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Robots Teaching Teachers: Acceptance of Technology in Higher Education

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Abstract

Background/purpose. This study aimed to investigate teachers' perceptions of using advanced technological tools, specifically the NAO robot, in co-teaching settings to enhance class development and promote complex thinking in higher education. Complex thinking is a crucial skill in higher education, enabling students to effectively address and solve multifaceted problems.

Materials/methods. A survey was conducted among 192 participants following a workshop where the NAO robot was used as a co-teaching tool. Participants were divided into three age groups: young adults (n=29, 15.1%), middle-aged adults (n=129, 67.2%), and older adults (n=33, 17.2%). The survey evaluated their experiences and perceptions of the robot's impact on the teaching-learning process.

Results. Findings highlighted the importance of integrating technological innovations, like the NAO robot, in higher education. Participants reported that such tools not only fostered the development of complex thinking but also enhanced the overall educational experience by making classes more engaging and accessible.

Conclusion. The use of cutting-edge technologies, such as the NAO robot, holds significant potential for driving innovation in higher education. These tools contribute to more interactive and effective teaching, supporting the development of essential cognitive skills and improving educational outcomes.

1. Introduction

The presence of technology permeates every corner within and outside the economic activities of each country. From organizational areas to educational environments, digital transformation is evident through innovative execution in manufacturing processes, information storage, implementation of security systems, teaching, etc. The leap forward in communication and information technologies (ICT) has generated new challenges and scenarios, imposing the need to prepare students and workers for using technology (Inamorato dos Santos, 2023). For example, the emergence of 3-D virtual learning environments in education requires a broader spectrum of media literacy skills, presenting new challenges for learners to become competent digital citizens (Qian, 2009). More specifically, the challenges in using ICT-based teaching and learning resources include the need for effective integration to achieve instructional objectives (Bano & Ali, 2022), management issues of ICT resources in e-learning environments (Basha & Abbas, 2011), and the adaptation to new forms of learning beyond traditional classrooms (Sah, 2014). Additionally, the rapid advancement of ICT has necessitated educational institutions to adopt new approaches and tools to modernize education and enhance productivity (Saif et al., 2022). Therefore, digital transformation has been considered as a solution to approach to wicked problems due to its ability to explore and act upon the opportunities of digital technologies (Dragičević et al., 2023) and the relentless technological development raises the presence of digital competencies in people, for them to carry out an appropriate role in work, educational or research areas.

ICT and digital transformation are crucial for the development of generic skills or competencies in people within organizations to be able to make inroads and explore problems of social relevance to find solutions from integrative thinking, with a mindset open to alternatives, linking business and educational sectors (Dragičević et al., 2023; Inamorato dos Santos, 2023) and, above all, synchronizing with industry and education 4.0. The technological revolution of the 21st century has been called the fourth industrial revolution or Industry 4.0 due to its advances in genetics, artificial intelligence, robotics, etc., which have made it possible to reach a high level of efficiency in the processes generated at the industrial level (Ramírez-Montoya et al., 2022). Industry 4.0 is characterized by intelligent, digital, and virtual interaction between company workers and their production methods through tools such as 3D printing, intelligent storage devices, the Internet of Things (IoT), and bio or nanotechnology. The arrival of Industry 4.0 has generated a significant impact on academic spaces, transfiguring the traditional teaching-learning processes to the so-called Education 4.0 (Ramírez-Montoya et al., 2022).

Education 4.0 refers to the implementation of technology in educational environments in order to improve pedagogical procedures, especially at higher education levels (Patiño et al., 2023), encouraging active learning (Ramírez-Montoya et al., 2022) where academic literacy and the digitalization of classrooms can be combined to integrate advanced technology such as virtual spaces, artificial intelligence, distance or remote education, through videoconferencing applications, messaging, discussion forums and digital technology that incursion into virtual reality, simulators, and nanorobotics. In other words, education 4.0 refers to integrating advanced technologies to build unique, collaborative and quality learning experiences to develop required skills in fundamental roles within the profiles of each professional area. The conjunction of diverse abilities makes up the transversal competencies of the 21st century.

Competencies refer to training that promotes transversal and disciplinary development in university students (Ramírez-Montoya et al., 2022). The competencies are associated with more complex elements of the formative processes since they refer to the conjunction of skills that contribute to constructing professional profiles of workers at the organizational level and in students to be able to face the needs of the present time. Competencies are formed from skills people possess, which can be fostered for future development. Among the essential competencies are complex

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thinking linked to the use of state-of-the-art technology, the digitalization of work, academic and research spaces, and collaborative work by various groups at an interdisciplinary level. For Patiño et al. (2023), complex thinking is one of the essential competencies that should be fostered in higher education students, as it allows them to face the challenges posed by current reality.

As defined by Morin (2005), complex thinking serves as a theoretical framework that synthesizes multiple dimensions of knowledge to navigate uncertainty, complexity, and interconnectedness in problem-solving and decision-making processes. By adopting Morin's perspective, this study aligns with the notion that complex thinking is crucial for fostering critical, creative, and transdisciplinary skills, particularly in the context of higher education and the integration of innovative technologies in teaching and learning. Complex thinking is composed of transversal meta-competencies such as critical, systemic, scientific, and innovative thinking, and disciplinary competencies such as functional, technical, and technological knowledge and skills; research, design, creation, implementation, use and proposal of technology-oriented to problem-solving, through holistic and transdisciplinary approaches (Patiño et al., 2023; Ramírez-Montoya et al., 2022; Suárez-Brito et al., 2022). This competency is closely related to digital literacy, which teaches skills in using technology and digital devices essential in higher education, especially in scientific research tasks and teaching activities. Teachers equipped with complex thinking abilities can design curricula and employ teaching strategies that foster critical and creative thinking in students, preparing them for the challenges of modern society and the demands of various fields (Aizikovitsh-Udi & Cheng, 2015). Likewise, Behar-Horenstein et al. (2009) demonstrate that faculty development programs can incorporate critical thinking concepts into instruction.

The complex technological network that envelops the world today weaves its diverse connections from where each person is located. This increases the inclusion of segregated or limited sectors of the population in accessing health, labor, and educational services. The 2030 agenda created by UNESCO in 2015 includes in its Sustainable Development Goals (SDGs) Sustainable Development Goal 4 (SDG 4) "Quality education", which intends to create quality education for all people within societies through technological implementation, which it implicitly considers when talking about educational inclusion in each nation (United Nations, 2024). This goal, in turn, is linked to Sustainable Development Goal 10 (SDG 10), "Reduction of inequalities," which is based on the reduction of cultural, socioeconomic, and gender inequality, promoting inclusion at the social level regardless of any condition, in order to ensure equal opportunities at the political and economic level in each nation (United Nations, 2024a).

On this topic, Arredondo-Trapero et al. (2016) carried out a study in regions belonging to Latin America and the Caribbean, specifically Mexico, Colombia, Peru, and Chile, through which it was possible to conclude that the inclusion of women in the political and economic spheres within the countries in question reduces the gender gap and makes a statistically significant difference on competitiveness. Sustainable Development Goal 17 (SDG 17), "Revitalize the global partnership for sustainable development," aims, among its various targets, to promote the development of environmentally sound technology to disseminate and diffuse them over countries in less favored conditions (United Nations, 2024b). Thus, these three Sustainable Development Goals are related to the intention of fostering competencies or skills in people to create learning that lasts at least a lifetime and that projects its effects beyond the classroom on applied areas of professional practice of each discipline, that has an impact at the national level, that allows the improvement of employment, health, and educational opportunities, and internationally fosters scientific development.

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2. Literature Review

The traditional meaning of robots often refers to automated machines designed to perform specific tasks, which may range from industrial applications to more complex functions. On the other hand, social robots are a subset of robots designed to engage with humans in a social context, exhibiting behaviors and communication patterns that facilitate social interaction (Cheng & Bakhoum, 2021). In practice, this is usually an electromechanical system that, by its appearance or movements, gives the impression of having a purpose of its own. The word robot can refer to physical mechanisms and virtual software systems, although the latter is often called bots (Lesort et al., 2020). With a Czech term originating more than 100 years ago, meaning "servitude," we can begin to understand the meaning of a robot: to serve and eventually accompany a human being. This is where the branch of social robotics, i.e., robots that accompany or interact in people's daily lives, comes into its own.

However, social robots are filled with more complex social functions, such as companionship, assistance, and even roles in education and healthcare. This distinction highlights the evolution of robotics from purely functional devices to entities capable of social engagement and emotional connections with humans (Cheng & Bakhoum, 2021; Kim et al., 2022). For example, robotics applied to medicine has applications such as assisting surgeons with extremely methodical and careful interventions, resulting in machines having better results, always assisted or directed by humans (Dupont et al., 2021). In nursing homes, social robots have been shown to improve the mood of residents with dementia and assist healthcare providers with daily tasks (Bemelmans, 2015). Likewise, social robots may support rehabilitation and improve the social interaction of individuals with disorders like ADHD and ASD (Daglarli et al., 2017).

Social robotics encompasses several transformative applications in education, two of which stand out due to their profound impact on teaching and learning environments. First, robots are increasingly used as assistants in educational settings, functioning either as extensions of the teacher or as companions for students (Lopez-Caudana et al., 2019; Tuna et al., 2019). Previous literature reports that children were more engaged with a Nao robot as a teaching assistant. However, it did not significantly change test scores, indicating a potential for robots to provide social presence and assist teachers (Mubin et al., 2019). Integrating robots as assistants in class allows educators to focus more on pedagogy and less on logistical burdens, enhancing the overall educational experience (Paul et al., 2021). These robotic assistants can carry out a variety of tasks, from providing social presence and engaging students (Cui et al., 2022; Idris & Halabi Azahari, 2024) to handling repetitive administrative tasks that typically consume much of teachers' time.

Educational robotics, also known as pedagogical robotics, is a discipline that aims to design, create, and implement robotic prototypes and specialized programs for educational purposes (Oliveira et al., 2019). Robotics in the classroom not only allows to study automation and process control topics in technology and computer science but also serves as an aid to learning in different areas of knowledge because it arouses interest in students as it is an eye-catching concrete object such as a robot. This, together with a methodology and adequate planning, stimulates students to learn subjects that would otherwise be more difficult to understand and not very motivating to study (Reyes et al., 2021). Ponce et al. (2019) set a clear example of how to improve learning processes, i.e., educational robotics is a complex scenario that, through robotic platforms, increases the attention span, motivation, and knowledge acquisition of students during their classes. Interestingly, at the end of the course, the students evaluate their perceptions of the learning process and of an NAO-type robot in the areas of physics, mathematics, and physical education. The results showed that the use of a robotic platform coincides with other research (Lopez-Caudana et al., 2020), where students are encouraged to improve the acquisition of knowledge and increase their motivation and attention span, resulting in the development of sub-competencies such as creativity, innovation, and scientific inquiry.

Second, robots serve as exceptional tools within STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. They facilitate interactive learning experiences and serve as interactive educational tools, facilitating abstract learning and promoting interdisciplinary approaches to creativity and technology use (Vascan, 2022). Robots are integrated into educational settings to enhance learning experiences, often through hands-on activities encouraging student engagement and skill development (Latip & Hardinata, 2020). This hands-on approach promotes a deeper understanding of complex subjects and nurtures skills, including critical thinking and problem-solving.

According to the United Nations (UN), education is an agent of change and innovation, and the so-called digital literacy contemplates the challenge of updating, boosting, and diversifying innovative technology. Rodríguez-Abitia et al. (2020) established how different institutions in Mexico and Europe have taken on the challenge of adopting technologies and applying them to the educational process. This study addresses a significant gap in the literature by exploring the role of social robotics, specifically the NAO robot, in higher education contexts. While prior research has examined the use of social robotics in lifelong learning (Piedade, 2021) and basic education (Bustamante-Meza et al., 2022), limited attention has been given to their potential for fostering complex thinking in higher education teachers. By analyzing teachers' perceptions of the NAO robot as a tool in virtual classrooms, this study investigates its capacity to enhance teaching-learning processes and improve attentional and motivational aspects during classes. This work contributes to the broader understanding of how innovative technologies can support the objectives of the Sustainable Development Goals, particularly in advancing quality education and reducing inequalities.

Considering all the information above, this work aimed to promote the development of the mega competence of complex thinking in a group of higher education teachers and to know their perception about implementing technology (NAO robot) as a tool in the virtual classroom. We analyzed to what extent higher education teachers perceive the use of technology during a class as a positive educational experience and if they consider that social robotics, specifically the use of an NAO robot, can enhance better teaching-learning processes and increase attentional and motivational aspects during the class. The research hypothesis guiding this work is as follows:

H1: Teachers' perceptions of using ICTs in higher educational settings are positive in the majority and are linked to their perceived effects on educational processes.

H2: Higher education teachers highly accept using robots in learning environments after the educational experience with the NAO robot.

H3: Teachers’ acceptance of using ICTs and social robots in educational contexts depends on their age and teaching experience.

H4: Participation in the workshop utilizing the NAO robot will enhance teachers’ complex thinking competencies, as evidenced by their engagement in workshop activities and their ability to evaluate the impact of using ICTs and social robotics.

This study anticipates contributing to the growing body of literature by offering evidence on integrating social robotics in higher education, emphasizing its role in fostering complex thinking and enriching classroom dynamics.?

3. Methodology

An informed consent form was provided to each participant in this study. It contained information regarding their participation in a virtual workshop on research methodology entitled "Research Manual for the Development of Scientific and Dissemination Articles." The workshop's objective was to impart introductory topics on research methodology to promote complex thinking and its sub-competencies, emphasizing scientific and innovative thinking through activities carried out in the workshop. The workshop was composed of two asynchronous one-hour sessions. It was made up of a presentation prepared by the teacher on the topic supported by the projection of a video and the presentation of slides that addressed, from each session, the main ideas, as well as a synchronous virtual class with the teacher accompanied by an NAO robot.

The study's sample comprised 192 participants distributed across three age categories: young adults (n=29, 15.1% of the total sample), middle-aged adults (n=129, 67.2% of the total sample), and old adults (n=33, 17.2% of the total sample). In terms of teaching experience, the overall average was 17.08 years, with young adults averaging 8.81 years, middle-aged adults 16.76 years, and old adults 25.13 years. The mean age of the total sample was 51.95 years (SD = 9.8), with young adults at a mean age of 36.31 years (SD = 5.29), middle-aged adults also averaging 51.95 years (SD = 5.06), and old adults at 65.70 years (SD = 4.28). The gender composition included 110 males and 82 females across the sample, with specific distributions of 19 males and 10 females among young adults, 69 males and 61 females among middle-aged adults, and 22 males and 11 females among old adults.

A questionnaire was conducted to evaluate students' perceptions of their experience with ICT and humanoid robots in educational settings. The sections that comprised the questionnaire were as follows: Section I Applications or tools within the classroom focused on identifying perceptions when using technological tools within the teaching-learning processes of a higher education course and/or class. Section II, Empowerment of classes with technological resources and NAO robots, aimed to observe students' perceptions of the inclusion of NAO robots to make teaching more efficient and technological tools and NAO robots for learning (both within the classroom) once NAO robots were implemented as technological tools to assist in the teaching processes. Section III Classroom performance considering the presence of the NAO robot. The questionnaire also had an initial section to collect general data on the participant's age, gender, and institutions of origin.

At the end of the virtual workshop, participants were asked to answer a questionnaire to rate their experience of the robot-assisted virtual classroom. This made it possible to address the use, improvement, and impact of both NAO robots and technologies in general to improve the teaching-learning processes.

This article carries out an applied case study with teachers. Thus, this mixed research technique analyzes a specific case related to teaching practice in an educational environment. In this type of study, a group of teachers or an individual teacher is selected, and their experience, pedagogical practices, challenges, and achievements are examined in detail in the context of their work. Therefore, this case study applied to teachers seeks to understand how they can validate pedagogical strategies and approaches in teaching and how these practices can also impact student learning (Herreid & Schiller, 2013; Yin et al., 2012).

In this manner, before the application of the survey, three sessions were held (two asynchronous and one synchronous), in which case different technologies were used, such as ITC, artificial intelligence, and NAO Robots. All these tools made the classes, carried out through a video conferencing platform, much easier to develop technically. In the case of the NAO Robots, these were programmed through a specialized team from the Tecnologico de Monterrey; all this, with different dialogues not only to complement the explanations of the sessions and assist the teaching professor but even to answer generic questions to make the class different and more aligned with the new disruptive trends suggested by the theory. Then, regarding the Robot NAO performance, Section III, "Classroom Enhancement with Technological Resources and Humanoid Robots," of the applied survey adopted semi-structured questions on a Likert scale to facilitate tabulation.

In sum (see Figure 1), the present study develops a case study based on three hypotheses tested after the workshop entitled "Research Manual for the Development of Scientific and Dissemination Articles." In this way, the teachers participating in this exercise on promoting complex thinking competencies validated all the hypotheses through the survey considered.

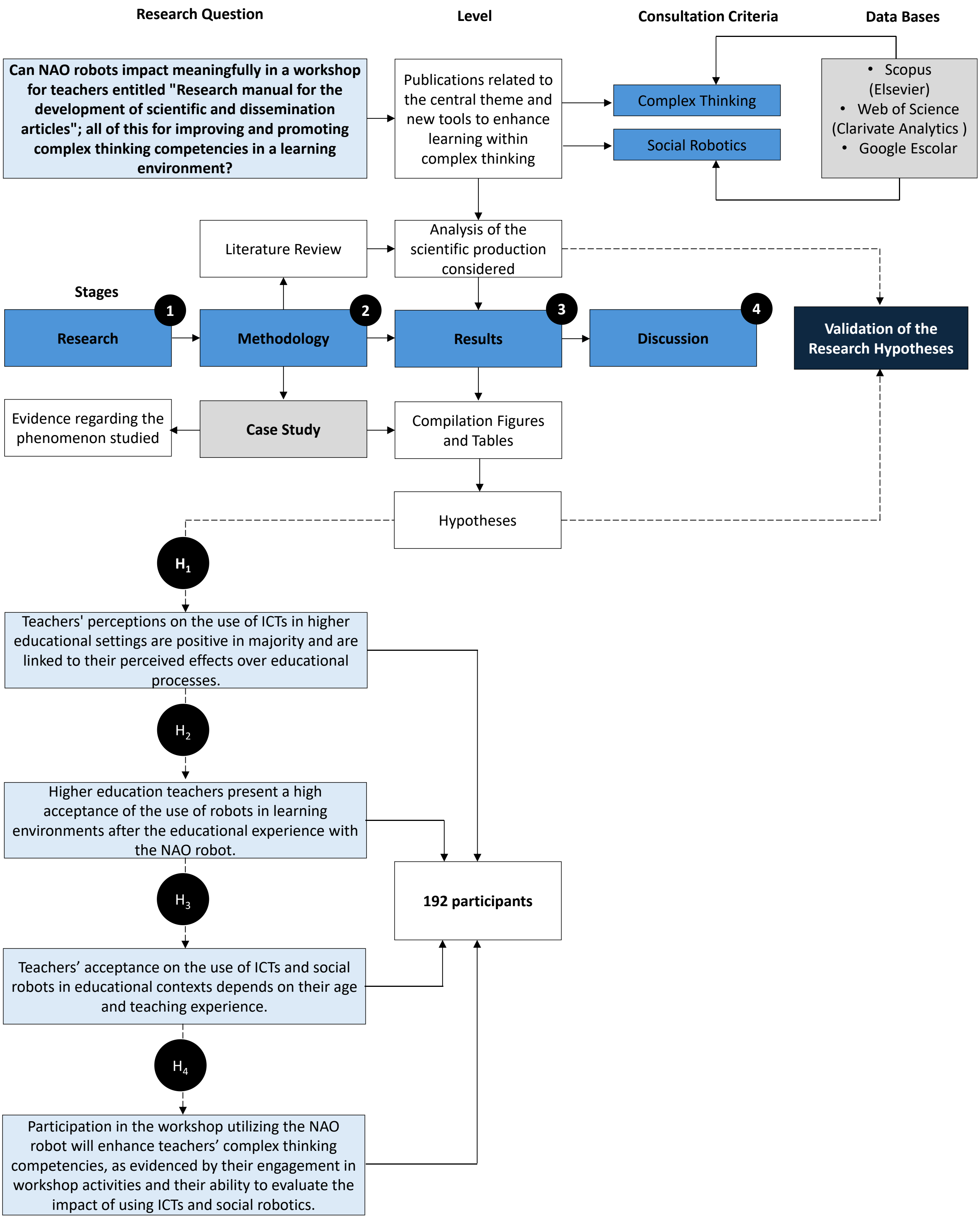

Figure 1. Depiction of a case study with robots for improving learning in higher education

The data analysis began with descriptive analysis, where demographic information, such as age, gender, and teaching experience, was examined. The mean and standard deviation were calculated for continuous variables like age and teaching experience. Next, the survey data, particularly the responses from the Likert-scale-based questions in Section III, were coded to assess the participants' perceptions of the NAO robot's impact in the classroom. This was followed by quantitative analysis, where descriptive statistics like frequency distributions and means were calculated to summarize the responses regarding the use of ICT and robotics. Descriptive trends were obtained to examine how perceptions varied across different age groups, such as young, middle-aged, and older adults, to understand the influence of age and teaching experience on technology adoption in education.

4. Results

This section presents the results obtained in each section of the Questionnaire. First, data regarding teachers' perceptions of using ICTs in the classroom are presented. Figure 2 shows a graph representing the percentage of the importance and use of ICTs in the participants' classrooms. The trend resulted in the higher the level of importance, the greater the use of ICTs. No one reported the option of "Not important", and no one reported having "never" used them. The results in the graph are the percentages of the crossover between the importance and use of ICTs distributed among all the participants' responses.

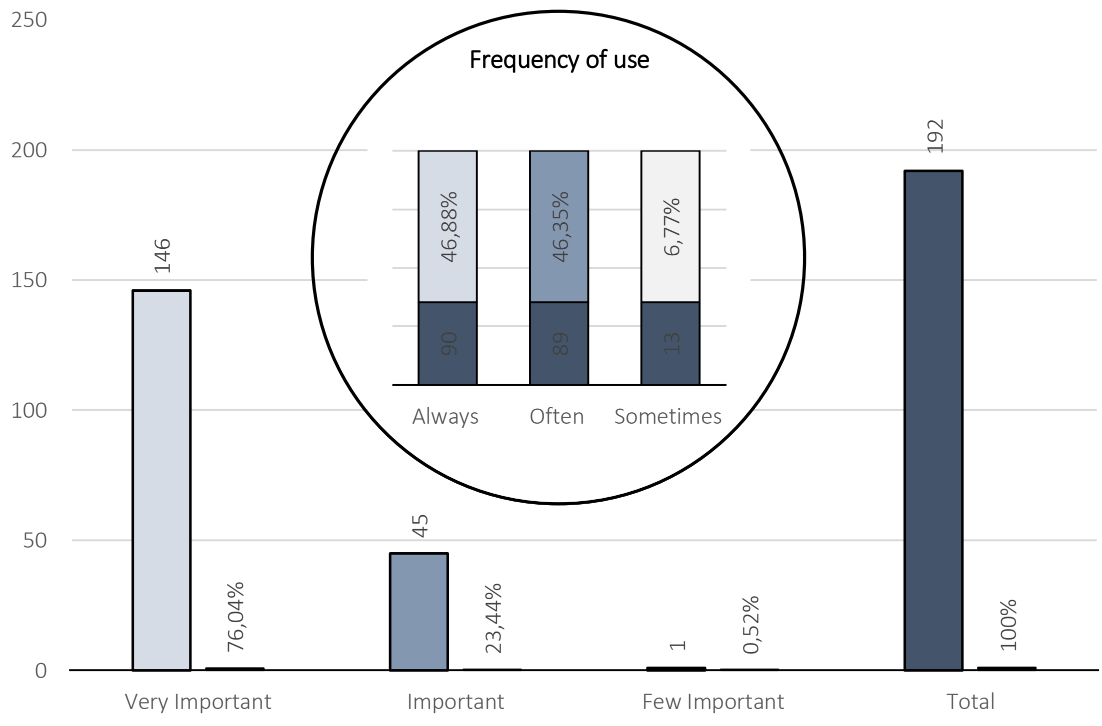

Figure 2. Percentage of frequency and use of ICTs

When observing the responses of the participants grouped by age (Figure 2), it can be seen that the oldest age group has the highest approval rates in contrast to the other groups, with a minimum of 85% acceptance. The middle age group has varied indexes for the different educational processes, but in general, it can be said that there is a high acceptance of ICT in promoting these processes since all responses were above 65% approval of ICT.

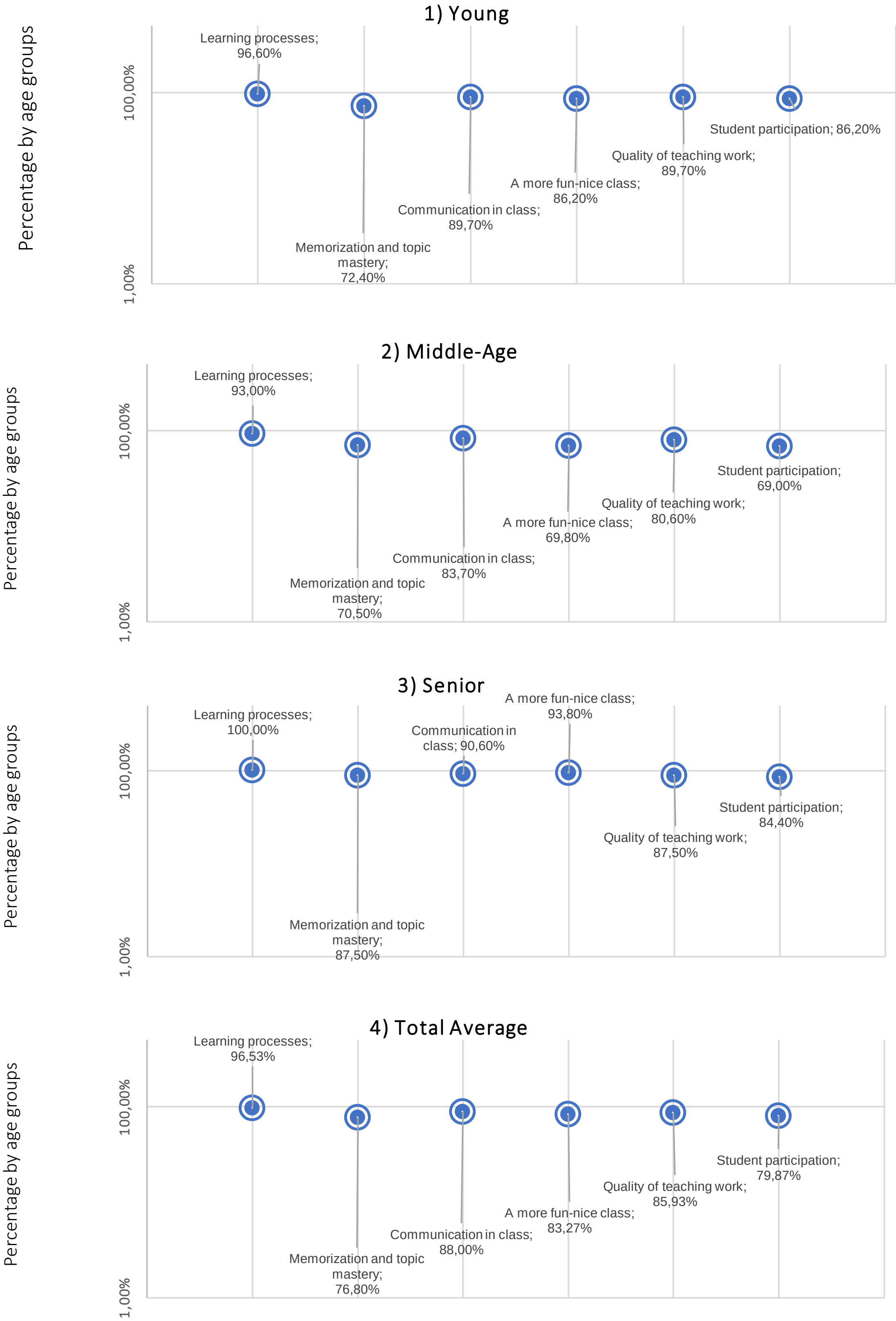

Figure 3. Percentage of Importance and Use of ICTs by Age

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Likewise, Figure 4 shows a relatively high perception rate regarding the promotion of educational processes in the classroom by ICT by teachers with different teaching experiences. The most experienced teachers perceived a higher percentage of improvement in educational processes in the classroom when ICT is involved.

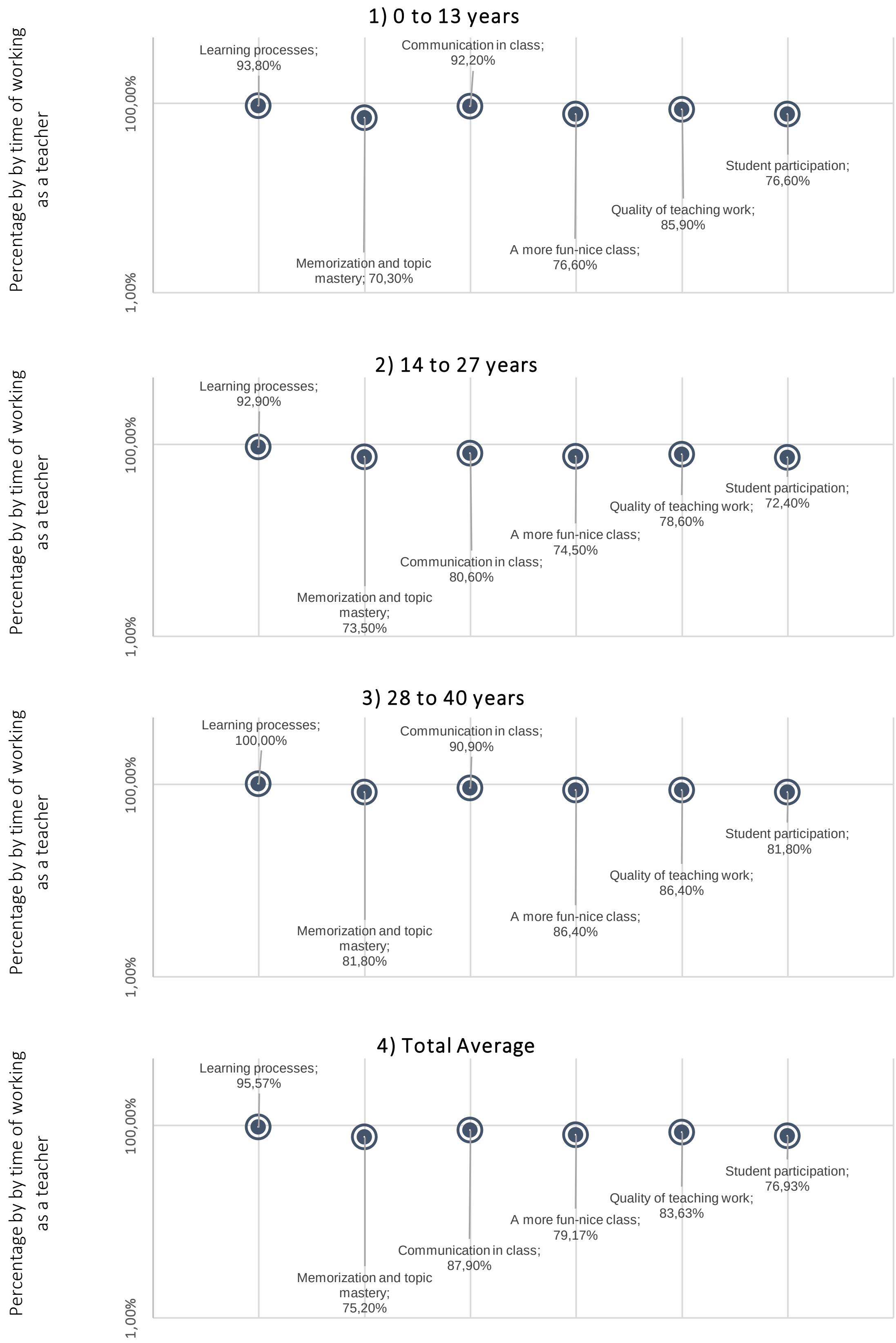
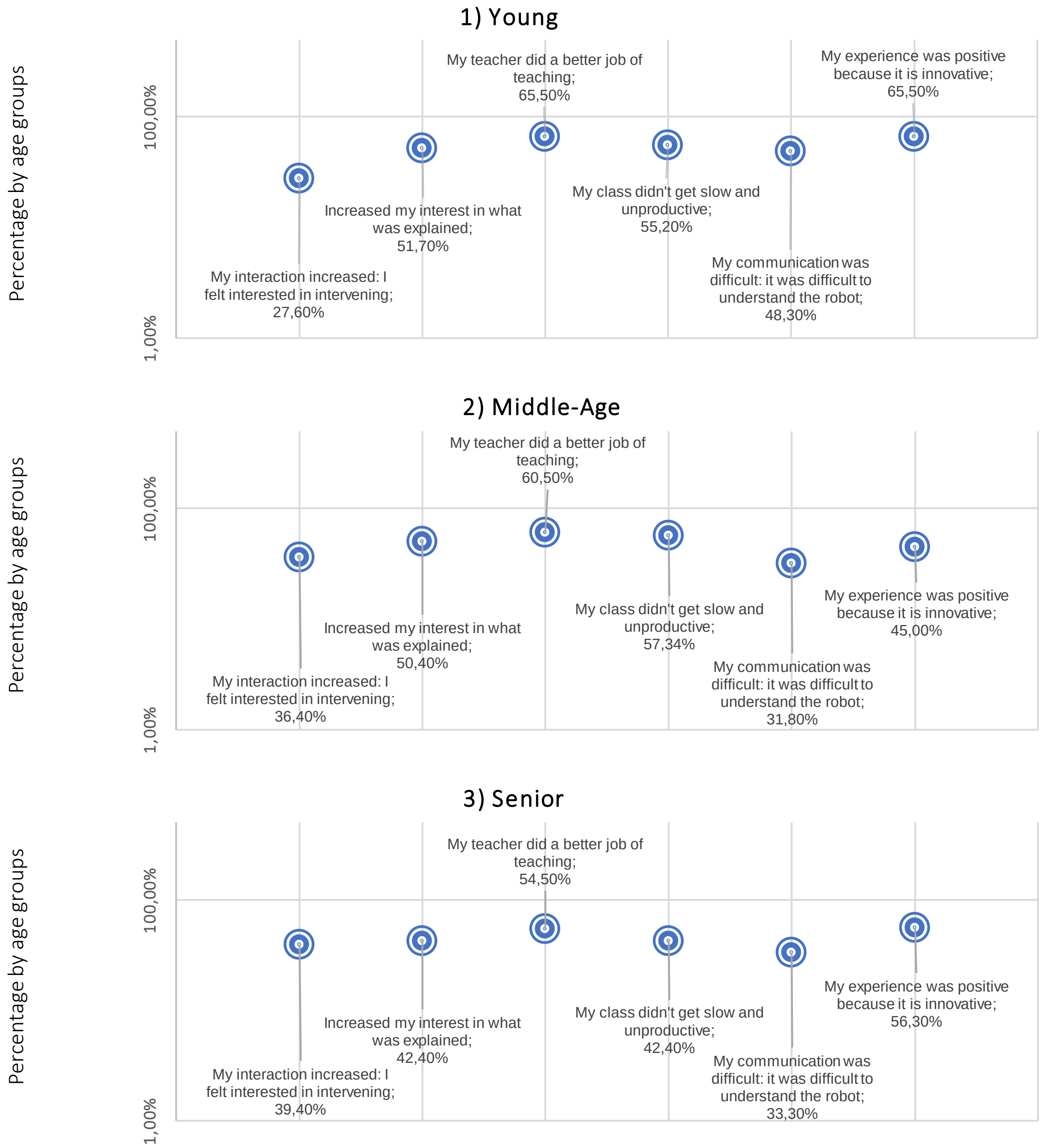


Figure 4. Percentage of Importance and Use of ICTs by Time as a Teacher

The following results relate to the teachers' perceptions about using humanoid robots to promote classroom teaching. Having the participants grouped by age, it can be observed that among the groups, there is a tendency for the younger group of teachers to respond with a higher percentage of positive perception. Figure 5 shows that the ratings generally range from 30% as a minimum to approximately 65% as a maximum. For the younger and older adult groups, the cases of "the teacher performed his job better" and "my experience was positive because it is innovative" were the best evaluated (65% valuation). Globally, the cases of "my interaction increased because I felt interested in intervening" and "my communication was difficult because it was difficult to understand the robot" were the lowest rated.



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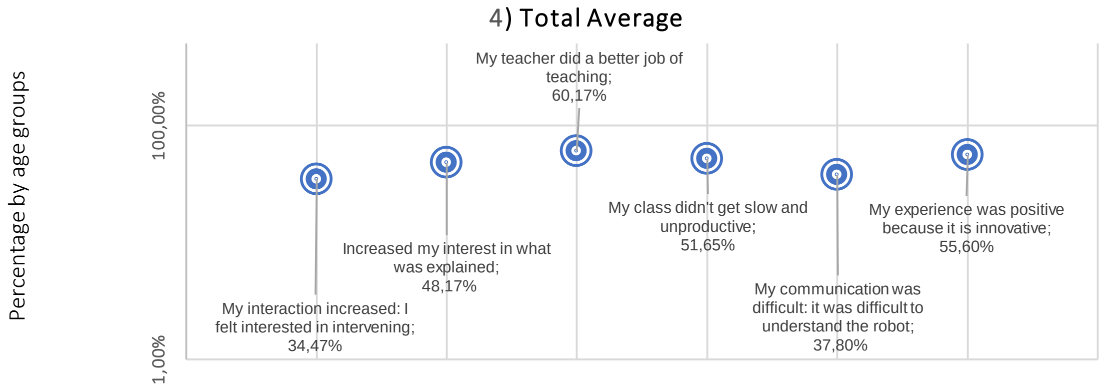
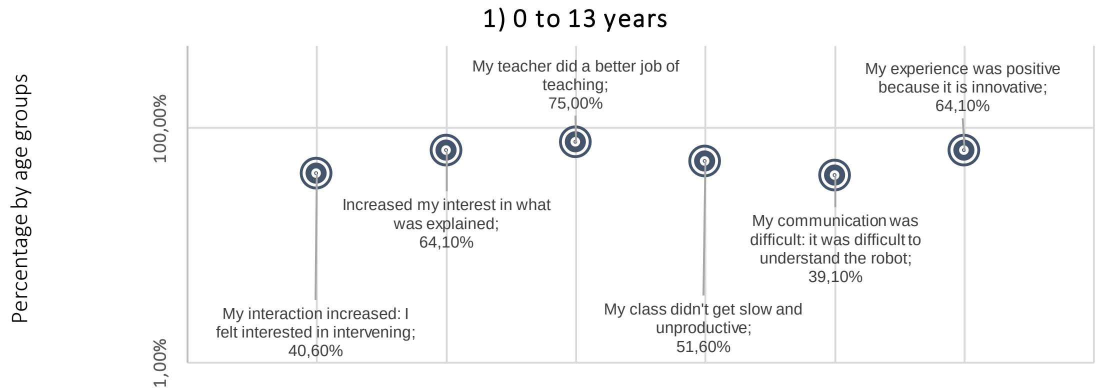
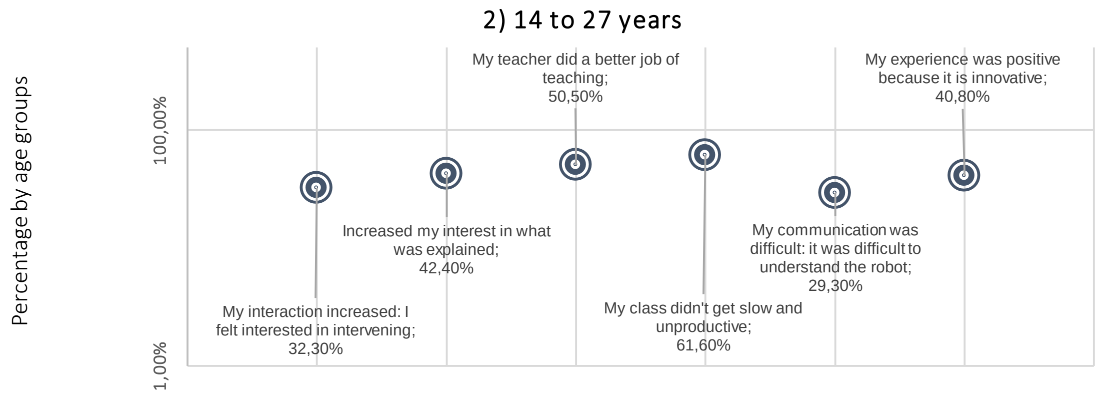


Figure 5. Percentage of Use of ICTs and Improvement

In this same context, Figure 6 shows the evaluation results of the participants' learning experiences grouped by their time as teachers. It can be observed that the teachers in the group who have worked from 28 to 40 years present lower levels of positive responses for all cases, in contrast with the other groups. On the other hand, those in the group from 0 to 13 years of age show relatively higher indexes, especially for the cases where "increased their interest in what was being explained, "the teacher did a better job of teaching," and "my experience was positive because it was innovative."





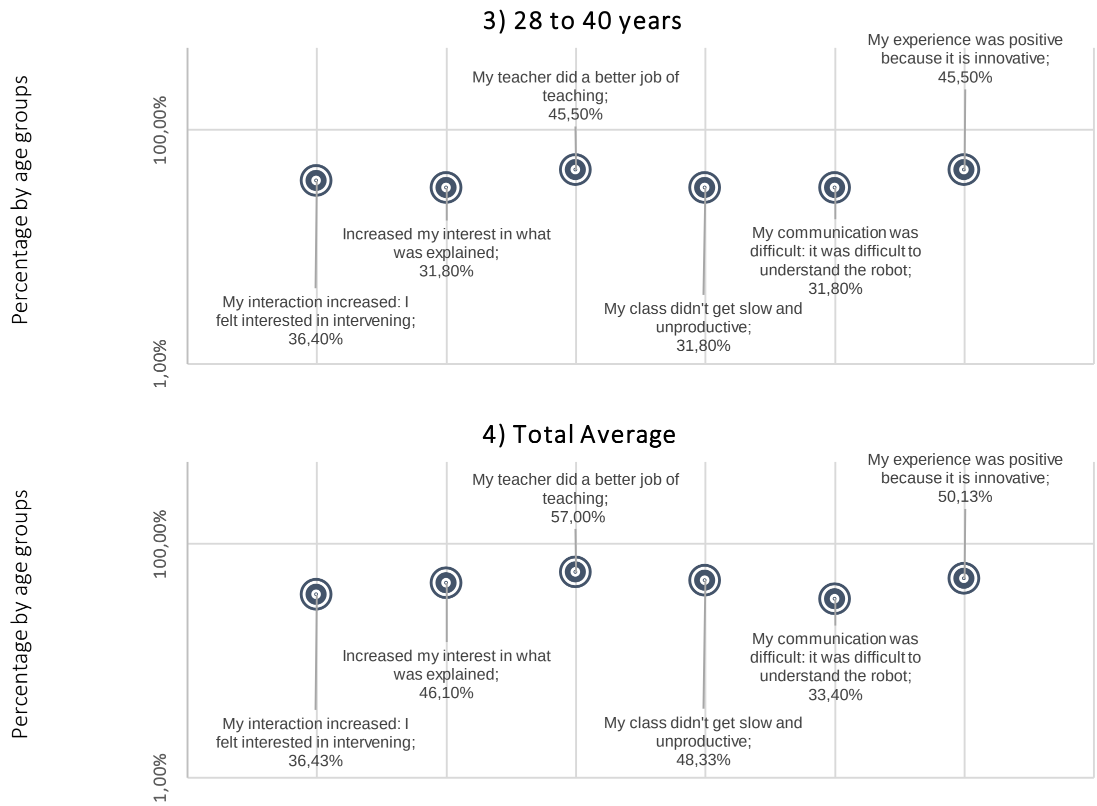


Figure 6. Percentage of Evaluation Results for Learning

Continuing with the analysis, the following table shows how teachers rated the use of the robot in different cases or contexts involving learning processes. In this question, teachers were asked to rate 1 to 5 a series of six educational cases taking into account the role of the robot, among which are the rigorousness of the class, entertainment, ease of remembering concepts, the possibility of improving learning, innovation in teaching processes and effectiveness in the transmission of information.

Therefore, teachers could report a score between 6 (lowest) and 30 points (highest), where the higher the score, the higher the robot's approval concerning the educational processes. Table 1 contains the average score and standard deviation for each group.

Table 1. Summary of scoring the use of humanoid robots in class

	Mean	Standard deviation
Gender		
Male	23.44	5.58
Female	22.42	5.93
Age		
Young	24.38	5.58
Middle-Age	22.70	5.88
Senior	23.16	5.24
Time working as a teacher		
0 to 13 years	23.64	6.35
14 to 27 years	22.64	5.45
8 to 40 years	22.86	5.14

The average scores tend to be similar among the groups, reaching between 22 and 25. In addition, they have relatively high scores, which indicates that the use of the robot is highly acceptable for promoting educational processes. Performance of technological tools and NAO robots within the learning space (advantages and disadvantages perceived in the synchronous session).

Finally, data is presented for how participants rated the advantages of using technological resources such as humanoid robots in class. In this case, participants were asked to rate from 1 to 5 how they found a series of 4 cases relevant: they allow education to advance with new teaching strategies, they favor learning in class, they increase student concentration levels, and they make the class more dynamic. In this way, they could obtain an overall score between 4 (minimum) and 20 points (maximum), which would be the level of importance they considered in using the technological resource in class. The higher the score, the greater the importance. Table 2 contains the average score and standard deviation according to the groups of participants.

Table 2. Summary of scoring the use of artificial intelligence (AI) in class

	Mean	Standard deviation
Gender		
Male	16.81	3.77
Female	16.17	4.50
Age		
Young	16.62	4.53
Middle-Age	16.32	4.18
Senior	17.41	3.27
Time working as a teacher		
0 to 13 years	17.66	3.06
14 to 27 years	15.66	4.55
28 to 40 years	17.27	3.73

The tendency is to obtain high scores. The participants have positively rated the use of NAO robots as a tool in class, with average scores between 15 and 18 out of 20.

5. Discussion

This study sought to analyze the experiences and perceptions of teachers after implementing various technological tools in a scientific research class. In this case, the teachers considered in the study are specifically from Latin America and belong to different fields of knowledge and different ranges of generations. Although there may be preferences according to the professional profile of the teachers, it was evident that the learning processes in higher education are similar because the tools considered in this study are helpful in any class, both to enhance teaching and to make higher education classes more dynamic and attractive. Therefore, it can be said that different findings have shown how implementing technologies in higher education contributes to future directions in developing strategies to enhance knowledge sharing by improving the classroom environment. This means that developing new knowledge among university students is contingent on establishing new ways to diversify traditional education models to favor the teaching environment among educators and the learning environment among students (Ozdamli & Cavus, 2021).

It is possible to say then that traditional and new technologies are currently key aspects for innovation in higher education and to justify using tools in class that genuinely enhance and make classes more friendly for students. It should also be added that today's future professionals depend not only on the techniques that institutions of higher education as teachers use to develop diverse competencies, including complex thinking (Baena-Rojas et al., 2022; Kearney, 2009; Ramírez-Montoya et al., 2022). However, such studies also allow documenting teachers' experiences after implementing specific resources that can effectively be consolidated as essential for their classes. Undoubtedly, including Education 4.0 in the teaching and student environment enhances the competencies and experiences of both parties. It can be said that evidence reveals every time a direct

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relationship between the possession of technologies and efficacy beliefs in various human processes, including education. It is for all this that the attitudes of teachers towards the use of technology become an essential competence to form better professionals that require multiple skills for the solution of diverse problems (Halili, 2019; Yerdelen-Damar et al., 2017;).

According to the current study, it is also essential to add that the technological experiences of teachers in teaching allow us to glimpse a relationship that was significantly supported by each of the four hypotheses proposed in this research. Thus, the results support the assumptions initially formulated where teachers' perceptions of the use of ICT in higher education environments are primarily favorable. Second, higher education teachers highly accept using robots in learning environments. Third, teachers' acceptance of ICT and social robots in educational contexts may depend on age and teaching experience. Fourth, participants develop levels of complex thinking through completing workshop activities and estimating the impact of the use of ICT and social robotics.

As other research affirms, all of the above assumes that teachers are increasingly integrating various technologies as teaching tools because they effectively believe that they can generate a notion of perceived usefulness, perceived ease of use, and even enjoyment of use. In other words, a series of advantages that, from the perspective of higher education institutions and professors or instructors, clearly enhance the entire teaching and learning process (Davis, 1989; Davis et al., 1992; Philipsen et al., 2019; Ranasinghe & Leisher, 2009; Venkatesh & Bala, 2008). In addition to all these, several key aspects are required, such as new knowledge, permanent updating, time, and even infrastructure to master this broad spectrum of digital tools. All of this helps significantly with the staging of classes but requires planning and organization for their implementation. Therefore, the implementation of various technological tools in class does not depend only on the teacher's interest but on a series of circumstances that must be overcome to achieve cutting-edge classes that also meet specific diverse needs among students (Ertmer et al., 2015; Vongkulluksn et al., 2020; Xie et al., 2018).

The current study shows several advantages of different technologies that enhance student learning in higher education. In this case, teachers who have acted as students have been able to corroborate from their perceptions, experiences, and teaching needs how ICT and social robotics can be more than useful in the classroom. However, there are still several challenges to achieving a more regular adoption of social robotics in higher education. All this, given that it is a tool with a certain level of complexity for its implementation in the classroom that also, at least for now, requires a technical team to accompany the teacher for the programming of the tool (Kennedy et al., 2016; Khaksar et al., 2020). It is also important to point out that another significant challenge today is for universities to have the resources to acquire robots. However, at present, they are somewhat expensive, and at some point, their massification could make their use in the classroom even more popular. Regardless of this expected massification, as with other technologies in the past, access to technology plays a determining role in implementing disruptive strategies in learning environments. Therefore, universities and higher education systems should seek to provide teachers with professional development programs and technical support to achieve a better transition in the use of specific, highly specialized tools (Horn & Goldstein, 2018; Hsu & Kuan, 2013; Ireh, 2010; Joo et al., 2016;) while increasing funding to ensure access to technology by renewing existing facilities and technologies, which in turn, will lead to a diverse learning environment and also develop complex thinking competency.

Integrating social robotics, such as the NAO robot, can significantly influence the development of complex thinking skills in higher education teachers. Social robots like NAO have shown the potential to enhance academic and socio-emotional learning skills, which can benefit teachers in higher education (Feidakis et al., 2023). The integration of social robotics in education can stimulate the development of the "4C" skills - Critical thinking, Communication, Collaboration, and Creativity - which are crucial for both learners and educators (Rapti & Sapounidis, 2023). By engaging with these technologies, teachers can enhance their own complex thinking skills while exploring innovative ways to facilitate learning. This study adds novelty by suggesting that the long-term mass adoption of these technologies could democratize access to advanced educational tools, creating more dynamic and engaging learning environments. This insight emphasizes the need for universities and higher education systems to invest in professional development programs and provide technical support, enabling teachers to transition more smoothly to using specialized tools.

6. Conclusion

From the current study, it is suggested that further research be conducted to continue to learn the impressions of different teachers and students about the influence of the implementation of digital technologies in higher education classes. Although there are many technological resources, it would be helpful to reproduce a study like this in other regions, not only in Latin America but also in other continents with different cultures and educational models. Investigating the use of ICT, social robotics, and other technologies that promise to make classes much more dynamic and engaging would be interesting.

The results of the descriptive analysis showed that teachers considered the use of technology as “important” and “very important” and that there is a qualitative relationship between this perception and how often they use ICT. Also, the impact of ICT on different educational processes was rated positively above 60%. Consequently, H1 was supported. Regarding H2, results showed that the acceptance of using robots in class was around 60% and below, with “communication difficulties” being the ones with the most significant impact. Therefore, H2 was partially supported, given that percentages around 60% were not interpreted as “high acceptance.” Just like with H1, H3 was supported since we observed differential effects of the teachers’ acceptance of ICT and social robots due to their age and teaching experience. Regarding H4, participants developed complex thinking abilities, ascertained by the activities carried out and the appraisal process regarding the use of ICT and the NAO robot, showing aspects of critical and scientific thinking and educational innovation features. Therefore, H4 was also supported.

The above, considering as in this case, the opinions of teachers from various fields of knowledge, since age and their experience as instructors, may influence how they perceive the different types of existing technologies for use in classes. It is also worth noting that the current study used closed surveys, and the results may have been affected by biases inherent to such methods. For this reason, other techniques, such as interviews, may be considered in the future to obtain more broadly the impressions of teachers participating in pilot classes measured with ICT, social robotics, or any other type of technology.

Similarly, to increase the scope of this type of study and further inform research on this topic, future directions are suggested to implement data collection methods such as classroom observations and behavioral reports and to involve an additional inventory of technological tools to gain new impressions of the whole topic.

The ease of implementation of NAO robots depends on several factors, including the user's level of experience, the availability of resources, and the complexity of the tasks to be performed with the robot. First, the programming interface is a challenge for using this type of robot in a classroom, even though the visual programming language "Choregraphe" offers a graphical interface that may be more accessible to beginners. Secondly, learning resources; that is why Aldebaran Robotics (now SoftBank Robotics) provides various learning resources, including technical documentation, online tutorials, and support forums where it is possible to find help and share experiences with other users. Thirdly, the availability of technical support is due to the problems that may arise during the process to avoid breaking the dynamics of the class sessions. Therefore, teachers interested in this technological resource require experience programming NAO robots to avoid potential incidents. However, as with any new technology, it may require time and effort to become familiar with the robot and take full advantage of its capabilities.

Finally, it should be added that other background factors may influence the level of use of technologies within the classroom in higher education institutions and the very perception of importance concerning all these tools. For instance, culture may influence how professors do or do not prefer these technologies. However, there may also be infrastructure limitations that prevent many institutions from doing these types of exercises and making their classes more engaging and in line with new technological and educational trends. Future research on these types of previous aspects could incorporate such characteristics at a specific level, all in order to recognize the effects of all these and even other factors that can be considered in the design of a new study like this one.

Declarations

Author Contributions. E.O.L-C.: Idea generation, introduction, and suggestions. P.S-B.: Abstract, conclusions, suggestions, review-editing, and writing, format adaptations. J.J.B-R: Data analysis, results, review-editing, and suggestions. All authors have read and approved the published version of the article.

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