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Information Communication Technologies, Artificial Intelligence, and Social Robotics: A Complex-Thinking Vector in Higher Education?

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Abstract

Various technological devices, especially information communications technologies (ICTs), have become increasingly remarkable in higher education to help develop students' skills and qualifications. Considering this trend, supported by several academic theories, this paper proposes a breakthrough guidebook for universities and other scholastic environments based on reasoning-for-complexity using mainly artificial intelligence (AI) and social robotics (SR). The current research provides the instructions to follow in a real class supported by AI and SR with a precise compendium of steps. On the one hand, this is done by reviewing previous studies on educational processes with AI and SR and synthesizing their findings to draw out common themes from the literature. These topics are categorized into clusters in the form of guiding questions that professors can use to prepare their classes. On the other hand, it describes the students' steps for completing the activities. These were developed with previous forms to establish different profiles and apply custom-made assessment activities. The final part of this paper involves a set of reflections regarding these two technological resources (AI and SR) to demonstrate their utility in education.

Keywords: *Artificial Intelligence, Educational Innovation, Higher Education, Reasoning for Complexity, Social Robotics*

Introduction

In the context of Education 4.0, digital transformation is one of the biggest challenges for global learning systems, which tend to move towards achieving the Sustainable Development Goals (SDGs) of 2030. Thus, higher education institutions (HEIs) invest time and resources in this digital transformation as a long-term strategy (Aditya et al., 2022). It means not only adopting new technologies to transform educational systems and services but also transforming and automating processes that increase their effectiveness and eliminate connectivity barriers (Rof et al., 2020). In other words, technology should act as an enabler of change and innovation (Ljungqvist &

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Sonesson, 2021) to favor learning and the acquisition of competencies and skills in students to generate solutions to the problems of the environment in which they live. Hence, it is necessary to ensure that the adopted technology is based on meeting learning objectives and favoring improvements in the school and the community.

The current SARS-CoV-2 pandemic that began in late 2019 has significantly empowered the use of technological devices, applications, and software for distance educational purposes (Dyer, 2014; Abu Talib et al., 2021). It is clear, in any case, that regardless of current public health situations, technological tools in general, including Information and communications technologies (ICTs), can be implemented positively and at any time to improve the training of higher education students. Therefore, presence in the classroom is not a prerequisite to using all possible technologies. Digital transformation is an innovative response to facilitate learning in both face-to-face and non-face-to-face environments, especially in the latter, where technologies dynamize communication and transmission of information despite the challenge of distance (Kaputa et al., 2022; Husain, 2022). In other words, the existing technological resources, including some recently created ones, have been put to the test abruptly due to the current pandemic. Nevertheless, the results have been very positive as students have developed quality knowledge derived from the strategies of universities and professors. The latter have tended to be trained at the pedagogical level to assume digital and distance learning innovatively and sustainably (Argüelles-Cruz et al., 2021).

In any case, it is necessary to emphasize that all these technological tools are essential components of complex thinking and reasoning for complexity. This is because technologies allow perceiving reality flexibly, promoting the opening of ideas and making it possible to better confront uncertainty. Likewise, within the logic of complex thinking, the tools focus on solving contextual problems by concatenating various types of knowledge, using creativity, critical thinking, systemic analysis, and metacognition (Martínez et al., 2019).

Accordingly, the various devices and technological resources created daily are a way to meet precisely the digital transformation mentioned. That is why, at the educational level, all these tools are increasingly a new means to transform the practice of educating students. Within these resources, some trends indicate that artificial intelligence (AI) and social robotics (SR) can be a vector to favor students' learning experience. In fact, it is believed that these may, in the future, constitute a real revolution for classrooms (Grewal et al., 2018; Weinstein & Holcomb, 2021).

Hence, using technology to develop transversal competencies, such as complex thinking, is promising.

This article intends, from all the previous ideas, to develop a detailed log that allows other professors and HEIs to replicate the implementation of a class with forefront technological resources. The program includes AI with customized evaluative activities for each student and classes assisted with an NAO robot to dynamize communication for a unique, innovative environment. Notably, this theoretical exercise is the first part of a pilot to be implemented later, considering that the Institute for the Future of Education (IFE) in Mexico has the technology described here to carry out this social experiment. Future research is expected to implement a practical exercise for the second part, and the results will be disseminated after knowing the students' perceptions of the pilot class.

To address this challenge, we propose developing a set of considerations for research centers focused on education and reasoning for complexity that wish to implement field studies with AI and SR. The first part of this paper reviews the relevant literature and identifies the main principles of these studies. Subsequently, the ideas are organized according to categories and stages to detail specific considerations for teachers and higher education institutions to apply in future initiatives. All of this is done regardless of the subject matter to be addressed. Thus, the logbook is primarily a pedagogical guide for any type of classroom or educational environment in higher education. Accordingly, this article is guided by the research question: What are the stages and considerations in developing an avant-garde pilot class that responds to current trends where students interact with Artificial Intelligence (AI) and Social Robotics (SR)?

Materials and methods

The current article is instructive for a cutting-edge educational model to achieve present and future initiatives in higher education. In this case, the model adopts information and communications technologies (ICTs), artificial intelligence (AI), and social robotics (SR) in university classes with undergraduate and graduate students, specifically through a course in "scientific papers development." Based on the central issue, this work develops a set of considerations for the ICTs, IA, and SR as technological resources for the classes. These considerations are in light of relevant research and include examples of educational technologies that can improve performance in learning and the teaching processes.

The technologies can impact SDG 4, whose goal is described as "... Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN, 2022). This is why it is necessary to enhance robotics, coding, AI, and other resources to end poverty, protect the environment, and ensure that all people enjoy peace and prosperity in the following decades. Hence, citizens, teachers, and governments work hard to create and adopt different approaches because science, technology, engineering, arts, and mathematics, known as STEM, will dominate in developing these previous ideas (Henze et al., 2022). Likewise, the cornerstone in the future of higher education seems to lie in complex thinking because this construct focuses on developing a huge set of strategies to increase students' competencies as potential professionals. With this competency, students and professionals confront much better some challenges that require problem-solving within life and society, applying human knowledge with critical, innovative scientific, and systemic thinking (Ramírez-Montoya et al., 2022).

Secondly, the following section describes a logbook with a complete inventory of technological resources besides ICTs, which, from specialized literature, supports potential categories and stages of a class based on all these tools. In other words, this logbook will allow characterizing an actual work plan for professors and HEIs interested in applying these initiatives to improve their students' classes.

Therefore, this paper seeks to identify the steps in the process of a state-of-the-art class that add value and enhance the quality of higher education classes. In this case, through a pilot applicable in the future to verify how technological resources can be used in a higher education class.

Results

General considerations for ICTs, AI, and SR as technological resources for education

Technological resources provide remarkable tools to facilitate different human processes to ensure the functioning of current social paradigms, including academic teaching processes. Every year technological enterprises, through their research and development departments, release new inventions, machines, robots, and gadgets. These make it possible for people to communicate better, besides improving interactions educational systems with innovative components (Von Braun et al., 2021).

The assimilation of these tools depends on various reasons, among which stand out (see Figure 1) organizational changes, staff training, direct use, and exploitation of the unique characteristics of each specific technology, and technical aspects, among others. Theoretical details related to technologies must also be considered, as is the case with the technology acceptance model. On the one hand, perceived usefulness is defined as the degree to which a person believes using a particular system would enhance their job performance. On the other hand, perceived ease of use is defined as the degree to which a person believes that using a particular system would be effortless (Venkatesh & Davis, 2000).

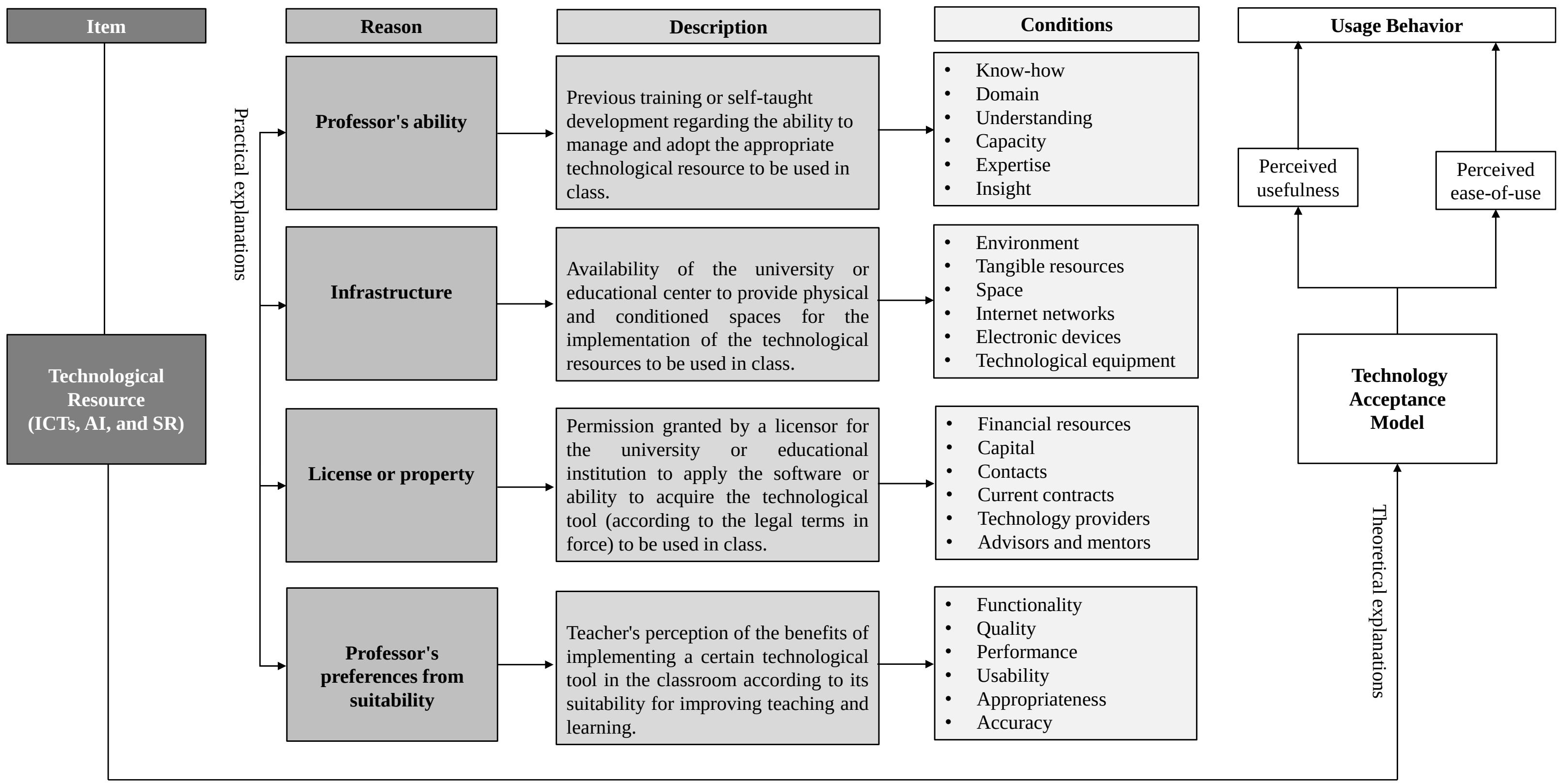

Figure 1. Reasons that interfere with the use of technological resources in the classroom
Source: own elaboration

Why ICTs are crucial for education and AI and SR could be relevant for the future of education?

The social changes faced by the world in recent decades have brought revolutions in all areas, including higher education systems. This is why educational institutions and universities work hard to develop different strategies to ensure access to new tools offered precisely by the technological revolution because they know how essential these items are for the future of education and especially for the scope of skills required by tomorrow's society. The deployment of technological resources in education should enhance human capabilities and protect human rights for effective collaboration between humans and machines in life, learning and work, and sustainable development (Visvizi et al., 2019).

Hence, the current labor requirements demand competencies among professionals that would have been difficult to imagine only a few decades ago. This is precisely the case with the first tools addressed in this research. ICTs can positively impact the interchange of information in synchrony and asynchrony and ensure ubiquity among users. Therefore, the emergence of ICTs has boosted e-culture, e-government, e-training, e-workplaces, and other social areas, including e-education. The technologies provoke relevant reflections on the ability of educational systems to get students to adapt to new trends and become better-qualified professionals of the future. This is why people today must update their skills and competencies, both educational and professional, to face the challenges of the labor market. The ICT-led revolution has widely affected all aspects of society at the workplace and the bureaucratic level; even e-learning has generated numerous expectations from teachers and other staff. ICTs in almost every field has necessitated adequately trained workers who work efficiently and effectively (Amritaa & Vibha, 2007).

Therefore, the present education has incorporated concepts related to the new challenges and commitments of HEIs in the knowledge society. These challenges imply significant changes in teaching models and the incorporation of ICTs. In today's world, the need for lifelong learning has been accepted. New technologies, which continue to evolve yearly, have played a significant role in higher education, given the growing social demands and recent socio-cultural trends including complex thinking (De Pablos-Pons, 2010; Kim et al., 2012).

In the case of AI addressed in this study, according to Zawacki-Richter, Marín, Bond, & Gouverneur (2019), it has been researched for more than 30 years. It is valuable today in one of the emerging fields, among many different disciplines and sectors: educational technology. The definition of artificial intelligence proposed by Baker & Smith (2019), "computers which perform cognitive tasks, usually associated with human minds, particularly learning and problem-solving," shows that the link of this technological resource with education can foster learning.

In fact, recent literature on educational innovation provides evidence that AI has positively impacted some processes in higher education. For example, AI has been applied to education to promote skills development, with some of its applications being differentiated to benefit individualized learning, the performance of automated administrative tasks, and advisory activities, among others (Nedungadi et al., 2014; Zheng, 2022). In this sense, AI is gaining more prominence within education, and although the term was proposed in 1970, the term artificial intelligence in education has recently been used. The above refers more specifically to an interdisciplinary field involving the use of technology in teaching-learning processes, as well as the relationship with other disciplinary areas, such as cognitive psychology and neurosciences, among others (Goksel & Bozkurt, 2019; Joshi et al., 2021).

Regarding SR, it is essential to point out that evidence suggests the relevance of this technological resource for promoting even further interactions among people and machines. This is because devices have become more critical and integrated into society, considering their problem-solving capability. Thus, SR in class can boost the interest of humans regarding how to convey specific information, just like with social robots, because their communication capability is a prominent feature (Akalin & Loutfi, 2021).

In recent years, robotic use has increased to support the elderly, young people, and children; robots can establish relationships and communication processes with outstanding results (Góngora et al., 2019; Pedersen et al., 2018). Several studies have shown SR used in different contexts, especially in education, to facilitate specific teaching and learning processes with enormous potential (Reyes et al., 2021; López-Caudana et al., 2019; Ponce et al., 2022). Although there is no specific definition of social robotics, since it is an area that does not follow a conventional design, it usually refers to the interrelationships of "robots as social partners" or "human-robot interaction" (Henschel et al., 2021). Specifically, the use of robotics in education is known as educational robotics or pedagogical robotics, whose general objective is the implementation of robotic prototypes and specialized programs for pedagogical purposes (López-Caudana et al., 2020). Their use has visibly increased in recent years, partly because of their association with different disciplines to develop fundamental skills and concepts in these areas (Sisman et al., 2021;

Screpanti et al., 2021). Hence, robots bring attention to the subjects being taught, stimulating competencies such as critical thinking, digital skills, and teamwork (Lowe et al., 2018; Gressmann et al., 2019; Johal, 2020).

It should be noted that within SR, several types of humanoid robots can be used with people and students. The NAO robot, for instance, stands out because it can be used in various professional and educational areas (Pachidis et al., 2018). It presents some advantages over others due to its versatility and "body language" and its impact on a wide age range, as it can be used with people from five years old to university students (Valagkouti et al., 2022) just like this current study.

Ultimately, all the previously explained items are potential components for upgrading higher education classes where students and teachers face new challenges in the learning process. Thus, technological resources should be a tool to facilitate the teaching and learning processes and provide unique, innovative, and intelligent methods for future education (Prentzas, 2013). Therefore, one of the most desirable competencies to develop in higher education students is reasoning for complexity. Considered a mega-competency, reasoning for complexity (also known as complex thinking) comprises four sub-competencies: creative, scientific, systemic, and innovative thinking. The sub-competencies that make up the complex thinking competency allow the student to be analytical, develop synthesis and problem-solving skills, and continuously learn. It implies mastering the cognitive skills necessary to develop scientific, systemic, and critical thinking. The shared global objective is to propose solutions to complex situations within the framework of the professional areas and to form citizens who contribute to the transformation of their environment (Pettersen & Nortvedt, 2018; Ramírez-Montoya et al., 2022).

Developing transversal competencies, such as complex thinking, in higher education is a priority for HEIs to foster in students the ability to solve problems inside and outside the classroom and promote the use of technological resources to better face challenges in current social life. The advantages and innovations that technology brings today to education make it imperative that students receive training to leverage their use (Hortigüela et al., 2019).

The step-by-step adoption process for ICTs in a higher education class

The ICTs can be implemented in higher education classes within different stages, in this case, the planning, entries, implementation, and outcomes within the class process (see Figure 7). These tools have immense asynchronous and synchronous uses regardless of distance, time, or budget boundaries. In fact, among the analyzed tools within this study, this is the oldest adopted in classes. They are widely used in universities and educational institutions due to their popularity among students and professors, their perceived usefulness and ease of use, and their very affordable price, among others. In some cases, ICTs offer free access and provide a diverse possibility of software and devices for boosting communications and information exchange.

Then, it can be said ICTs ensure better class processes, considering the vast array of tools in this category of technological resources (see Table 1). They also avoid geographical distance problems because specific tools can be amazingly ubiquitous and used anywhere with internet access.

Table 1.

Features of ICTs usually adopted in higher education

Name or Type*	Description	Details to consider
Word Processors (Microsoft Office 365, OpenOffice, LibreOffice, among others)	Office is a suite of software (Word, Excel, PowerPoint, Publisher, Access, OneNote, Outlook, Project, and Visio) from Microsoft that allows you to create, access, and share documents through Microsoft Office for a one-year rental.	- It allows developing and editing documents for classes. - It allows performing complex mathematical calculations and processing large amounts of information that can then be converted into tables, figures, graphs, charts, and diagrams. - It allows making dynamic presentations for the transmission of information to different types of audiences. - It allows generating brochures, banners, flyers, and other documents requiring layout. -It allows the management of information that uses the concepts of relational databases and can be handled using queries and reports. - It allows the placement of notes (entered by hand or keyboard) and offers the possibility of adding drawings, diagrams, photographs, multimedia elements, audio, video, and scanned images. - It allows e-mail management. - It allows project management, such as organizing plans, assigning resources to tasks, tracking progress, managing the budget, and analyzing workloads. - It allows the creation of vector graphics and layouts.
Google Classroom	It is a free tool with multiple applications to help educators assess student progress efficiently, whether at school or home.	- It allows online grading of assignments, facilitating the process and reducing paper consumption.
Cloud-Storage Service (Google Drive, Dropbox, iCloud, among others)	This is used to save and share documents and folders.	- It allows the online work of documents at individual and group levels. - It allows the hosting of various types of files.
Kahoot	Interactive game for use in the classroom includes options for quizzes adapted to classroom topics and other playful activities with animation.	- It allows questions and quizzes to be asked and answered by students in real-time.

Edmodo	It is a technological, social, educational, and free platform that allows communication between students and teachers in a closed and private environment in the form of microblogging, created for specific use in higher education.	- It allows sharing documents and information and communicating like a social network.
Padlet	Digital platform for creating collaborative murals, offering the possibility of building spaces where multimedia resources can be presented, whether videos, audio, photos, or documents.	- It allows you to publish, store or share resources individually or collaboratively.
Popplet	It is a tool that organizes ideas visually.	- It allows sharing videos, drawings, photos, and other things and customizing them.
Videoconferencing tools (Zoom, Microsoft Teams, GoToMeeting, Hangouts, Skype, among others)	Programs for bi-directional or multipoint reception and transmitting audio and video signals by people in different locations for real-time communication.	-It allows meetings with groups of people in remote locations, sharing files, and interacting on the Internet.
WhatsApp Messenger	Instant messaging application for smartphones.	- Allows sending and receiving messages via the Internet, as well as images, videos, audio, audio recordings (voice memos), documents, locations, contacts, gifs, stickers, and calls and video calls with several participants at the same time, among other functions.
YouTube	Page designed to share videos, movie clips, TV shows and music videos, amateur content such as video blogs, etc.	- It allows you to upload videos and share them easily with other users through various platforms and devices.

Source: own elaboration based on Cueva & Inga (2022).
Note. Although there is a wide range of ITCs, here are some that can be implemented for a cutting-edge class in higher education.

It should be added that ICTs as technological resources are not new; however, they tend to undergo significant improvements and advances every year. Therefore, these tools do not become obsolete and continue to be crucial components for classroom innovation. For all these reasons, according to each class's needs, teachers should implement ITCs to improve the teaching process. Figure 2 shows step-by-step how this tool can support the development of a course in higher education.

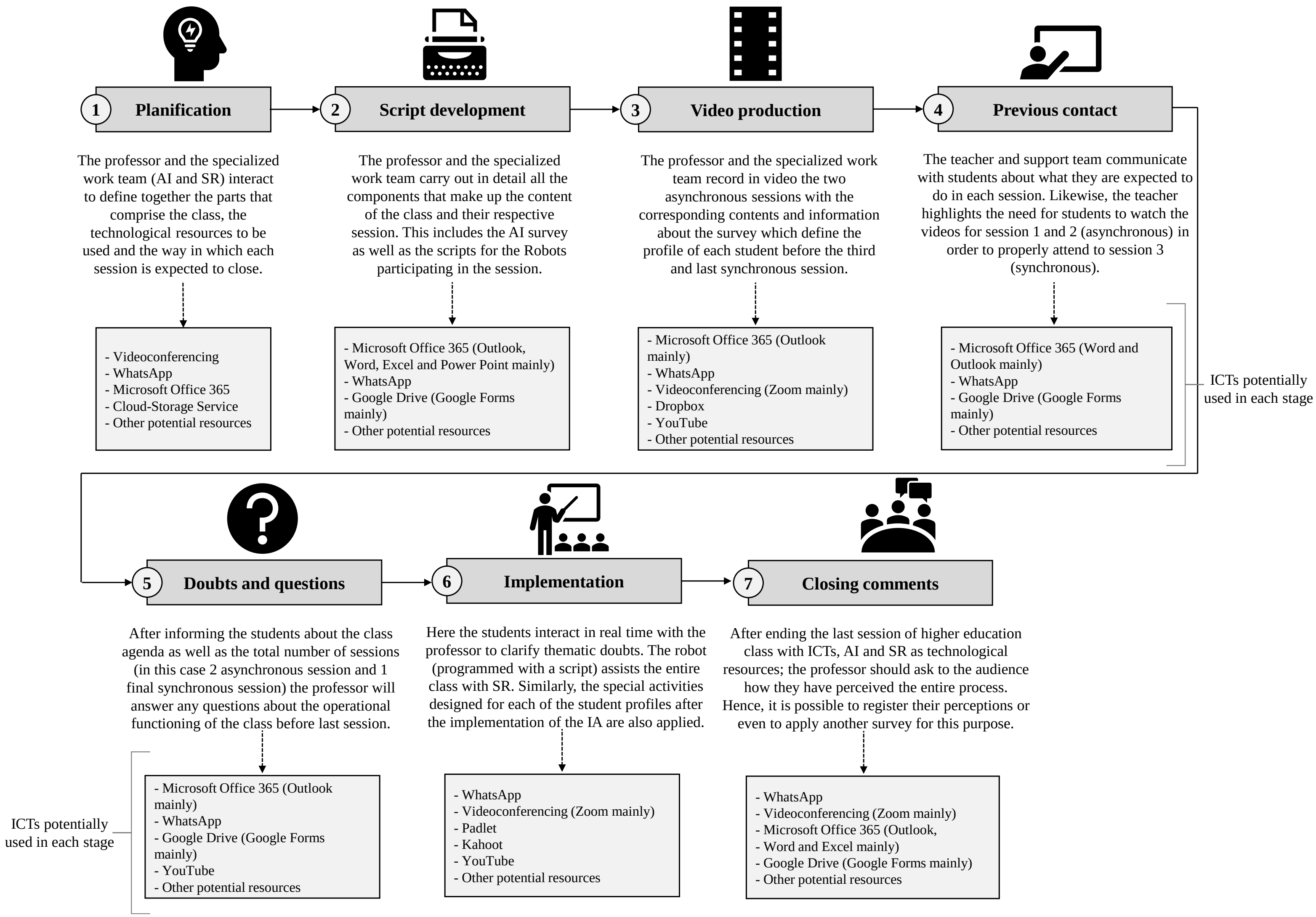

Figure 2. Steps for supporting a higher education class with ICTs Source: own elaboration

The step-by-step adoption process of AI in a higher education class

AI can be embraced in several ways in a higher education class because the versatility of this tool provides different options for analyzing the behavior of governments behavior and their educational systems, universities, professors, and students. Regarding students, this work precisely focuses on them because it is essential to show how AI can impact their performance in any traditional class procedure. Then, evaluation of their learning becomes purposeful because their learning process includes special assignments in or out of classes, tasks, library visits, use of computer labs, tests, exams, and gamification activities. All require measuring students' achievement of goals and skills and problem-solving. AI can ensure a better evaluation process because students will be reviewed and tested according to their capabilities, features, and profiles, the latter without detracting attention from the expected competencies they must attain to be professionals when they end higher education.

Evidence exists that gamification in the classroom for learning purposes increases students' motivation to study. However, it is necessary to handle these techniques carefully because sometimes, at specific moments, motivation can decrease when introducing leaderboards among students (Furdu et al., 2017). Therefore, it is essential to promote competency, considering each student has a specific profile. AI can help with this issue because this technological tool can address the possibility of programming activities and assignments customized to the students' needs. Bartle (1996) proposed an interesting approach with four types of profiles of gamers (see Table 2), which can be adopted in higher education. In this manner, knowing each kind of individual helps in presenting personalized strategies. Then, AI is relevant and entirely suitable for identifying university students' indicated profiles to classify them and later allocate activities, tests, exams, and other assignments according to their features.

Table 2.

Features of gamers' or students' profiles to be identified with AI

Profile	Color reference*	Description	Details to consider
Achievers	Red	The main goal of the Achievers is to collect points and level progress. They explore to find new sources or improved ways of achieving points. They socialize to discover what other players know about acquiring points. They kill if it is the only way to eliminate the others who get in their way or if they will win many points. Achievers play to master the game, do things to the game, and act on the world. They prefer a hierarchy and a short time to attain it.	- Provide basic communication facilities. - Provide a game manual. - Provide levels to progress. - Raise the rewards for achievement. - Provide complex activities.
Explorers	Orange	The main goal of the Explorers is to discover; they love a game that exposes its internal machinations to them. They look for exciting features and figure out how things work. Achieving points are the means for exploring new phases. For them, scoring points is tedious, and anyone can achieve it. They are not fans of killing actions because of possible future retributions. They socialize because they want to explore what others know and as a source of novel ideas. Explorers want the game to surprise them and interact with the world. They are proud of their knowledge of the game's finer points.	- Lower the rewards for achievements. - Provide many small examples that can be solved quickly. - Provide cryptic hints when players appear stuck.
Socializers	Blue	The main goal of the Socializers is to empathize with others, joke, entertain and listen to others; they are interested in others and their interests. They explore to understand what the others are doing. They achieve points to gain access to the community. They kill only if another attacks their best or dearest friend as an impulsive act. Socializers are proud of their contacts, influence, and friendships. They interact with other players.	- Provide more communication facilities. - Increase the connectivity between rooms and the number of simultaneous players. - Allow communication facilities to be easy and intuitive.
Killers	Green	The main goal of the Killers is to impose themselves on others because they know that the individual will be upset, and they cannot do anything about it. They achieve points to become powerful enough to begin troubles and distress. They explore to discover novel ideas to kill people. They socialize to learn about the other's habits and to discuss tactics with their pairs (other killers). Killers want to act on the players without the consent of the other players. They only want to demonstrate their superiority over others. For them, accumulated knowledge is futile if it can be applied, and if it is used, they do not enjoy it unless it affects an individual. They are proud of their reputation and their oft-practiced fighting skills.	- Increase more player-on-player commands - Provide a game manual - Allow communication facilities to be easy and intuitive. - Include commands relating to fights.

Source: own elaboration based on Bartle (1996) and Bartle (2020).

Note. The students' gamer or profile names must be changed into colors to avoid bias because of the name type. This does not mean that students do not realize that clusters or categories exist for some student profiles. However, for learning purposes, they should know that before starting classes, they complete a survey because professors need to understand their interests and preferences; therefore, class members do not need to see the description of each profile. This categorization is only essential for professors who prepare, organize, and establish special activities in their classes through AI based on gamification according to each group of students.

After the previous categorization, it is possible to address four customized layouts based on each student's profile type. In other words, the personalized activities must consider a diversity of exercises that fit the best way possible to indicate clusters and individual interests. For instance, a killer type must want activities that make them feel superior, like a leaderboard or challenges with instant feedback. The socializer type requires activities and challenges where teamwork is essential. The explorer type wants small activities that help them master the interface; they prefer to explore different buttons. The player type needs activities that make them feel like the master of the interface. They want immediate progress levels and points, but they want to earn them. This profile shows a marked preference for complex tasks.

At the same time, this potential classification is supported by three student profile types: personality traits, gamer type, and gamified user. The first is based on the Big Five model or the OCEAN model, according to McCrae & Costa (1997) and John & Srivastava (1999), which describes five personality traits whose behavior depends on the perception and attitudes of the individual, as shown in the following list:

1. The Openness personality trait appreciates divergent thinking and is curious and creative.
2. The Conscientiousness personality trait is a rule-follower with clear goals in life.
3. The Extraversion personality trait loves social interaction and has an optimistic attitude.
4. The Agreeableness personality trait has altruistic behavior and is tolerant of others.
5. The Neuroticism personality trait is impulsive, stressful, and has a bad temper.

The second, based on some additional features according to Bartle (1996):

- Socializers: Purpose and relatedness motivate these players. They are altruistic and share without expecting a reward. They appreciate social connections and interactions.
- Explorers: Autonomy motivates these players. They want to create and explore. Thus, they seek freedom of expression without external control.
- Achiever: Competency and rewards motivate these players. They want to prove that they can achieve a difficult task. Besides, they interact within the play to receive something in return.
- Disruptor: Change motivates these players. They enjoy testing the boundaries and disrupting the system to force negative or positive changes.

And the third, based on some complementary features, according to Marczewski (2015):

- Philanthropist: Purpose motivates these players. They are altruistic and share without expecting a reward.
- Socializer: Relatedness motivates these players. They love social connections and interactions.
- Free Spirit: Autonomy motivates these players. They want to create and explore. Thus, they seek freedom of expression without external control.
- Achiever: Competency motivates these players. They want to prove that they can achieve a difficult task.
- Disruptor: Change motivates these players. They love to test the boundaries and disrupt the system to force negative or positive changes.
- Player: Rewards motivate these players. They perform any activity just for the prize.

Méndez et al. (2022) applied these previous features and the indicated theory about human attributes in a specific study. In this interesting exercise, AI was used in a survey to classify the profiles of a group of persons considering the personality traits and the gamer type to deploy an interactive interface for households to teach how to save energy. Hence, in this current paper, the same principles are adopted to classify each student in clusters within higher education (see Figure 3).

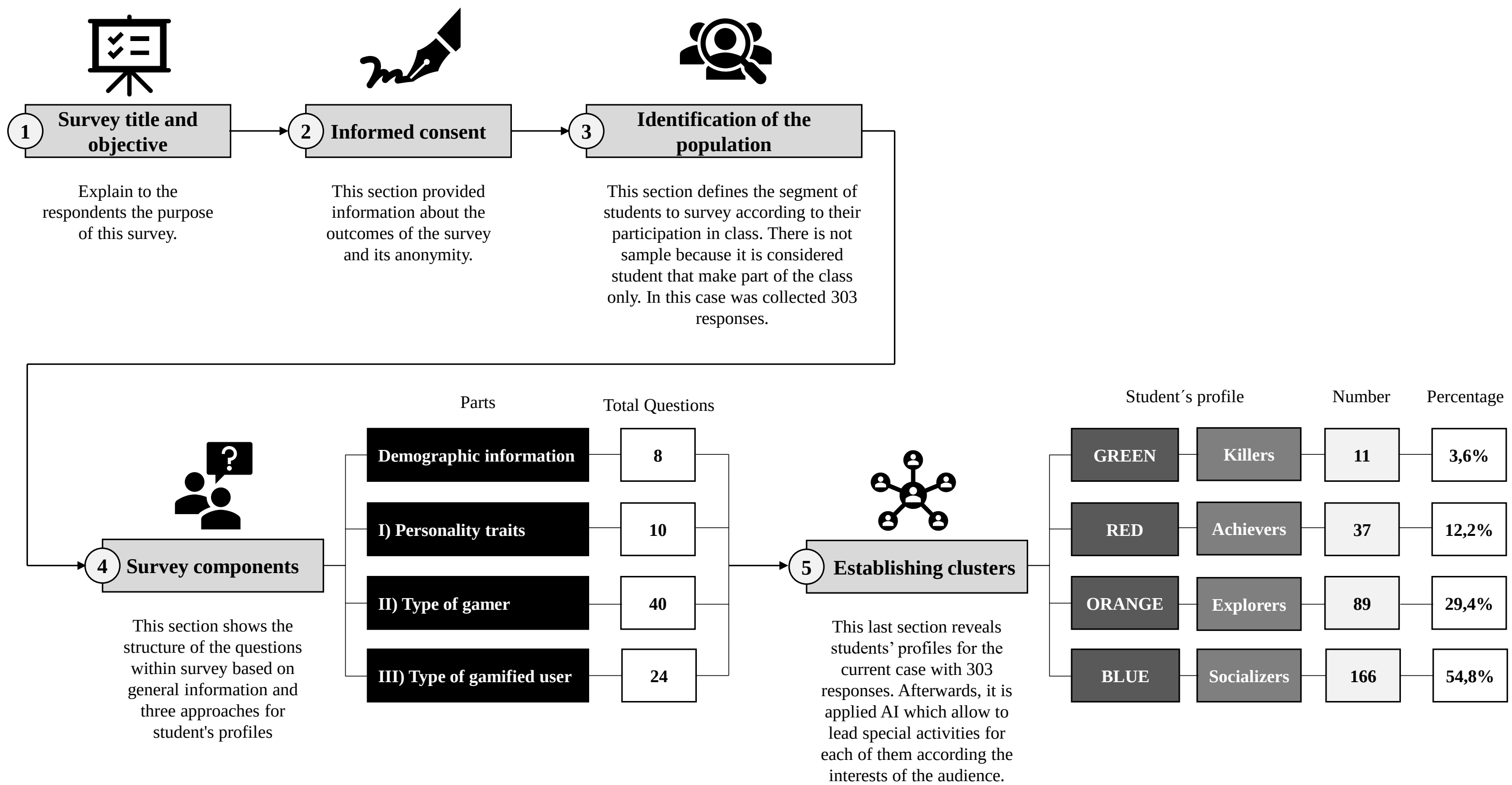

Figure 3. Steps to deploy an interactive interface under features of students' profiles with AI
Source: own elaboration

Next, an interactive dashboard was created (see Figure 4) based on the personality traits and the type of gamer. The dashboard was built in MATLAB/Simulink R2021a to guide the way to implement AI among students and define their profiles with a survey.

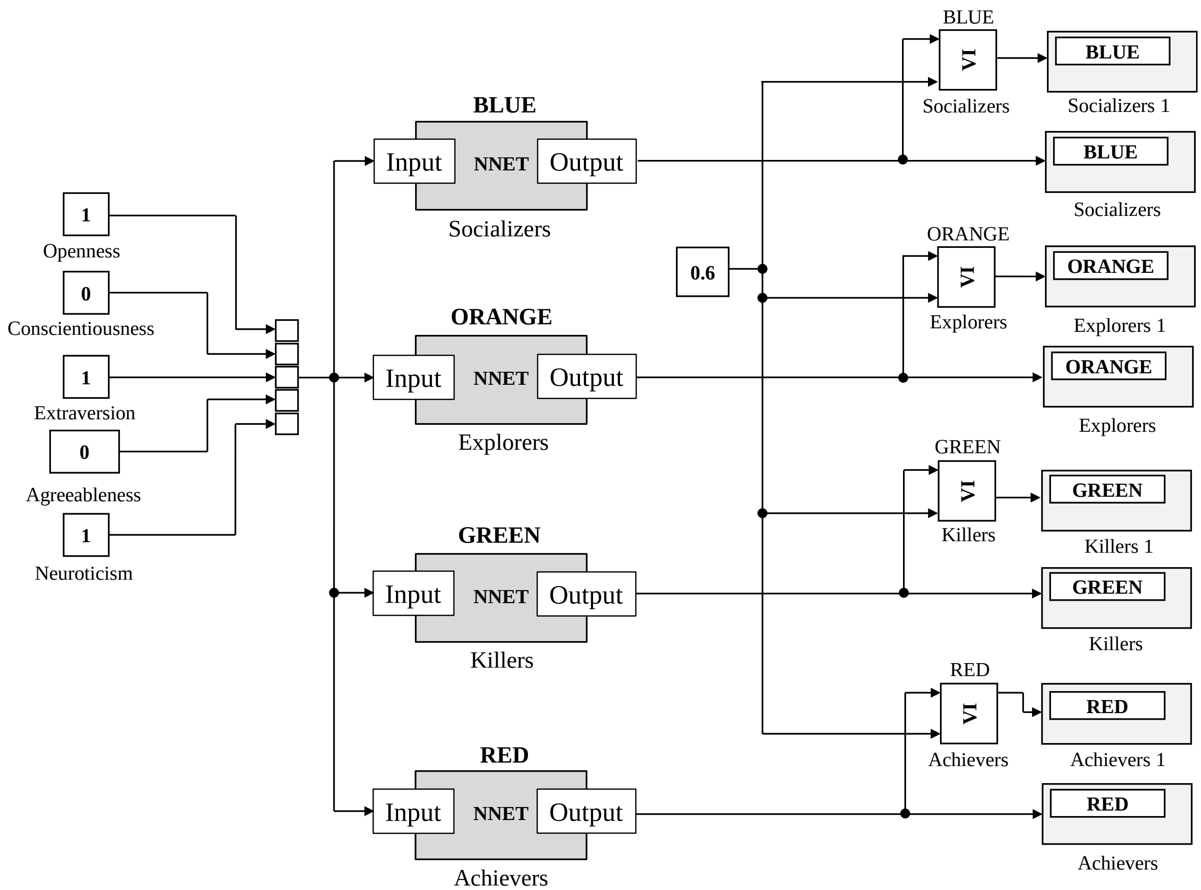

Figure 4. Simulink block diagram for the interactive interface
Source: own elaboration

Lastly, regarding this section (see Figure 5), it is possible to identify the included questions of the survey addressed to all the students before carrying out any activity for classes or the assessment process. In this manner, this query will ensure that each student receives a set of customized activities, assignments, and tests according to their way of thinking and obviously according to some personality traits.

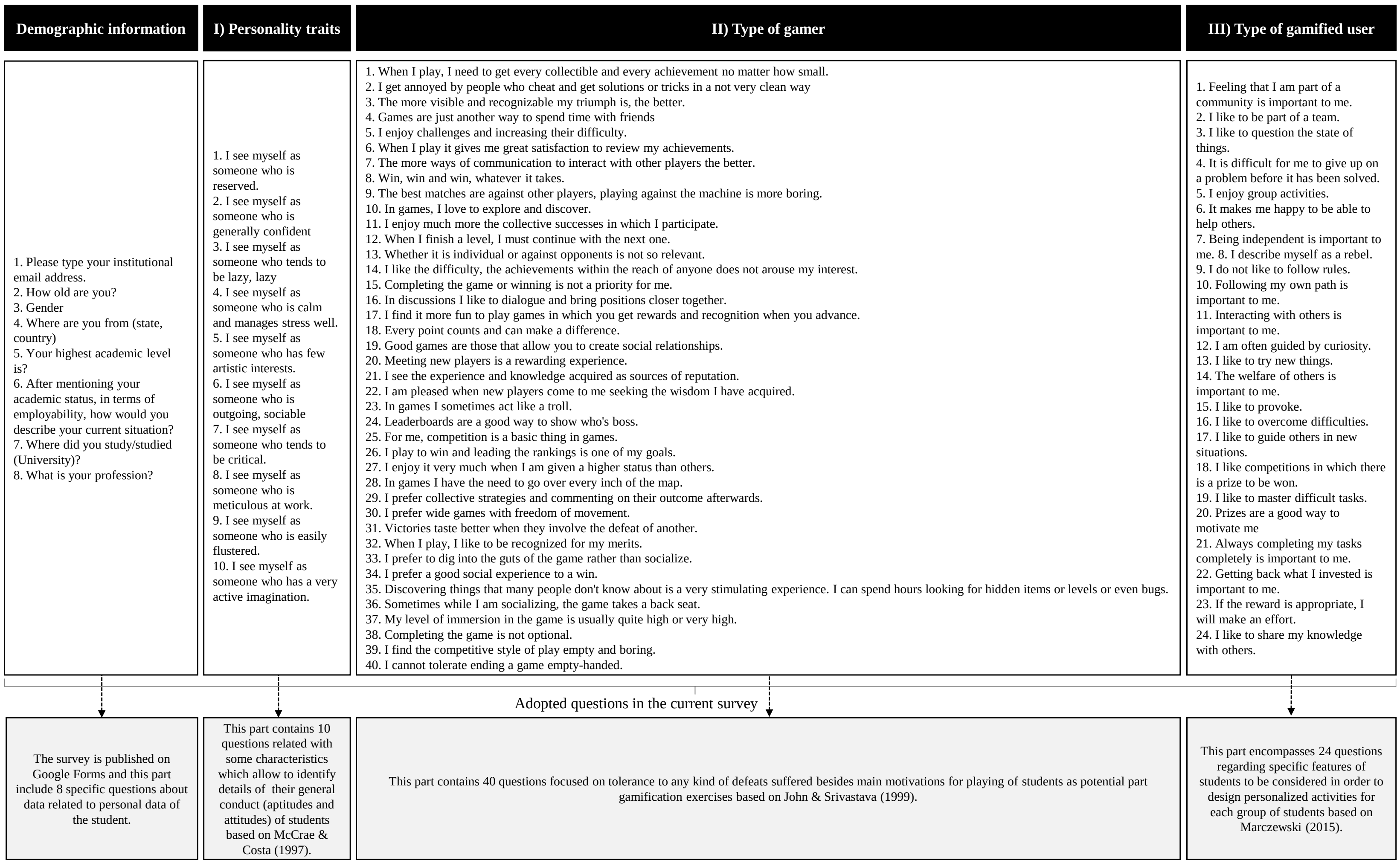

Figure 5. Design and components of the survey for identifying students' profiles with AI
Source: own elaboration

Discussion

The step-by-step adoption process of SR in a higher education class

SR, as the third technological resource of this research, can be implemented in higher education at all stages and planned sessions. In this manner, as previously pointed out with the theory, these tools show remarkable potential usability with different audiences in asynchronous and synchronous ways, no matter age, gender, and level of study. Therefore, SR can support classes with pre-recorded videos or courses in real time because the professor and specialized work team previously prepared the thematic content of their sessions. Although it is a little complicated to plan classes with this resource because the professor would need to master specific skills regarding robot programming and maintenance, the technological advances suggest that this tool would be much easier to handle.

Furthermore, among the considered tools within this study, SR is more complicated to be adopted in classes because it requires a significant budget (current robot prices are high). Nevertheless, educational institutions and universities need to provide this tool, with different types nowadays (see Table 3), and the physical infrastructure to ensure the most suitable environment for classes with this technological resource.

Table 3.

Features of SR to be adopted potentially in higher education

Name or Type*	Description	Details to consider
Nao robot	It is a programmable and autonomous humanoid robot with an onboard multimedia system.	This robot identifies a group of defined and determined words that this machine can reproduce with its voice and complete with its expressions and body movements.
Pepper robot	It is a semi-humanoid robot designed with the ability to read emotions.	This robot is intended to enhance people's lives, facilitate relationships, have fun with people and connect them with the outside world
Maggie robot	It is a semi-humanoid robot designed as a person's companion.	This robot interacts with people through touch, language, and vision to help those who are alone.
Enon	It is a personal assistant rolling robot. This is self-guiding, with limited speech recognition and synthesis.	This robot can provide guidance, transport objects, escort people, and perform security patrolling, according to the programmed instructions.

Source: own elaboration based on Akalin & Loutfi (2021)

Note. Although there is a wide range of robots to be used for SR purposes, here are some that can be implemented for a cutting-edge class in higher education, considering their current popularity.

It should be added that SR as a technological resource is currently being tested within various universities that are trying to revolutionize educational systems and teaching methodologies. In this sense, planning and steps are more than relevant (see Figure 6) for professors to mark the path regarding what they want within their higher education classes, regardless of the topic or the discipline to be taught. In this sense, a specialized work team is essential for an innovative course because this group of experts currently supports the professor's interests and needs in adopting RS and AI.

In any case, there is no doubt that in the following years, all these devices will be more friendly in terms of use. Professors will not require intense technical support or a specialized work team to implement these technological resources, just like with ICTs, which every day are more intuitive, allowing professors more independence in class planning.

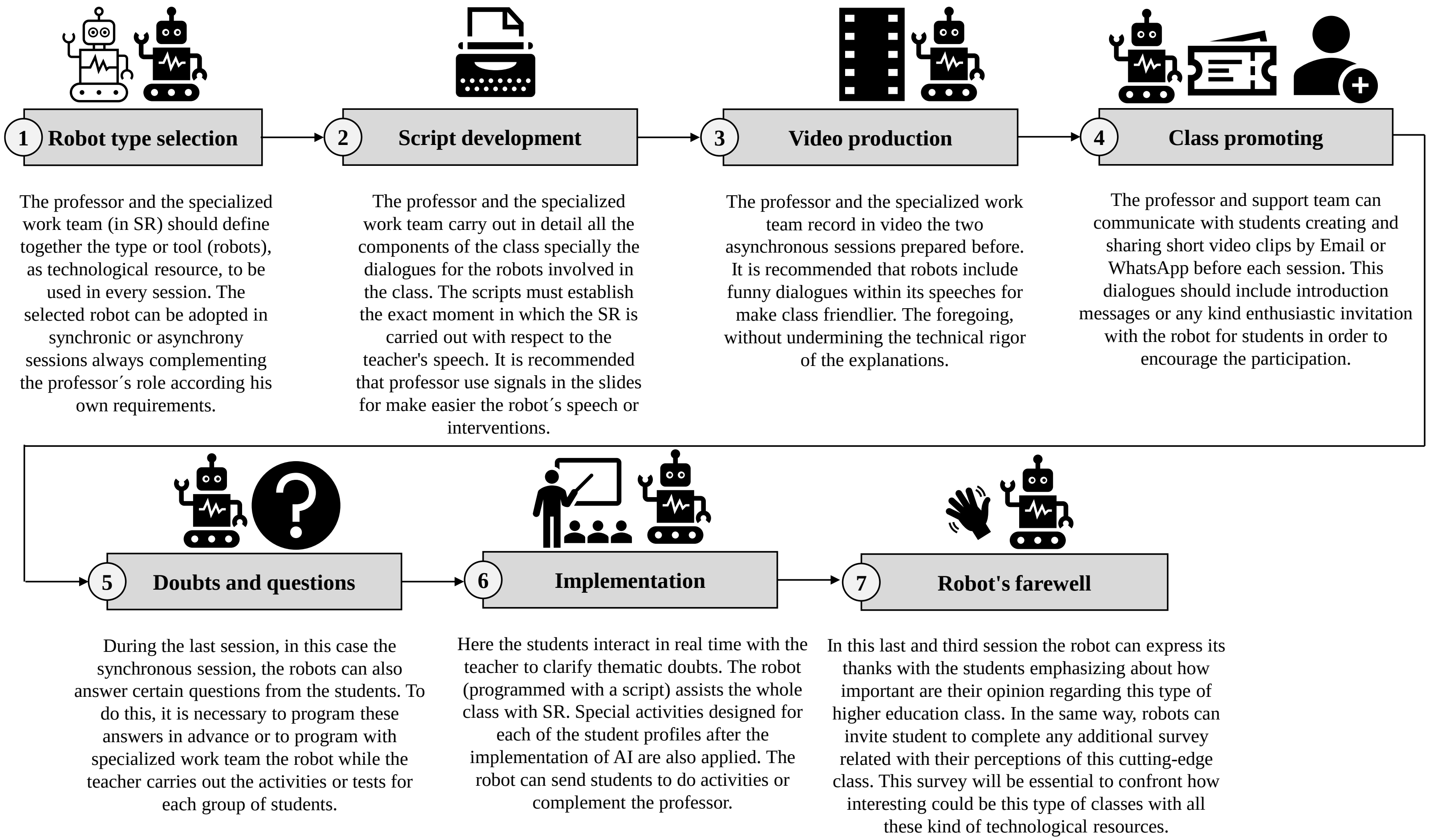

Figure 6. Steps for supporting a higher education class with SR
Source: own elaboration

As seen throughout this model, the present class or workshop in "scientific papers development" is carried out in three sessions. The first two (completely asynchronous) explain the topic in question. Then the third and final section (completely synchronous) resolves all students' questions about previously covered topics. In this third section, activities and special tests adapted to the students according to their profiles are also carried out.

Accordingly, class planning depends not only on the teacher but also on the conditions and infrastructure of the HEIs. Thus, the distinction of the class stages (see Figure 7) is essential to identify what is done in each section. According to the guide or manual, this distinction allows knowing which technological tools or resources can be applied in each section and how they can be implemented, as described with ICTs, AI, and SR.

Among the technological resources mentioned in this research, ICTs are the primary tools most applied in educational systems today, but this does not mean that they are not new. Certainly, new devices, functions, and updates are continuously being created to add to the existing ones, so their potential and incidence in the present higher education model should not be underestimated.

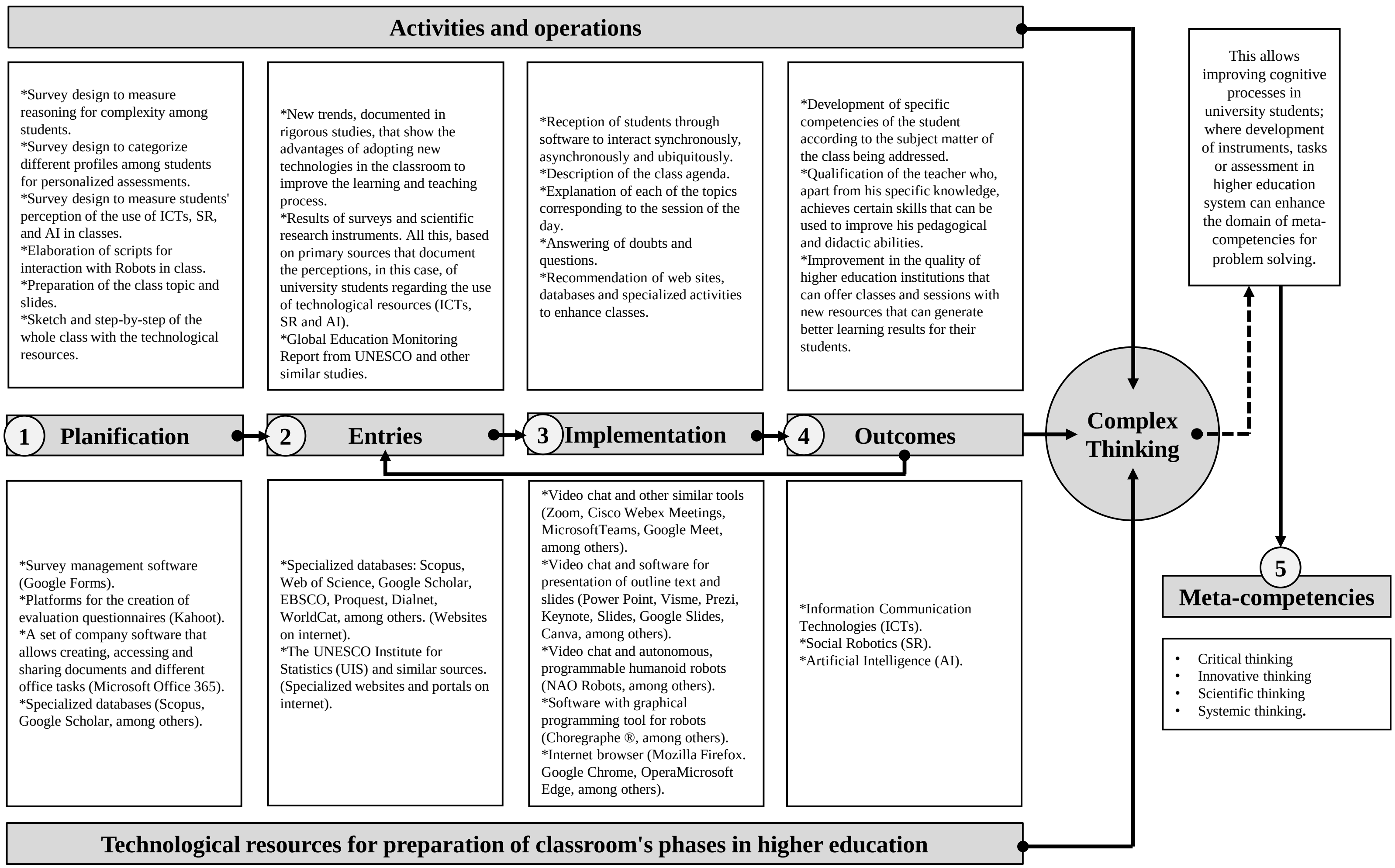

Figure 7. Class preparation stages with potential adoption of technological resources
Source: own elaboration

Conclusion and Implications

The ideal and most suitable higher education class is always under construction. This is because university students develop new learning needs according to the environment's conditions, the present technological advances, and, above all, the contemporary society's requirements that seek more qualified professionals with diverse skills and better problem-solving capabilities. It is here where complex thinking plays a key role since it promotes the development of higher education strategies and potentiates future professionals' capabilities with the meta-competencies of critical, innovative, scientific, and systemic thinking.

This paper delves into three types of technological resources: ICTs, AI, and RS. It should be noted that new discoveries and advances may include new devices that expand these tools' utility range and create new categories of tools that continue the evolution of higher education and the current knowledge revolution. International organizations such as UNESCO, aware of this situation, work hard to promote the use of new technologies in the classroom to train better people and individuals who know how to adapt to changing circumstances and, above all, to transform the environment with disruptive solutions.

Among the technological resources described in this blog, ICTs are the essential tools most applied in educational systems today, but this does not mean that they are not new. New devices, functions, and updates are continuously being created among the existing ones, so their potential should not be underestimated, nor their incidence within the present higher education model. AI has outstanding potential, given that this tool is novel for higher education and can revolutionize the way classes are offered. The professors and HEIs will be able to carry out segmented evaluation activities and tests, in other words, tailored or adapted to each student according to their profile, representing a different and attractive way to measure future professionals' competencies. SR is a novelty since adopting robots to attend classes can be a strategy where the student feels more motivated to participate and more familiar with the current digital environment with various technologies accompanying them to help resolve everyday societal problems.

Finally, as a possible future research line, it is advisable to develop a new perception instrument to capture all the impressions of students and professors. In this way, it will be possible to recognize from the first source if the technological resources applied in higher education are perceived as effective and generate positive impacts on teaching and learning.

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