ph.D. student's mastery of research skills and these four competencies. To achieve these aims, learning models need to be developed to accommodate these competencies [3], problem-solving oriented learning, the one that allows achieving these goals fully [18].

In research conducted by Moore [19], he found that for tenured academics, critical thinking was identified as self-reflection, judgment, skepticism, rationality, and activist engagement with knowledge. In other research work, creativity was associated with originality, imagination, and problem-working [20], but also with meaningful knowledge production [14]. Two concepts, independence and originality are connected to critical thinking and creative thinking and some supervisors had concerns regarding their uses by PhD students [21]. If students aren't prominent in their study field, too much independence or originality in the construction and development of doctoral research can lead to unfinished projects [21-24]. However, critical and creative thinking is interconnected and should be integrated into the learning process in doctoral education.

Brodin found that critical and creative thinking sometimes hindered each other during the doctoral journey. “Results indicate that critical thinking often overshadows creative thinking in practice” [11]. Brodin and Flick [25] argue that to help students in their doctoral research is necessary to implement and encourage critical creativity. In Brodin’s words, “Critical creativity implies an increased awareness of the feasibility of innovative ideas and new ways of proceeding, as well as the ability to communicate these ideas and actions. (...) Development of these abilities is deeply dependent on educational encouragement of both critical and creative thinking in the (...) doctoral program” [11].

1.2.1. The 4Cs as a Process and a Product in Doctoral Education

The 4Cs are soft skills that are important currently for Ph.D. students. These skills, related to the research skills, are needed for the researcher to perform well their research activities [5]. These skills must be developed during the doctorate, aiming to reinforce the skills in science dissemination, teamwork, innovation, and originality. It is important to highlight cutting-edge knowledge that is at the forefront of a field of study or work, and in the interconnection between areas, which entails that a researcher must not only be a specialist in their area but must also know the possible interconnections between areas. It is necessary, among others, to own qualities such as adaptability, flexibility, dependability, resilience, and critical thinking. In doctoral education, the 4Cs can be viewed as both a process and a product [11].

As a process, the 4Cs can be incorporated into the doctoral curriculum to help students develop these skills through the course [14]. As a product, the 4Cs represent the knowledge, skills, attitudes, and behaviors that doctoral graduates own, but also in the Ph.D. thesis and papers published [14]. Graduates with strong 4C skills are more successful in academia, the job market, and research. The 4Cs approach to doctoral education is both a process and a product that aim to equip graduates with the skills and competencies they need to succeed in a fast-changing and complex world. Therefore, doctoral programs should

prioritize the development of the 4Cs in their students, to better prepare them for the future.

A model for the development of Creativity, Critical Thinking, Collaboration, and Communication (C4) in Doctoral Students that reflects the 4Cs competencies as a Process and as a Product (Fig. 1) emerges.

When students enroll for Ph.D., they are in the *Foundation Stage* which is characterized by Baseline Skills (doctoral students enter their programs with foundational skills in creativity, critical thinking, collaboration, and communication), Awareness (they become aware of the importance of these skills in academia and research) and Skill Assessment (self-assessment and feedback from advisor’s help identify strengths and areas for improvement in these skills).

During the doctoral journey and the socialization process that is inherent to it, Ph.D. students first have an *Exploration Stage*, which implies a Curriculum Integration (doctoral programs incorporate coursework and activities that foster creativity, critical thinking, collaboration, and communication), the Skill Development (students engage in structured exercises, discussions, and projects designed to enhance these skills) and Mentorship (faculty advisors guide skill development and model effective practices). After that, a dynamic process occurs between the *Application*, the *Feedback*, and the *Reflection Stages*, Fig.1. The *Application Stage* consists of the Research Projects (doctoral students apply creativity and critical thinking to design and execute research projects), Collaboration (they collaborate with peers, advisors, and external researchers to address complex research questions), and the first Presentation and Publishing (Ph.D. students communicate their findings through presentations and publications, refining their communication skills). The *Feedback and Reflection Stage* has a Feedback Loop (doctoral students receive feedback on their work, which informs further skill development), a Reflective Practice (they engage in reflective activities to assess their growth and identify areas for improvement), and Peer Learning (collaborative reflection with peers enhances self-awareness and skill refinement).

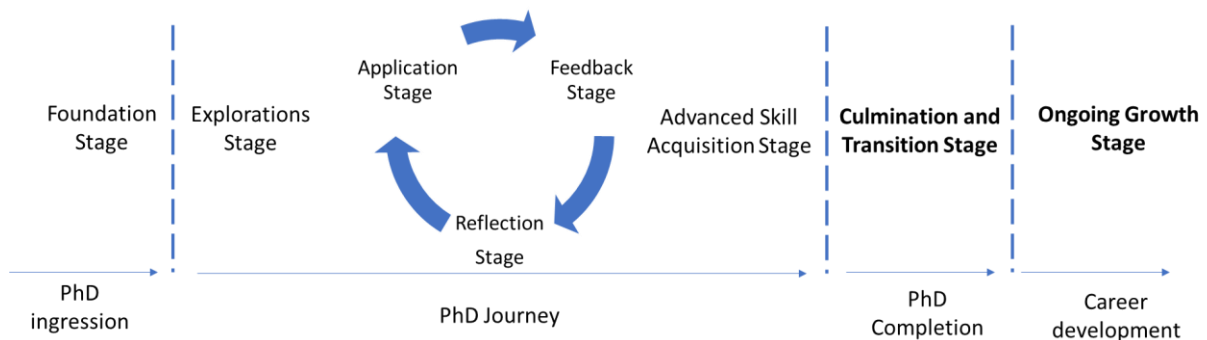


Figure 1. The Doctoral Student Development Model: Creativity, Critical Thinking, Collaboration, and Communication (C4 Model)

The *Advanced Skill Acquisition Stage* is the last phase before the Ph.D. completion. It integrates specialization (as students' progress in their doctoral programs, they develop specialized expertise that demands advanced creativity and critical thinking), leadership in collaboration (they take on leadership roles in collaborative research projects, honing their collaboration skills), and teaching and mentoring (Doctoral students teach, mentor undergraduates, or assist in training, and refining their communication skills).

The completion of the Ph.D. occurs in the *Culmination and Transition stage* and implies that students achieve some outcomes such as the writing of the dissertation/thesis (the dissertation or thesis represents the culmination of their creativity and critical thinking), establishing professional networks (Students establish professional networks through conferences and collaborations), and Job Market Preparation (as they prepare to enter the job market, students refine their communication skills for interviews, job talks, and presentations).

The last phase of the 4C's model is related to career development and is the *Ongoing Growth stage*. It consists of Professional Development (doctoral graduates continue to develop these skills in their careers through ongoing professional development opportunities), Research and Innovation development (creativity and critical thinking remain vital as they conduct research and contribute to their fields), and Mentoring (experienced professionals may mentor new scholars, emphasizing the importance of collaboration and communication in the field).

### 1.2.2. Doctoral Education, 4Cs Skills, and the Construction of a Researcher

Doctoral education is the highest level of academic education that one can pursue. Becoming a researcher and expert in a scientific field is a rigorous and demanding process. Doctoral education provides in-depth knowledge, advanced research skills, and the ability to solve complex problems through critical thinking and creativity. But it is more than just obtaining a degree, it is the process of constructing a researcher and creating a unique intellectual identity [23, 24]. It is a journey that involves exploring ideas, conducting research, analyzing information, creating new knowledge, and the socialization process [23-25]. Doctoral education is an opportunity to immerse in a study field, push the boundaries of knowledge, and make a significant contribution to academia.

The process of constructing a researcher begins with the selection of a research topic and the development of a research question. It involves mastering the relevant literature and theories, conducting empirical research or experiments, analyzing data, and interpreting results. Doctoral students also learn how to present their findings in academic conferences and publications, thereby contributing to the advancement of knowledge. In addition to developing expertise in a specific area of research, doctoral education also promotes the development of transferable skills such as critical thinking, problem-

solving, communication, and teamwork which are crucial for success in both academia and industry.

During the doctorate, the academic self is constructed, and usually, it implies the fit towards the integration into the higher education institution's culture (assimilation), rules, and a socialization process in which the student learns to identify, accept, and appropriately use the frames of mind in their research environment [11]. The acquisition of the scientific field language and norms is important to become a responsible scholar and being accepted by peers as a member of the disciplinary community [23-27]. This fit, to the research and institution environment, to the culture, to peers, is inherent to the socialization process in the Academy and may condition the innovation process and its recognition by peers and scholars [23-27]. Brodin in their research [11] found that Ph.D. students felt sometimes conflicting relations between creative and critical thinking reflecting tensions between scholarly traditions and new knowledge development. If, on one hand, to be seen as future scholars, Ph.D. students had to follow the scholarly traditions (and conform to the existing theoretical and methodological frames in a certain research field), on the other, they believed that they had to contribute to new knowledge based on innovation and originality (academic authorship). As Brodin [11] mentions "Many students experienced that doctoral education implied a learning space primarily embodying critical, rather than creative thinking" (...). "They did not primarily learn to become creative and independent scholars but rather learned how to play safe through critical thinking within scholarly traditions and academic authorship". This conflict can leave Ph.D. students in a dilemma between being creative or fitting the mold.

### 1.3. The 4Cs Competencies and Qualities for Achieving the Ph.D. Degree in Portugal

The based competencies that a doctorate must have, are related to the fact that he/she will work with innovations and original knowledge, and most known and have advanced and specialized skills and techniques. Particularly important are also the synthesis and evaluation skills, which are necessary for the resolution of critical problems in the field of research and/or innovation, for the extension and redefinition of knowledge or practices. Concerning attitudes, having a Ph.D. implies demonstrating a considerable level of authority, innovation, autonomy, and scientific or professional integrity, and making a firm commitment to the development of innovative ideas or new processes at the forefront of study or work contexts, including research.

The Guidelines, regarding the attributes that a doctorate must achieve to be awarded the doctoral degree, after completing a third cycle (corresponds to level 8 of EQF), are presented on the page of the "Direção Geral do Ensino Superior".

(<https://www.dges.gov.pt/pt/pagina/doutoramento?plid=3>)

71), the Portuguese government institution that regulates the Portuguese Higher Education System. The attributes that a PhD student must have to award the doctoral degree are: showing the “capacity for systematic understanding in a scientific field;” presenting “Competences, skills, and investigation methods associated with a scientific field;” having “the capacity to conceive, project, adapt and perform significant research respecting the demands imposed by patterns of academic quality and integrity;” “Having carried out a significant body of original research which has contributed to challenging the boundaries of knowledge, part of which merited national or international dissemination in renowned publications”; “Being capable of critically analyzing, evaluation and synthesizing new and complex ideas;” but also, “Being capable of communicating with their peers, the rest of the academic community and society in general in their expert field;” and have “The capacity to promote technological, social or cultural progress in academic or professional terms in a knowledge-based society” [28-30]. These attributes are part of the Portuguese Republic laws that regulate Higher Education Institutions. An overview of Portuguese Republic law allows us to see the change in Higher education since the Bologna Process implementation in 1999. The “Law- decree n° 74/2006, 24 Mars- Graus e diplomas do Ensino superior”, approves a legal regime of academic degrees and higher education diplomas, but had several changes over the years (Changed by: Law- decree, n° 107/2008, 25 June; Law- decree, n° 230/2009, 14 September; Law- decree, n° 115/2013, 7 August; Law- decree, n° 63/2016, 13 September; Law- decree, n° 65/2018, 16 August; Law- decree, n° 27/2021, 16 April (current)), as it was also necessary to adopt and implement the Bologna Process on higher education system. In this sense, the new legal framework was approved on the “Law- decree n.° 42/2005, de 22 February - Regulatory principles of instruments for the creation of the European higher education area (ECTS)”, which approved the regulatory principles of instruments for the creation of the European Higher Education Area (ECTS), that had been changed by the Law- decree, n° 107/2008, 25 June - Structuring Diplomas of Higher Education, Degrees, Degrees and Equivalences.

The product of the Ph.D. is not only the researcher, but also the “drawing up of an original thesis, especially for this purpose, appropriate to the nature of the branch of knowledge or specialist, or the compilation of a coherent and relevant set of research works or, in the field of the arts, a work or set of works or accompanied by a written statement of reasons.” (<https://www.dges.gov.pt/pt/pagina/doutoramento?plid=371>). “Doctor degree” is given to those who have obtained approval in the public act of oral discussion of the Ph.D. thesis. It is the higher education institution’s responsibility to approve, among other subjects, the curricular structure and the program and the rules of the dissertation, project,

or report of internship, including orientation, presentation, defense, and jury. In all these assumptions regarding the steps and the demand to achieve and award a Ph.D. degree, the 4CS competencies (Critical thinking, Communication, Collaboration, and Creativity) emerge as crucial to achieve them. Knowing how to communicate is important, not only to do the dissemination process (oral and written) where writing and speaking relevant data and describing cutting-edge knowledge achievements are important but also because it is crucial for social and academic recognition. To achieve the desired innovative knowledge is essential to have a solid base knowledge in a specific area, but also creativity and critical thinking. Without them, there is no innovation or originality. In a world of networks and research teams, having personal and professional skills to work in different teams collaboratively and cooperatively is essential.

#### 1.4. Research Context and Goals

This research aims to characterize doctoral education in this institution, through the lens of supervisors’ and students’ points of view. Several publications have reported on the practices of Ph.D. supervisors [31, 32], and the perceptions of Ph.D. students [33-34]. This research work intends to reduce the gap concerning the characterization and development of the learning and innovation skills (4C's) development in Doctoral Education at the School of Science and Technology | FCT NOVA and bring light to the practices used to develop and empower Ph.D. students regarding them during the doctorate. It also intends to reduce the gap in knowledge about the development of creativity, critical thinking, collaboration, and communication, during doctoral research. In this context, it is important to understand the perception of Ph.D. students regarding 21st-century skills (Learning and Innovation Skills (critical thinking, communication, collaboration, and creativity)). This paper aims to present data regarding the doctorate students’ point of view regarding practice, feelings, and confidence concerning the four skills: Critical thinking, Communication, Collaboration, and Creativity.

## 2. Methodology

### 2.1. Research Tasks

This exploratory study case aims to collect data concerning the Ph.D. students’ perception regarding the four competencies of learning and innovation proposed by the framework of the 21<sup>st</sup>-century partnership: Creativity, communication, collaboration, and critical thinking. The research subjects are NOVA School of Science and Technology | FCT NOVA PhD students.

## 2.2. Research Methods

To collect data, a survey, inspired by others already applied in higher education institutions in other countries [35-37], was applied and disseminated, via institutional email to Ph.D. students in NOVA School of Science and Technology | FCT NOVA, in June 2022. Changes have been made in the original surveys to be suitable for doctoral education. The survey validity was ensured by the experts, and the reliability was obtained using Cronbach's alpha. The survey had two parts. The first one had close questions regarding the sample's characterization. The second part had close questions, aimed at collecting data regarding the confidence in PhD students' ability to gather tasks related to, creativity (17 items), communication (10 items), collaboration (14 items), and critical thinking (10 items). A four-point Likert scale (disagree (1), disagree (2), agree (3), and strongly agree (4)), was used to measure confidence in their creativity, communication, collaboration, and critical thinking skills. The Cronbach's alpha reliabilities across the four subscales were  $\alpha = 0,94$ .

## 3. Findings

The development of creativity, critical thinking, collaboration, and communication skills is crucial for doctoral students as they engage in advanced research and scholarship.

The NOVA School of Science and Technology | FCT NOVA is a school of NOVA Lisbon University that aims to be an innovative research institution, which owns European scholarships and European finance research projects [31]. In this sense, it is important for stakeholders and institutional polity decision-makers to identify strengths, weaknesses, and blind points in the educational structure, regarding innovation. Especially the third cycle where students have demands to develop original innovative research with (a glimpse of) novelty and being developers.

The data from the 2021/2022 school year (DGEEC\_DSEE\_DEES\_2022\_insc\_site\_2021\_20222.xls x) show that 619 students are enrolled in PhD in NOVA School of Science and Technology | FCT NOVA, 81 in part-time and 538 in full-time. Considering the 619 students, only 139 are enrolled for the first time, and only 124 have scholarships (20% of the total PhD population enrolled).

### 3.1. Sample Characterization

Only 10% of the Ph.D. students answered the survey. The survey had questions that allowed the sample characterization regarding gender, age, the type of enrolment (partial or full time) in the Ph.D. and the Doctorate course year of enrolment.

Regarding gender, 52% were female and 46% identified themselves as males (Table 1).

**Table 1.** Gender characterization of the survey respondents

Gender	Number of respondents	%
Female	32	52
Male	28	46
I do not answer	1	2

More than half of the respondents were between 25 and 30 years old (Table 2).

**Table 2.** The age of the survey respondents

Age/years	Number of respondents	%
25-30	32	52
31-35	14	23
36-40	4	6,5
41-45	3	5
46-50	1	2
51-55	3	5
Over 56 years old	4	6,5

The type of enrolment in the Ph.D. was scrutinized. Eighty percent of Ph.D. students were full-time, and a lower percentage were enrolled in the Ph.D. part-time (Table 3).

**Table 3.** Answers of the PhD student regarding the enrolment

I am attending my PhD in...	Number of respondents	%
Full-time	49	80
Part-time	12	20

The year of enrolment was scrutinized (Table 4). All PhD courses, in the NOVA School of Science and Technology | FCT NOVA, have 4 years [36].

**Table 4.** Answers of the Ph.D. student regarding the year of enrolment

I am enrolled in the	Number of respondents	%
The first year of the course	10	16
The second year of the doctoral course	19	31
The third year of the doctoral course	13	21
The third and final year of the doctoral course	1	2
The fourth year of the doctoral course	18	30

### 3.2. The Four Competencies: Collaboration, Communication, Critical Thinking, and Creativity

Collaboration and communication imply direct

interaction with others. But although critical thinking and creativity mean interactions with others, they are more personal as they are related to individual traits and to education and social lived experiences (creativity), with the self-construction of knowledge (metacognition) and with judgment and the acceptance of error as an important part of the construction, validation, and evolution of knowledge (critical thinking).

### 3.2.1. Collaboration

Collaboration is the process of working together with others towards a common goal or aim. It involves sharing ideas, knowledge, skills, and resources to achieve a desired outcome. Collaboration can take different forms, such as group work, teamwork, partnership, co-creation, and co-design. Business, education, research, and creative industries use this skill to maximize productivity, creativity, and innovation. Effective collaboration requires active listening, clear communication, mutual respect, and a willingness to compromise and adapt. It involves a democratic cheer of tasks, making compromises to achieve common goals and complete the task. It is more than cooperation, as all the group members engage in all phases of the project (and not the experts), and this interaction benefits all. This type of teamwork reinforces a sense of belonging and personal identification with the cause (problem/ task).

**Table 5.** Doctoral students' perception regarding their collaborative skills

I am confident in my ability to ...	Average	SD
be polite and kind to teammates/research group.	3.8	0.4
follow rules in team meetings/research groups.	3.8	0.4
offer support and assistance to others in their work when necessary.	3.8	0.5
recognize and respect other perspectives.	3.7	0.5
improve my work after receiving feedback.	3.6	0.7
make sure that all the ideas of the team members/research group are also valued.	3.6	0.5
stay informed about the project and gather vital information to support the ideas of the research team/ group.	3.3	0.7
set a timetable with tasks and objectives as a team and monitor the progress of their achievement.	3.3	0.8
follow the rules for the decision-making of the research team or research group.	3.2	1.0
establish team standards or make agreements on the functioning of the research team/group together.	3.2	0.9
use proper/ appropriate body language when presenting.	3.1	1.0
help the team manage conflicts and resolve team/research group problems.	3.1	1.1
involve all team members/research groups in the final project.	3.1	1.1
come physically and mentally prepared every day.	2.7	1.0
Average	3.4	0.8

Data from collaborative skills Ph.D. students' perceptions are shown in Table 5.

All the statements presented a good agreement, ranging from 3.8 to 2.7. The worst percentage of agreement is related to "I'm confident in my ability to be mentally and physically prepared each day" with 2.7 in a range between 1 (totally disagree) to 4 (totally agree). The average of PhD students' confidence regarding collaborative skills is 3.4 which can signify that these respondents are greatly confident in their collaborative skills.

Collaboration implies teamwork, leadership, time management, and flexibility, enabling learners to work in teams, building on their ideas, and working constructively with others to achieve shared objectives. Collaboration skills push students to understand the value of compromise, guidance, and strong relationships in achieving objectives while learning to appreciate the diverse input and accommodation of individual strengths. As collaboration is the art of working with others, emotional intelligence is a requirement for it.

### 3.2.2. Communication

Communication is the process of exchanging information, ideas, thoughts, and feelings between two or more individuals or groups, in open channels between the speaker and the listeners that allows sending a message and the reception of the same. Effective communication involves transmitting information clearly and accurately, receiving and understanding information correctly, and responding appropriately to the message received, which implies expressing ideas, values, needs, concerns, goals, and beliefs, discussing, and debating, being clear, simple, accessible, contextualized, and inherent to a specific field (literacy). It is an essential tool for building relationships, expressing emotions, sharing knowledge, achieving common goals, and issuing and exchanging knowledge, innovation, and teamwork.

The perceptions of confidence in communication skills were collected and analyzed. PhD students are confident in their abilities to communicate with others (Table 6).

The statements presented a good agreement, ranging from 3.5 to 3.1. The average of PhD students' confidence regarding communication skills is 3.2, which can signify that these respondents are noticeably confident in their capabilities regarding communication skills.

The development of this skill in doctoral education has different faces. The most common is the communication with peers that happens throughout the doctoral journey, during the data or results presentation to the other students or peers in seminars, conferences, encounters/ meetings. The other degree of communication is the one that occurs with the public. The ability to communicate ideas effectively is essential and 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. Communication implies presentations and public speaking,

clear and concise writing, fluency, and field vocabulary. Communicating implies the development of skills related to technology (use of programs or applications to help communication and present data and results), with the ability to speak and explain, clearly a message (fluency and field vocabulary) but also with neurolinguistic programming capabilities. Communication is linked to the socialization process of the Ph.D. student in the research team, in the academy, and in the research area. Students easily communicate with peers, researchers, experts, and others if they develop a sense of belonging.

**Table 6.** Doctoral students' perception regarding their communication skills.

I am confident in my ability to ...	Average	SD
use visual aids such as presentation slides, demonstrations, and other media to present conclusions, reasoning, and evidence supporting the final design solution.	3.5	0.6
complete tasks without having to be remembered.	3.4	0.7
present all information, concisely, and logically.	3.3	0.6
present information and evidence of support	3.2	0.7
organize time well during a presentation, including an interesting introduction and a convincing conclusion, without elements that are too long or too short.	3.2	1.0
respond to the public's questions clearly and completely.	3.2	0.7
organize the information well.	3.2	0.8
use time, and run meetings, efficiently.	3.1	0.8
track the progress of my research team/group, according to pre-defined objectives and deadlines.	3.1	1.0
clearly and completely address alternative options or perspectives contrary to my opinion, or other solutions, for the design and implementation of a project.	3.1	0.9
Average	3.2	0.8

### 3.2.3. Critical Thinking

Critical thinking is the process of analyzing, evaluating, and making conclusions or judgments based on evidence, data, and reasoning. It involves questioning assumptions, considering multiple perspectives, recognizing biases and fallacies, and making informed decisions and actions. It emphasizes the ability to think for oneself, weigh evidence, and make logical, well-informed, and defensible decisions. Critical thinking is linked to thinking with autonomy and independence and can be related to the degree of confidence of the student in their knowledge, sources (literature, practical data, and results analysis), and judgment.

In the context of doctoral education, this ability is relevant as research work needs to have critical minds to ensure that the research data and results are analyzed. Critical thinkers proceed to achieve a new but effective solution, a compromise, or an idea. The confidence in the

ability to think critically was assessed (Table 7).

**Table 7.** Doctoral students' perception regarding their Critical thinking skills

I am confident in my ability to ...	Average	SD
understand how knowledge or insights can be transferred to other situations or contexts	3.3	0.6
develop and improve ideas	3.2	0.7
Adapt a communication style suitable for the purpose, task, or public	3.1	1.0
help the research team/group, solve problems, and manage conflicts	3.0	1.0
use idea-generating techniques such as brainstorming to develop original ideas.	3.0	1.1
determine the best design for a task or project, from a set of ideas.	2.8	1.1
use ingenuity and imagination, get out of typical approaches, and generate innovative design solutions, for a project.	2.8	1.1
find sources of information and inspiration when others cannot.	2.8	1.1
create new, unique, and surprising ideas that add my personal touch to the structure/design of the final project.	2.7	1.3
based on typical design or common materials or ideas, transform and/or innovatively use them, generating new, intelligent, or unimaginable forms or ideas.	2.6	1.3
Average	2.9	1.0

The higher average regarding critical thinking was 3.4 with the sentence "I am confident in my ability to review the drafts of papers and justify the revisions proposed by me with evidence/proof." The lowest average in this skill is the degree of confidence of Ph.D. students in their "ability to create new, unique, and amazing solutions for a project (2.8)." This statement is related to innovation and knowledge construction.

It should be emphasized that some statements show lower degrees of confidence: "I am confident in my ability to find sources of information and inspiration when others cannot" (average 2.8); "I am confident in my ability to create new, unique and surprising ideas that add my personal touch to the structure/design of the final project" (average 2.7), and "I am confident in my ability to base on typical design or common materials or ideas, transform and/or use them in innovative, intelligent or unimaginable forms or ideas" (average 2.6).

### 3.2.4. Creativity

Creativity is the ability to use imagination, originality, and innovation to generate new ideas, concepts, and solutions to problems. It involves challenging existing norms and thinking "outside the box" to produce novel and unique ideas that have value and impact. A creative person



can switch / exchange perspectives and see an object, idea, look has inherent personal qualities such as flexibility, resilience, critical thinking, and innovation, but also adaptation to new environments (Physical or mental). A creative person can be creative in a knowledge field but not in others.

In the context of doctoral education, this ability is important as research work needs not only to have critical minds to ensure originality and novelty but also innovation. Creativity degree of confidence concerning PhD students was accessed and results are presented in Table 8.

**Table 8.** Doctoral students' perception regarding their creativity

I am confident in my ability to ...	Average	SD
review the drafts of papers and justify the revisions proposed by me with evidence/proof.	3.4	0.6
collect relevant and sufficient information from diverse sources.	3.3	0.7
evaluate the reasoning and evidence(s) that support an argument.	3.3	0.5
justify the choice made when creating the final project, giving valid reasons, supported by evidence.	3.2	0.6
combine different elements or sources of information in a project.	3.2	0.7
identify what needs to be known about a problem, task, or project.	3.2	0.7
assess the usefulness, accuracy, and credibility of the information collected for the development of a project.	3.2	0.6
develop project monitoring/monitoring issues that focus on or extend its scope.	3.1	0.6
develop strategies (questions, checklists, and so on) to understand the achievement of a project's objectives.	3.1	0.8
develop questions or other monitoring and monitoring strategies to understand the development of a project.	3.0	0.6
create ideas targeted at a research objective or project.	3.0	0.7
identify in detail what needs to be known to answer questions from a project.	3.0	1.0
understand and assess the needs of a project.	2.9	0.9
justify choices of evaluation criteria for a project.	2.9	0.9
justify choices of criteria used to evaluate the research design, prototypes, and/or final solutions of a project.	2.8	1.0
use knowledge learned from this project to solve new problems and develop new projects.	2.8	1.2
create new, unique, and amazing solutions for a project	2.8	1.1
Average	3.1	0.8

This result reflects a lack of confidence in students in their capabilities to be creative, open minds, and lack of autonomy to propose innovative ideas. These results reflect the blockage that may arise from fitting into a field of study

and research when they become academics or scholars. Creativity in doctoral education is linked to the development of autonomy, deepening knowledge in the scientific field, and engagement in the research project.

In resume, it should be underlined that these four skills are increasingly important in today's workforce [3-6] and that these students perceived that possess them. Although these skills are not completely developed, which is shown by the results regarding students' confidence in doing some tasks, they reflect that almost all PhD respondents are still in the doctoral journey, Fig. 1.

The results show that these Ph.D. students have a huge confidence in their communication skills (81% on average), which are essential for them to disseminate their research/work, to communicate effectively in different environments and contexts, to teamwork as listening, reading but also in articulating thoughts and ideas effectively and expressing themselves. These students have confidence in their collaboration skills (85% on average), including working competently with others to achieve a common goal, which reflects their capability to work in teams. These Ph.D. students showed they felt confident in doing tasks related to creativity (77% on average), feeling well prepared to promote innovation, originality, novelty, effectiveness, and ethics, but less confidence in critical thinking skills (73%), namely using them to create new information and transform it.

## 4. Conclusions

The 4Cs skills form essential pillars in contemporary learning methodologies and theories aim to promote increased student engagement and empower learners to take ownership of their learning experiences.

The development of creativity, critical thinking, collaboration, and communication skills is crucial for doctoral students as they progress through their programs and prepare for careers in academia, research, or other fields. At the beginning of their doctoral journey, students should hold a foundational level of knowledge and skills related to their specific field of study. This includes mastering coursework, understanding research methodologies, and gaining expertise in their chosen area of research. As students' progress, they develop critical thinking skills by engaging with complex concepts, theories, and research in their field. They learn to evaluate evidence, identify gaps in the literature, and apply critical thinking to their research questions. Throughout their doctoral studies, supervisors should encourage students to think creatively and innovatively. They explore new research ideas, propose novel solutions to existing problems, and challenge conventional wisdom in their field. Doctoral students engage in collaborative research projects and interdisciplinary learning experiences. Collaborative efforts expose students to diverse perspectives, problem-solving approaches, and methodologies from different

disciplines. Effective communication is a fundamental skill that doctoral students develop throughout their program. They learn to communicate their research findings.

By developing these skills, learners are better positioned to overcome challenges, maximize opportunities, and develop strong 21st-century skills. The 4cs skills are essential in the learning process as they promote active and effective participation in education and allow learners to exhibit a range of strategies that promote concept development and learning ownership, which is crucial to a successful academic trajectory. Encouraging critical thinking among students can be achieved by challenging them to analyze and evaluate complex theoretical debates or empirical data. Creativity can be fostered by providing opportunities for students to engage in independent research, which can lead to novel ideas and approaches in their field. To facilitate collaboration, group projects, and problem-solving activities can be assigned, which require students to work together. Additionally, communication skills can be improved by training students in academic writing, presenting research results, and engaging with stakeholders.

Data analysis revealed that students are noticeably confident regarding their ability to use critical thinking, work collaboratively, communicate with peers or with society, and be creative.

Although we did not specifically deepen the “Doctoral Student Development Model: Creativity, Critical Thinking, Collaboration, and Communication (C4 Model)” (Fig. 1), data can be related to the fact that 53% of the sample students were in their 3<sup>rd</sup> or 4<sup>th</sup> year of enrollment, and are at the end of the Ph.D. Journey (Advanced Skill Acquisition Stage). They have already developed competencies during their doctorate. Nevertheless, the others (47%) are still in the first years of enrollment and have less confidence to do the task.

However, the answers of some students (enrolled in the 3<sup>rd</sup> or 4<sup>th</sup>-year course) show a lower degree of confidence in their creativity, critical thinking, and collaboration. This fact can be understood, considering the invisible forces that emerge from the struggle between belonging to a group (fitting the mold), obeying the research area rules/beliefs (being an academic) and completing the doctorate, or being innovative (questioning research areas rules/dogmas), not fit in the academic culture paradigm, which can leave to attrition.

With this research, the survey was validated, and its reliability was confirmed. However, the sample (Ph.D. students’ respondents) was a limitation and didn’t allow for validation of the proposed model (Fig. 1). To evaluate the model presented, further research will be done in this institution, in the next year, with a larger sample.

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