Chapter 14
Aerial Robots: To Use or not to Use Them in Teaching and Learning?

Tryfon Sivenas and George Koutromanos

Abstract The aim of this study was to examine pre-service and in-service teachers' perceptions regarding the use of drones in teaching. The study sample consisted of 80 pre-service and 101 in-service teachers. After a brief introduction to drone technology, the participants completed tasks that required assembling, programming, virtually simulating and flying 16 multirotor drones. Data were collected via an online questionnaire using variables and questions adapted from the Theory of Planned Behavior. The results indicated that pre-service and in-service teachers showed positive attitudes, intention and behavioral beliefs towards using drones in teaching. A positive correlation between attitudes and intention was found. Results also indicated that a number of pupil skills and subjects will be enhanced by using drones in the classroom. Finally, pre-service teachers had stronger intentions and more positive attitudes, behavioral beliefs and perceptions compared to in-service teachers. This study has a number of implications regarding the use of drones in teaching as well as the need to develop teacher training programs in order to successfully integrate drone technology into future classrooms.

Keywords Educational aerial robotics · Drones · Pre-service and in-service teachers · Attitudes · Beliefs · Perceptions

14.1 Introduction

In recent years, the Internet and technological evolution have resulted in the development of next generation mobile robotics with applications in various sectors (Bogue, 2020), divided into underwater, ground and aerial robotics (Fulton et al., 2019; Rubio et al., 2019). In the field of education, ground robotics were introduced by Papert

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(1993) in the early 1980s, who offered his own perspective on the theory of constructivism, through the theory of constructionism. According to the theory of constructionism, manipulating an artifact is essential for the construction of knowledge and turns students from passive receivers to active participants during the learning process (Papert, 1993). The theory of constructionism can be applied in educational robotics since many robots require design, control, assembly and programming concepts (Alimisis, 2013; Staszowski & Bers, 2005).

Nowadays, various ground robots have been developed (e.g., NAO, Pepper, Bee-Bot, Mindstorms), the use of which in education has shown positive effects on learning (Ahmad et al., 2020), such as increased knowledge (Khanlari, 2015), motivation (Arís & Orcos, 2019) and engagement among pupils (Kim et al., 2015) as well as the development of various skills (Toh et al., 2016). Contrary to ground robotics, underwater robotics in the field of education began around the end of the first decade of the 2000s. Despite its limited extent, underwater robotics has shown a positive effect, with participants mentioning motivation, higher levels of interest, creativity and active engagement (Scaradozzi et al., 2019; Stolkin et al., 2007).

The implementation of aerial robotics in education began in the early 2010s. Aerial robotics is a field which combines several disciplines (e.g., Mechanical and Electrical Engineering, Biomedical Engineering, Computer Science) and explores the design, construction, and operation of aerial robots (Feron & Johnson, 2008; Lupashin et al., 2014; Santoso et al., 2021). An aerial robot is defined as any robot that is capable of flight. Aerial robots can either fly under the remote control of a human or -after programming and configuration- offer various levels of autonomy which allow them to fly without human intervention (Sampedro et al., 2018; Zarafshan et al., 2010). A category of aerial robots is drones (Liew & Yairi, 2013; Nonami et al., 2019). A drone is defined as an unmanned aerial vehicle which can be remotely operated by a user or fly on its own using its embedded systems (Arnold et al., 2018; Mahony et al., 2016; Zeng et al., 2019). Drones have certain affordances that are not found in other robots, such as the ability to fly, interact and perform tasks in the three-dimensional environment; the secure collection of aerial data; the ability to take pictures and record videos through bird's-eye view, provided by their camera (Tezza et al., 2020); and the ability of autonomous flight (Karydis & Kumar, 2017; Rubio et al., 2019). Recently, a category of drones has emerged specifically designed for educational purposes, such as Ryze Tello EDU, Makeblock Airblock for STEAM education, Parrot Mambo EDU, and Bitcraze Crazyflie. Drones for education have a number of additional affordances, such as flight programming through visual block-based programming environments (e.g., Scratch, Blockly, Dronely), flight simulation for drone operation training (e.g., DJI virtual flight, Drone flight simulator), as well as a number of mobile apps with educational activities for students (e.g., DroneBlocks, Makeblock, Tynker, Tello EDU). All of the above have contributed to the advancement of research on drone use in every level of education. However, the use of drones by teachers remains limited.

To date, the majority of literature in the field of education mainly focuses on the use of drones by students. A number of researchers noted that students, following their interaction with drones, showed enhanced interest and engagement (Carnahan et al., 2016), critical and innovative thinking (Cliffe, 2019), decision making (Abarca et al., 2017), computational thinking (Bermúdez et al., 2019), increased motivation (Chen et al., 2019), understanding of aviation regulation (Chou, 2018), cross-domain learning as well as positive attitudes towards problem-solving and hands-on capabilities (Niedzielski, 2018). In general, it appears that drones create "an enjoyable learning environment" (Carnahan et al., 2016), enable pupils to explore the world through "bird's-eye view" via use of the camera (Ng & Cheng, 2019) and constitute "one of the most innovative educational tools" (Niedzielski, 2018). In view of this, drones can play a facilitating role, as they help pre-service and in-service teachers to become familiar with and confident in educational robotics (Cañas et al., 2020).

Consequently, even though drones have been used in education for almost a decade, there are few studies that investigate the perceptions of pre-service and in-service teachers in using drones in teaching. To the best of our knowledge, no study investigates the factors which affect the use of drones in teaching according to pre-service and in-service teachers. According to Teo (2011), the teacher is one of the key players in any effective uptake of Information and Communication Technologies (ICT) in schools. Several empirical and literature review studies (e.g., Scherer & Teo, 2019; Scherer et al., 2019; Teo & Lee, 2010) which make use of the framework of many technology acceptance models and theories (e.g., Technology Acceptance Model, Theory of Planned Behavior) have indicated that the attitudes, beliefs and perceptions of pre-service and in-service teachers regarding technology constitute major psychological factors that impact the implementation and continuation of digital technologies in teaching. As stated by Reich-Stiebert and Eyssel (2016), it is important to investigate potential end users' (i.e., teachers') attitudes before digital technologies are introduced into practice and, especially, to investigate their expectations, concerns and obstacles in order to enhance their acceptance. By exploring the perceptions of pre-service and in-service teachers regarding the use of drones in teaching, one can identify the factors that could encourage or discourage technology acceptance and, therefore, drone use in the classroom.

The aim of the present study was to explore pre-service and in-service teachers' attitudes, beliefs, perceptions and intentions regarding the use of drones in their future classrooms. Making use of the theoretical background of the Theory of Planned Behavior (TPB) (Ajzen, 1991), this study addresses the following research questions:

1. What is the intention and attitude of pre-service and in-service teachers regarding the use of drones in their future teaching?
2. What are the behavioral beliefs of pre-service and in-service teachers regarding the advantages and disadvantages of using drones in teaching and learning, as well as the control beliefs regarding the factors that facilitate this use?
3. Is there a statistically significant correlation between pre-service and in-service teachers' intention and behavioral and control beliefs regarding the use of drones in teaching and learning?
4. What are pre-service and in-service teachers' perceptions regarding the skills that can be developed through the use of drones in teaching and learning?

5. In which subjects do pre-service and in-service teachers believe that drones can be used?
6. Are there any statistically significant differences between pre-service and in-service teachers regarding their intentions, attitudes and behavioral and control beliefs about the use of drones in teaching and learning, their perceptions regarding the skills that can be developed through the use of drones, and the subjects in which drones can be used?

This study contributes to the field of aerial robotics in education and, using variables adapted from TPB, fills the gap by exploring and revealing pre-service and in-service teachers' intentions, attitudes, perceptions, and behavioral and control beliefs relating to the use of drones in teaching. After investigating current research in the field of ground educational robotics, this study is the first to investigate the perceptions of pre-service and in-service teachers on aerial robotics. These will assist further research on the design of a drone training framework for in-service teachers, on the one hand, and a teaching framework within current pre-service teachers' study programs in university education departments, on the other hand. It will also assist the ever-growing research on educational drones.

The structure of this chapter is as follows: Sect. 14.2 describes the terms, characteristics, types and categories of drones. Section 14.3 presents the theoretical framework of this study as well as relevant studies regarding pre-service and in-service teachers' attitudes and perceptions towards educational robotics. Next, Sect. 14.4 presents the study's methodology, while Sect. 14.5 presents the results. Lastly, Sect. 14.6 discusses the results and presents the main conclusions as well as the limitations of the study and directions for future research.

14.2 Characteristics of Drones

Opinions differ regarding the origin of the term "drone". According to some sources, it originated from the male honey bee, the drone (Custers, 2016; Perrelet, 1970). According to other sources, the term is an acronym, i.e., "Dynamic Remotely Operated Navigation Equipment" (D.R.O.N.E.) (Nurdin et al., 2019). Some of the most commonly used terms in research literature include "Remotely Piloted Aircraft System" (RPAS), "Unmanned Aerial Vehicle" (UAV), as well as "Unmanned Aircraft System" (UAS) (FAA, 2021; Vergouw et al., 2016). The term that tends to prevail is "Unmanned Aircraft System" (UAS), proposed by the US Federal Aviation Administration (FAA). The definition of a UAS is "an aircraft that is operated without direct human intervention from within or on the aircraft" (FAA, 2021). Aside from these terminologies, the drone is referred to in related literature as "flying robot" (Tomić & Haddadin, 2019), "aerial robot" (Park et al., 2016), "airborne robot" (Kim, 2013), "robotic aircraft" (Abutalipov et al., 2016), "micro aerial vehicle" (Kumar & Michael, 2012), "quadcopter" (Allison et al., 2020), and "quadrotor" (Rojas Viloria et al., 2020).

The large number of terms is due to the drone's interdisciplinary nature, the evolution of its terminology, and the perspective from which each study chooses to approach it. According to certain disciplines, a drone is not defined only as the robotic flying vehicle, but also as the entire infrastructure system that supports the communication of the robotic flying vehicle with the control station/controller/operator (Feron & Johnson, 2008; Nex & Remondino, 2014). So, studies that focus on the technology embedded in drones tend to use terms that simply describe the drone as a robotic flying vehicle/flying platform, while studies that focus on drone infrastructure tend to use different terminology in an attempt to include the entire range of its abilities (Custers, 2016). For example, studies that focus on engineering often refer to drones as multicopters/multirotors or quadcopters/quadrotors (e.g., Allison et al., 2020; Gaponov & Razinkova, 2012), studies that focus on aerospace technologies refer to drones as UAVs, aerial robots or flying robots (e.g., Boon et al., 2016; Nurdin et al., 2020), studies that focus on robotics refer to drones as micro aerial vehicles or quadcopters (e.g., Cliffe, 2019; Kumar & Michael, 2012), studies that focus on geomatics refer to drones as RPAS or UAS (e.g., Tomić & Haddadin, 2019), while there are studies that refer to aerial robots by their commercial name, i.e., drones (e.g., Nex & Remondino, 2014).

On the other hand, several researchers claim that the large number of terms has emerged due to attempts by the research community to stop the propagation and use of the term "drone" and replace it with new terms, since they believe it triggers negative visions and perceptions to the public due to its association with warfare (Aydin, 2019; Custers, 2016; PytlikZillig et al., 2018). So, even though certain terms (UAV, UAS, RPAS) have been established to better describe drones, they have been adopted only by air traffic organizations and, partially, by the research community, while the public as well as manufacturers (DJI, 2021; Parrot, 2021) still refer to them as drones.

In educational research literature, there are two types of drones being used, i.e., multirotor or multicopter drones and fixed-wing drones (Niedzielski, 2018). Drones that are described as multicopters or multirotors are propelled by a number of rotors (≥ 2) (Boon et al., 2017). A type of drone that belongs to this category is the quadrotor or quadcopter type, which has four rotors (Vergouw et al., 2016). Drones of this type do not require a large amount of space for takeoff, since they launch vertically and are durable and easy to use (Allison et al., 2020). As for the flight area, multirotor drones can be used within the interior space of a classroom or a gym as well as in any exterior space. On the other hand, fixed-wing drones rely on their wings to fly (Boon et al., 2017). They have features that are similar to airplanes, require a fair amount of space for their takeoff, are not as flexible to use as their multirotor counterparts, but are capable of traveling a large distance. Due to increased space requirements, they can be deemed appropriate for use in exterior spaces, such as a school yard or an outdoor area built especially for takeoff.

Another characteristic of drones relates to flight autonomy, i.e., the time during which the drone can remain airborne before its battery runs out. Even though the average flight autonomy of a drone for education depends on various factors (e.g., drone size, use of camera, maneuvers, speed, weather conditions, use in an interior or an exterior space), it is at any rate considered relatively small due to the limited capacity of its battery (Chou, 2018). For example, a drone for education can have an average flight time of 8–10 min (e.g., Ryze Tello EDU). This type of limitation will become increasingly scarce in the future as the capacity of the battery is expected to increase (which will in turn lead to an increase of the average flight time), as research focuses on new lightweight high-capacity batteries (Selim & Kamal, 2018), charging stations (Jawad et al., 2019) and new charging systems for drones (Wu et al., 2020).

One of the affordances of drones is a camera for taking pictures and recording videos through bird's-eye view. Another affordance is the ability to program the drone in order to perform an autonomous flight. The autonomous flight is performed after the drone's programming and configuration. The user can write a code in several programming languages (e.g., Scratch, Python, Swift, Java, C++, Assembly) or design a flight plan using an autopilot (e.g., Pixhawk autopilot, ArduPilot) in order for the drone to perform an autonomous flight. During the execution of the program, the drone performs the flight with no additional intervention by the user. Another affordance is real-time data collection (Vergouw et al., 2016).

The latter is accomplished through the built-in real-time data collecting sensors (e.g., of altitude, speed, distance, temperature) in addition to other sensors which allow drones to navigate autonomously in an area. Also, additional sensors can be attached which enable the measurement of such things as barometric pressure, slope and thermals. Moreover, drones are repairable and upgradeable (Tripolitsiotis et al., 2017).

Drones for educational purposes are available in two forms: pre-built drones (also known as "commercial off-the-shelf drones" and "ready-to-fly drones") (Tezza et al., 2020) that are ready for flight, and drones that require assembly by the user, known as drone construction kits (also known as "do-it-yourself drones"). Representative examples of pre-built educational drones are: Ryze Tello EDU, Makeblock Airblock for STEAM education, and Parrot Mambo EDU. On the other hand, drone construction kits (e.g., Flybrix, Rotor Riot) resemble educational robotics kits, enabling the user to experiment and create various constructions and designs, while their use in education has been extensively studied through the use of Lego NXT, Toyobo, and Gogo board (Ng & Cheng, 2019).

Drone operation is achieved through flight controller, joystick, smart mobile devices (i.e., smartphone, tablet), computer, as well as facial, body or hand gestures (Tezza et al., 2020). One of their distinctive features is that they can be programmed with the purpose of performing an autonomous flight. This can be realized with the use of various visual block-based programming environments (e.g., Scratch, Dronely, Blockly), which are appropriate for beginners (Chevalier et al., 2016; Tilley & Gray, 2017) and facilitate the explanation of many programming concepts (e.g., loops, conditions, variables, sequences). Thus, manufacturers and developers provide mobile apps which not only allow programming but also enable the user to fly the drone in simulation. These applications (mobile apps) are available for people over the age of five, some representative examples being Tynker, Tello EDU and DroneBlocks. Finally, platforms, mobile apps and MOOCs (Bertrand et al., 2018) have been created for teachers and contain activities, suggestions and examples of use in formal or informal learning environments (e.g., DroneBlocks, Tello EDU, Tynker).

14.3 Theoretical Framework

In order to explain pre-service and in-service teachers' attitudes, beliefs and perceptions towards ICT and Robotics, a variety of theories and models consisting of different sets of psychological factors have been used and adopted. Examples of these theories and models are the Theory of Planned Behavior (TPB) (Ajzen, 1991), the Technology Acceptance Model (TAM), TAM 2 and TAM 3 (Davis, 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000; Venkatesh et al., 2003). Two of the most widely used models are TAM (Davis, 1989) with its extensions (i.e., TAM 2, TAM 3) and TPB. These two models were adopted from the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980).

According to TAM, two beliefs play an important role in the acceptance of any technology. These are perceived usefulness and perceived ease of use. The belief of perceived usefulness is the "degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320), while the belief of perceived ease of use is "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320). Both beliefs affect the attitudes towards using the system. Attitude is defined as "the individual's positive or negative evaluation of performing the behavior" (Ajzen & Fishbein, 1980, p. 6). Furthermore, these attitudes determine intentions which in turn affect actual system use. Recent meta-analyses of TAM studies on the intention of teachers to implement ICT in their teaching have indicated that it constitutes a valid model (Scherer & Teo, 2019; Scherer et al., 2019). Since this study investigated the beliefs of pre-service and in-service teachers regarding the perceived advantages and disadvantages of using drones in teaching, as well as the beliefs regarding the factors that facilitate this use, TAM may not have been comprehensive enough to identify these beliefs. TPB was considered the most appropriate theoretical framework.

According to TPB, intention is explained by attitude and two other factors: subjective norm and perceived behavioral control (Ajzen, 2020). Subjective norm is "the person's perception of the social pressures put on him to perform or not perform the behavior in question" (Ajzen & Fishbein, 1980, p. 6), while perceived behavioral control is defined as the individual's perception regarding the ease or difficulty of performing the behavior (Ajzen, 1991). Furthermore, the theory claims that the factors that determine attitude towards behavior, subjective norm and perceived behavioral control are the behavioral, normative and control beliefs respectively. According to Ajzen (2020), a behavioral belief is "the person's subjective probability that performing a behavior of interest will lead to a certain outcome or provide a certain experience" (Ajzen, 2020, p. 315). In addition, Ajzen (1991) supports, based on normative beliefs, that "a person who believes that most referents with whom he is motivated to comply think he should perform the behavior will perceive social pressure to do so" (Ajzen, 1991, p. 7). Finally, control beliefs are related to the presence of factors and conditions which facilitate the performance of the behavior or not (e.g., skills, availability of time, resources) (Ajzen, 2020). In this study, we consider that behavioral and control beliefs are important for the adoption of drones in future classrooms.

Previously, researchers have used TPB or its extensions (e.g., Teo et al., 2016) to investigate educators' attitudes, beliefs and intentions to use various digital technologies in their teaching (Chien et al., 2014; Sadaf et al., 2012; Sadaf & Johnson, 2017; Smarkola, 2008; Sungur-Gul & Huseyin, 2021; Teo & Lee, 2010; Watson & Rockinson-Szapkiw, 2021). For example, Smarkola (2008) used TAM and TPB to investigate pre-service and experienced teachers' beliefs which contribute to their intentions to use ICT in their teaching. In another study, Sadaf et al. (2012) examined pre-service teachers' behavioral, normative, and control beliefs regarding their intentions of future use of Web 2.0 technologies in their teaching. Similarly, Sadaf and Johnson (2017) used the conceptual framework of TPB in order to explore teachers' behavioral, normative, and control beliefs related to digital literacy integration into their classrooms. More recently, Sungur-Gul and Huseyin (2021) used TPB to explain pre-service teachers' mobile learning readiness. Watson and Rockinson-Szapkiw (2021) examined pre-service teachers' intention to use technology-enabled learning, while Chien et al. (2014) used variables of decomposed TPB to explore teachers' beliefs about technology-based assessments in classrooms.

Given the power of TPB in explaining how teachers' beliefs could contribute to their intentions of using digital technologies, variables of this theory were used as the conceptual framework of this study. More specifically, in this study we hypothesized that in order for pre-service and in-service teachers to use drones in their teaching, we must consider that these will help their teaching by offering specific advantages for them and their students (i.e., behavioral beliefs). In addition, we hypothesized that in order for pre-service and in-service teachers to use drones in their teaching, they need to feel that they have all the factors (e.g., time, support, and training) that can facilitate its use (i.e., control beliefs). Therefore, by measuring pre-service and in-service teachers' beliefs, it can be explored why they hold specific attitudes and perceptions towards the use of drones in teaching. Furthermore, we used intention and attitude, which are common variables in TAM and TPB.

14.3.1 Pre-service and In-service Teachers and Robotics

Despite the growing interest in educational robotics, there is a lack of studies investigating pre-service and in-service teachers' attitudes, beliefs and perceptions towards the use of robots in teaching (Tang et al., 2020). Following a review of the literature, two categories of studies were identified. The first category comprises research in which the sample was informed about the attributes and affordances of educational robots through presentations, websites, articles and videos. In these studies, the sample did not have the opportunity to interact with the robots. The second category comprises research where the sample interacted with the robots and conducted a number of activities with them. The most relevant studies of both categories are presented below.

Khanlari and Mansourkiaie (2015) explored in their study the perceptions of 11 in-service teachers of primary education regarding the use of robots in the context of STEM learning. The sample had little to no experience in educational robotics; therefore, to accustom them, the researchers created a website that contained articles and videos about educational robotics. Once the teachers studied the material, they answered an online questionnaire. The findings of this study indicated that most teachers want to integrate robots in their teaching activities. They also recognized that "… robotics is a useful educational tool for primary grades…". On the other hand, a number of teachers mentioned that, while they are familiar with robotics, they avoid implementing it in teaching because it makes them anxious. Subjects in which teachers mentioned they would use robots were Mathematics, Science and Geometry, while they stated that their use will improve technology literacy in primary education.

Another study, by Khanlari (2015), investigated the beliefs, the barriers as well as the support that teachers perceive they require in order to use robotics in the classroom. Eleven in-service teachers of primary education with no prior knowledge of educational robotics participated in the study. As with the previous study, this study made use of a website that contained articles and videos on educational robotics in order to inform the teachers. Next, teachers answered an online questionnaire. Khanlari (2015) found out teachers believe they need to be trained to integrate robotics into their teaching. In addition, teachers believe that robots help to develop various skills in pupils, such as mathematical reasoning, and problem-solving and several lifelong skills (e.g., critical thinking, cooperation, decision making, creativity), as well as to improve communication skills. As obstacles, teachers mentioned a lack of educational robots in school, infrastructure problems, time-consuming procedure for the integration of drones in the classroom, a lack of technical and instructional support, and the fact that they do not feel confident enough to use this technology in their classes.

In another study, Reich-Stiebert and Eyssel (2016) investigated teachers' attitudes, predictors of attitudes, and preferred application areas regarding educational robots. The sample was 59 primary and secondary education teachers with little experience in educational robots. The researchers made a short presentation of the features and functions of educational robots and showed teachers pictures of the humanoid robot NAO. Data collection was done through questionnaire. The results showed that teachers' attitudes ranged from neutral to negative regarding teaching and learning with the use of educational robots. Furthermore, they mentioned that they would use robots in the subjects of Informatics, Mathematics and Physics. However, they were neutral regarding their use in the subjects of Biology, Chemistry, Geography, History and Foreign Languages.

In their study, Kennedy et al. (2016) investigated teachers' attitudes, willingness and factors that influence engagement with educational robots. The sample consisted of non-educators as well as 35 in-service teachers of primary education. The sample saw various pictures of the NAO humanoid robot and subsequently answered to a questionnaire which measured attitudes and willingness to use robots. The results showed that teachers are cautious but potentially accepting to use educational robots.

What follows are indicative studies in which the sample had the opportunity to interact with the robots. Fridin and Belokopytov (2014) investigated the first-time acceptance of robots. The sample consisted of 18 pre-school and elementary teachers who participated in a professional workshop on educational robots. A number of teachers had an interaction with the NAO robot, while others observed the procedure. Data collection was done with the use of a questionnaire that was created according to the Unified Theory of Acceptance and Use of Technology (UTAUT). The findings indicated that teachers generally accept that a human-like robot can function as an interactive tool in teaching.

In another study, Chevalier et al. (2016) investigated the perceptions of 43 in-service teachers of primary and secondary education regarding educational robotics. They participated in the study in the context of robotics teacher training sessions and used the Thymio II robot. The data collection was done using a questionnaire. The results showed that teachers believed that the robot allowed pupils to acquire knowledge. The subjects they would choose to teach using a robot were: Mathematics, Science, General Education, Art and, to a lesser extent, Languages and Physical Education. The results also showed that teachers believe that, via utilization of the robots, pupils can develop certain skills that are related to learning strategies, creative thinking, communication, collaboration and reflective process.

In their study, Kim and Lee (2016) examined how robot programming education affects teachers' attitudes towards robots. The sample consisted of 40 pre-service teachers who were divided into a control group and an experimental group, in the context of a robot programming class. The participants in the experimental group interacted with Lego Mindstorms EV3 robots, assembled them, programmed them via block-based programming and conducted assignments that were based on their sensors. Data collection was done with the use of a questionnaire. The results showed that, even though the pre-tests of the experimental group revealed negative attitudes towards robots, the post-tests revealed significantly more positive outcomes.

In a more recent study, Khanlari (2019) conducted a workshop with the aim of investigating the perceptions of teachers regarding the use of robotics in STEM education and whether it will foster positive attitudes towards STEM careers. The sample of this study consisted of 58 in-service teachers of primary education that had no prior knowledge of educational robotics. Teachers engaged in hands-on robotics activities using preassembled Lego Mindstorms and were subsequently asked to program and make calculations with the robot. Data collection was done using pre/post questionnaires that measured attitudes and perceptions. The results indicated that the teachers had initially negative perceptions on the effects of robotics (48%), while after their interaction with the robots they had more positive perceptions (78%). Furthermore, the results indicated that participants had positive attitudes regarding the use of robots in STEM disciplines, e.g., Mathematics and Science. Also, among other things, the teachers mentioned that the pupils, through their involvement with

Lego Mindstorms, will acquire technological literacy, mathematical reasoning and problem-solving skills.

In their study, Sisman and Kucuk (2019) investigated teachers' perceptions and experiences regarding their use of educational robotics. 30 pre-service elementary teachers participated in the study, in the context of an educational robotics course. Data collection was done through survey, observation and interviews. The participants were asked to assemble robotic designs (e.g., chick, owl, bull, dog robots) using educational robotics kits. The results showed that the participants had an increased level of collaboration, satisfaction, enjoyment and motivation.

Based on the literature review above, several conclusions can be drawn. Firstly, there is a limited number of studies that focus on attitudes, beliefs and perceptions of teachers towards the use of robots in teaching. Secondly, according to the findings of existing studies, the majority of teachers show positive intentions (Khanlari, 2015; Khanlari & Mansourkiaie, 2015)—with some exceptions—regarding the use of robots in teaching. Thirdly, while a number of teachers initially appear to have a neutral or even negative attitude towards robots, after hands-on interaction with them, they show a change in attitude (Kennedy et al., 2016; Khanlari, 2019; Kim & Lee, 2016). Of particular interest is the fact that even the teachers who have a negative attitude towards robots still acknowledge the benefits of their use in the classroom, the benefits they offer to students, and the subjects which would be most suitable for their implementation (Kim & Lee, 2016; Reich-Stiebert & Eyssel, 2016). The abovementioned studies also show a number of limitations regarding the use of robots in education, the most important of which relate to the lack of teacher training programs as well as the lack of educational robots in schools.

TPB will contribute to the better understanding of the factors that influence the beliefs of pre-service and in-service teachers in the use of robots in education. In conclusion, the review of the literature confirms the research gap, since, to the best of our knowledge, no study has investigated pre-service and in-service teachers' attitudes, beliefs and perceptions towards using aerial educational robotics in teaching.

14.4 Methodology

14.4.1 Elicitation Study

As mentioned in a previous section, among the objectives of this study was to investigate pre-service and in-service teachers' behavioral and control beliefs regarding the use of drones in teaching and learning, as well as their perceptions regarding the skills that can be developed through the use of drones in teaching and learning and the subjects in which drones can be used. In order to develop the questionnaire regarding these beliefs and skills, an elicitation study was conducted involving 15 pre-service teachers and 18 in-service teachers who voluntarily participated in the study. All participants had experience with the use of drones for educational purposes and were excluded from the main study. The elicitation study was conducted according to the guidelines suggested by Ajzen and Fishbein (1980, p. 261) and Ajzen (2020). More specifically, participants were asked to answer the following questions of an online open-ended questionnaire: (a1) What do you view as the advantages of using drones in your teaching? (a2) What do you view as the disadvantages of using drones in your teaching? (behavioral beliefs), (b1) What factors or circumstances make it easier for you to use drones in your teaching? (b2) What factors or circumstances make it more difficult for you to use drones in your teaching? (control beliefs), (c) Which skills do you believe can be developed using drones in students' learning, and (d) What do you believe are the school subjects in which drones can be used?

Two researchers in ICT in education independently coded the generated behavioral and control beliefs and perceptions for skills and subjects. Their results of coding and the classification of the answers indicated a satisfactory agreement which ranged from 85 to 93%. This elicitation study resulted in the development of 46 closed-ended items: (a) 20 items regarding behavioral beliefs, (b) 9 items regarding control beliefs, (c) 9 perceptions regarding skills, and (d) 8 perceptions regarding subjects. These beliefs and perceptions were then tested and modified through a pilot study with the participants of the elicitation study. The latest version of beliefs and perceptions items was used in the questionnaire of the main study.

14.4.2 Main Study

14.4.2.1 Participants

The participants (n = 181) of this study were both pre-service (n = 80, 44.2%) and in-service teachers (n = 101, 55.8%) of primary education. Pre-service teachers were enrolled in a compulsory "Information and Communications Technologies in Education" course at the Faculty of Primary Education of the National and Kapodistrian University of Athens. In-service teachers were enrolled in postgraduate courses and seminars on ICT in education and online learning at the same university. All the participants voluntarily signed up to participate in this study. Among these participants, 144 (79.6%) were female and 37 (20.4%) were male. Table 14.1 summarizes the descriptive statistics of the participants.

14.4.2.2 Instruments

Data was collected by an online questionnaire, which consisted of two main parts. The first part referred to the participants' demographics (i.e., gender, age). The second part was divided into six sections. Sections 14.2.3 and 14.2.4 contained the scales of intention and attitude toward the use of drones in teaching respectively.

Table 14.1 Descriptive statistics of the participants

	Pre-service teachers		In-service teachers	
	N	%	N	%
Gender				
Male	12	15	25	24.8
Female	68	85	76	75.2
Age				
≤25	75	93.8	0	0
26–35	3	3.8	52	51.5
36–45	2	2.5	37	36.6
≥46	0	0	12	11.9

Sections 14.2.5 and 14.2.6 contained items of behavioral and control beliefs respectively, while Sects. 14.2.7 and 14.2.8 contained items of perceptions. The items used in Sects. 14.2.4, 14.2.5, 14.2.6 and 14.2.7 of the questionnaire were based on the beliefs and perceptions identified in the elicitation study. The items used in the study are shown in the tables in the following section.

14.4.2.3 Intention

Participants' intention to use drones in their teaching was measured using a 3-item scale adopted from Ajzen (1991). These items were (a) "I intend to use drones in my teaching in the future", (b) "I will try to use drones in my teaching in the future" and (c) "I plan to use drones in my teaching in the future". All items were rated on a 5-point Likert-type scale (from 1 = Strongly disagree to 5 = Strongly agree). The factorial analysis supported the unidimensional structure of the construct (Principal Axis Factoring led to a one-factor solution, accounting for the 77.98% of variance), while Cronbach's α value supported its reliability ($\alpha = 0.847$). Thus, the 3 items were averaged to yield a measure of intention in which a higher score indicates a strong intention to use drones in teaching.

14.4.2.4 Attitude

The participants' attitude towards the use of drones in their teaching was measured using a semantic differential scale adopted from Ajzen and Fishbein (1980, p. 261) and Ajzen (2020). More specifically, participants were asked to rate the use of drones in their teaching on a set of five 5-point polar adjective scales with end-points of (a) Harmful/Beneficial, (b) Unpleasant/Pleasant, (c) Bad/Good, (d) Worthless/Valuable, and (e) Unenjoyable/Enjoyable. The factorial analysis supported the unidimensional structure of the construct (Principal Axis Factoring led to a one-factor solution, accounting for the 72.70% of variance), while Cronbach's α value supported its reliability ($\alpha = 0.906$). Hence, the five adjective scales were averaged to create a measure of attitude in which a higher score indicates positive attitudes towards the use of drones in teaching.

14.4.2.5 Behavioral Beliefs

Participants' behavioral beliefs were measured by 20 items based on the results of the elicitation study (see Table 14.3). These items represent different advantages and disadvantages of drones in teaching and learning and are not considered a unidimensional construct. The 20 items were rated on a 5-point Likert-type scale (from 1 = Strongly disagree to 5 = Strongly agree).

14.4.2.6 Control Beliefs

Participants' control beliefs were measured by 9 items regarding various factors or circumstances which facilitate them to use drones in their teaching (see Table 14.4). These items were identified in the elicitation study and were rated on a 5-point Likert-type scale (from 1 = Strongly disagree to 5 = Strongly agree). As in the case of behavioral beliefs, the items of this section were not considered a unidimensional construct.

14.4.2.7 Perceptions on the Skills

Participants' perceptions on the skills that can be developed using drones in teaching were measured by 9 items (see Table 14.7). These items reflect different perceptions for skills and, therefore, were not a unidimensional construct. These 9 perceptions were also obtained from the elicitation study and were rated on a 5-point Likert-type scale (from 1 = Strongly disagree to 5 = Strongly agree).

14.4.2.8 Perceptions on Subjects

Participants' perceptions on the subjects in the teaching of which drones can be used were identified in the elicitation study and were measured using 8 items/subjects (see Table 14.8). The question in this section was "In which of the following subjects do you believe drones can be used in order to further assist your teaching?" Participants were asked to rate the 8 subjects of this question on a 5-point Likert scale (from 1 = Strongly disagree to 5 = Strongly agree).

A pretest for the validity of the questionnaire was conducted by three academic experts in ICT in education to ensure its clarity and comprehensibility. In addition, a pilot study was conducted by 8 pre-service teachers and 12 in-service teachers. These participants were asked to make comments and suggestions regarding the length of the questionnaire as well as the comprehensibility of the items. Few modifications of the wording and the beliefs and perceptions items sequence were made according to the above-mentioned participants' feedback. The required time to complete the questionnaire was approximately 7 min. All items were presented in the Greek language.

14.4.2.9 Procedure

The study took place in the academic year 2020–2021 and was conducted in four phases. In the first phase, after taking the necessary COVID-19 measures, the participants attended, in small groups of 20 persons, a one-hour presentation on drones, their capabilities, the methods used to operate them, as well as all the fields in which they are used today. In the second phase, the participants were instructed on the use of drones. Then, they interacted with four types of drones, through assembling, programming, simulating and flying them. More specifically, the interaction was accomplished in three stages. In the first stage, the participants were asked to form groups of two and assemble a drone, using the drone kits available. In the second stage, they were asked to create a code in a block-based programming language with the help of the DroneBlocks simulation application (DroneBlocks, 2021). In the third stage, the participants were asked to fly the drones in the university's outdoor area. In the final phase, the participants completed the online questionnaire. The duration of the second and third phase ranged from 3 to 4 h for each participant.

14.4.2.10 Drones Used in the Study

The drones used for the purpose of the research combine such features and abilities as to be representative of the average drone available today. In the beginning, the pre-built Parrot Bebop 2 quadcopter (Parrot, 2021) was chosen, which has a built-in camera and GPS. Then, the pre-built quadcopter Ryze Tello EDU (DJI, 2021) was chosen, which has a built-in camera, as well as the Makeblock Airblock STEAM drone (Makeblock, 2021), which has magnetically detachable rotors that allow it to take different forms (e.g., dualcopter, tricopter, quadcopter, hexacopter). These two drones provide access to mobile apps for programming, simulation and flight. Finally, a drone construction kit was chosen, namely the Flybrix Drone Kit (Flybrix, 2021). A total of four drones of each type were used (16 models in total), while there were additional batteries available for each drone model.

14.4.3 Statistical Analyses

All analyses were carried out in SPSS 25 for Microsoft Windows. The scale data (i.e., intention and attitudes) were tested for normality using the Kolmogorov-Smirnov test. The results showed that the data were not in normal distribution. Therefore, in order to find whether there were any statistically significant differences between pre-service and in-service teachers regarding these variables and the remaining variables that are all ordinal (namely, behavioral and control beliefs and perceptions), we employed the non-parametric Mann–Whitney *U* test. In addition, to examine if there was a statistically significant correlation between participants' intentions and attitudes, as well as between their intentions and behavioral and control beliefs regarding the use of drones in teaching and learning, Kendall's τ_B correlation coefficient was used.

14.5 Results

14.5.1 Intention and Attitudes of Pre-service and In-service Teachers

As we have seen, one of the research questions of this study related to pre-service and in-service teachers' intentions and attitudes towards the use of drones in their teaching. Table 14.2 shows the mean values (M) and standard deviations (SD) of these two scales. As can be seen, the mean values are above 4, thereby indicating positive attitudes and intentions towards using drones in teaching. Concerning the differences between the two groups of participants, the results of the Mann–Whitney U test presented in Table 14.2 indicate that there was a statistically significant difference between pre-service and in-service teachers' intention. This indicates that pre-service teachers had a significantly stronger intention to use drones in their teaching in the future than in-service teachers. Furthermore, Kendall's correlation coefficients showed that there was a positive relationship between pre-service ($\tau_b = 0.496$, $p = 0.000$) and in-service teachers' ($\tau_b = 0.474$, $p = 0.000$) attitudes and their intentions.

Table 14.2 Means (M), standard deviations (SD) and Mann–Whitney U test of pre-service and in-service teachers' attitude and intention

Scales	Overall		Pre-service teachers		In-service teachers		U	*p*
	M	SD	M	SD	M	SD		
Intention	4.31	0.664	4.39	0.731	4.24	0.602	3286.500	0.028*
Attitude	4.47	0.644	4.51	0.669	4.44	0.625	3582.000	0.182

* The mean difference is significant at the 0.05 level

This suggest that, when attitudes towards using drones in teaching increases, then intention to use drones also increases.

14.5.2 Behavioral and Control Beliefs

Another research question of this study related to participants' behavioral and control beliefs. Tables 14.3 and 14.4 shows the 20 behavioral and 9 control beliefs respectively which were identified in the elicitation study and measured in the main study. More specifically, Table 14.3 shows that the behavioral beliefs are related to the various advantages and disadvantages of using drones in future classrooms. Inspection of the values per behavioral belief item in Table 14.3 indicates that participants of this study evaluated very highly in all behavioral beliefs regarding the advantages of drones in teaching. In addition, they evaluated lowly in all behavioral beliefs regarding the disadvantages of drones (see items 14–20). These results in the majority of items indicate that, on average, participants had positive to strongly positive beliefs regarding the use of drones in teaching. Importantly enough, pre-service teachers had the highest mean score in all items regarding the advantages of drones as well as the lowest mean score in all items regarding the disadvantages of drones compared to in-service teachers.

Table 14.3 also presents the results of Mann–Whitney's U. As we can see, statistically significant differences were found in 6 of the 20 behavioral belief items. In all of the behavioral belief items regarding the advantages, pre-service teachers had significantly higher values than in-service teachers (see items 1, 2, 3, 5, 6, 7, 10). In contrast, in-service teachers had significantly higher values in behavioral beliefs regarding the disadvantages of drones in teaching.

Table 14.4 shows the control beliefs identified in this study. These consisted of four groups of factors of circumstances which related to: (a) support from head teachers and colleagues, (b) financial issues and availability of drones, (c) training opportunities, (d) and time and legal issues. The descriptive analysis shows that these beliefs were evaluated very high, which indicates that participants believed that the availability of these factors of circumstances would facilitate the use of drones in teaching. Among these beliefs were those that were related to training in drone use as well as training on the integration of drones in teaching. The results of Mann–Whitney's U show that there was statistically significant difference between the two groups of participants in 4 of the 9 control beliefs. Pre-service teachers' mean scores on the beliefs "My training in the use of drones" and "My training on how to integrate drones in my teaching" were significantly higher than in-service teachers' mean scores. On the contrary, in-service teachers had statistically higher mean scores than pre-service teachers on the beliefs which related to head teacher support and availability of drones in schools.

Behavioral and control beliefs were analyzed further. Each belief was correlated with intention. As mentioned in a previous section, correlation was measured using Kendall's correlation coefficients. These correlations are presented in Tables 14.5 and

Table 14.3 Median (Mdn), Mean scores (M) and Standard Deviations (SD) for behavioral belief items: comparison of pre-service teachers and in-service teachers

The use of drones in my teaching will	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
1. Promote cooperative teaching	5.00	4.00	4.55	0.727	4.31	0.644	3086.500	0.002*
2. Promote the interdisciplinary approach of knowledge	5.00	4.00	4.56	0.653	4.37	0.595	3245.500	0.010*
3. Promote learning by doing	5.00	5.00	4.69	0.493	4.52	0.593	3493.500	0.064
4. Promote inquiry-based learning	5.00	5.00	4.58	0.591	4.58	0.534	4015.500	0.934
5. Make my lesson more fun for me	5.00	5.00	4.59	0.758	4.47	0.593	3384.000	0.030*
6. Make my lesson more fun for pupils	5.00	5.00	4.69	0.493	4.64	0.540	3912.500	0.652
7. Make my lesson more pleasant for me	5.00	4.00	4.64	0.733	4.41	0.619	3046.500	0.001*
8. Make my lesson more interesting for pupils	5.00	5.00	4.66	0.502	4.54	0.557	3615.500	0.152
9. Increase pupils' learning motivation	5.00	5.00	4.56	0.524	4.47	0.576	3714.000	0.286
10. Increase pupils' interest for learning	5.00	4.00	4.61	0.562	4.45	0.574	3394.500	0.034**
11. Enhance pupils' knowledge	4.50	4.00	4.40	0.686	4.36	0.642	3840.500	0.526
12. Encourage pupils' creativity	5.00	5.00	4.58	0.591	4.50	0.610	3793.000	0.415
13. Help pupils to improve their spatial skills	5.00	5.00	4.61	0.562	4.54	0.592	3805.500	0.431
14. Make preparing for lessons more time-consuming**	2.00	2.00	1.75	0.666	2.00	0.812	3372.500	0.039*

(continued)

Table 14.3 (continued)

The use of drones in my teaching will	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
15. Require additional training on my part**	2.00	2.00	1.75	0.646	1.81	0.717	3884.500	0.627
16. Require that I acquire knowledge in problem-solving techniques**	2.00	2.00	1.90	0.668	1.99	0.818	3802.500	0.465
17. Require time for pupils to become familiar with the drone**	2.00	2.00	2.01	0.720	2.08	0.845	3945.500	0.771
18. Infringe personal data**	3.00	3.00	3.01	0.934	3.40	0.928	3170.000	0.008*
19. Make me anxious**	3.00	3.00	2.68	0.925	3.25	0.963	2770.000	0.000*
20. Require additional attention to avoid pupils' injuries**	2.00	3.00	1.99	0.819	2.63	1.017	2611.000	0.000*

* The mean difference is significant at the 0.05 level
** Items for which the scoring was reversed

14.6, regarding behavioral beliefs and control beliefs respectively. As we can see in Table 14.5, many of the behavioral beliefs significantly correlated with participants' intention. Therefore, these correlation results show that the participants who had positive perceptions towards the advantages that drones will have in teaching were likely to have more strong intention regarding the of use drones in their teaching.

As indicated in Table 14.6, 4 of 9 pre-service teachers' control beliefs and 2 of 9 in-service teachers' control beliefs correlated with their intention to use drones in their future classrooms. Pre-service teachers' beliefs were the ones that were related to training in the use of drones, time availability, and head teacher and colleagues' support, while in-service teachers control beliefs were those that were related to training in the use of drones and availability of drones in their schools. These positive correlations suggest that, when pre-service and in-service teachers' beliefs regarding the factors or circumstances which facilitate the use of drones in teaching and learning increase, then their intention to use drones also increases.

Table 14.4 Median (Mdn), Mean scores (M) and Standard Deviations (SD) for control belief items: comparison of pre-service teachers and in-service teachers

What factors or circumstances make it easier for you to use drones in your teaching?	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
1. My training in the use of drones	5.00	4.00	4.70	0.582	4.43	0.572	2936.500	0.000*
2. My training on how to integrate drones into my teaching	5.00	4.00	4.69	0.466	4.37	0.717	3112.500	0.002*
3. Cost reduction of drones	4.00	4.00	4.09	0.983	3.90	0.911	3492.500	0.099
4. Creation of a repository of good practices of drone utilization	4.00	4.00	4.06	0.847	4.17	0.775	3779.000	0.425
5. Establishment of a legal framework regarding the use of drones in school	4.00	4.00	4.03	0.914	3.88	0.898	3666.000	0.261
6. Time available for the preparation of my lesson	4.00	4.00	4.19	0.731	4.11	0.747	3822.500	0.502
7. Support from the school's head teacher	4.00	5.00	4.10	0.836	4.36	0.756	3352.000	0.034*
8. Support from my colleagues at school	4.00	4.00	3.94	0.817	3.74	0.868	3566.500	0.152

(continued)

Table 14.4 (continued)

What factors or circumstances make it easier for you to use drones in your teaching?	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
9. Availability of drones in school	5.00	5.00	4.34	0.779	4.63	0.578	3258.000	0.010*

* The mean difference is significant at the 0.05 level

14.5.3 Skills Developed Through the Use of Drones During Teaching and Learning

Another research question of this study related to pre-service and in-service teachers' perceptions regarding the skills that can be developed using drones in teaching and learning. Table 14.7 presents these perceptions. The mean values for both participants' groups are over 4, indicating that the majority of them believed that the use of drones will improve pupils' various skills. Analysis indicated that participants had the most positive perceptions towards certain skills such as: spatial skills, digital skills, creativity and basic programming principles. The results of Mann–Whitney's U showed that, in digital skills and creativity, pre-service teachers had statistically significant positive perceptions compared to in-service teachers.

14.5.4 Subjects in Which Drones Can Be Used

As we have seen, another research question of the current study related to participants' perceptions regarding the subjects that drones can be used in teaching. Table 14.8 presents the results related to this research question. As seen in this table, the results indicate that pre-service and in-service teachers had more positive perceptions regarding drone use in the subjects of Physics, Mathematics, Geography, Technology and Environmental Education. In contrast, they had less positive perceptions regarding drone use in the subjects of Physical Education, History, Art and Theatre Education. Furthermore, the results of Mann–Whitney's U showed that there were statistically important differences between the groups of the participants in the subjects of Physics, Theatre Education and Environmental Education. In these subjects, pre-service teachers had higher mean scores compared to in-service teachers.

Table 14.5 Kendall's correlation for pre-service and in-service teachers' intention and behavioral beliefs

The use of drones in my teaching will	Pre-service teachers	In-service teachers
	Intention	Intention
1. Promote cooperative teaching	0.650** (0.000)	0.451** (0.000)
2. Promote the interdisciplinary approach of knowledge	0.553** (0.000)	0.434** (0.000)
3. Promote learning by doing	0.375** (0.000)	0.243** (0.005)
4. Promote inquiry-based learning	0.227* (0.023)	0.334** (0.000)
5. Make my lesson more fun for me	0.239* (0.015)	0.305** (0.000)
6. Make my lesson more fun for pupils	0.103 (0.301)	0.316** (0.000)
7. Make my lesson more pleasant for me	0.283** (0.004)	0.440** (0.000)
8. Make my lesson more interesting for pupils	0.120 (0.229)	0.232** (0.008)
9. Increase pupils' learning motivation	0.273** (0.006)	0.268** (0.002)
10. Increase pupils' interest for learning	0.282** (0.005)	0.259** (0.003)
11. Enhance pupils' knowledge	0.333** (0.001)	0.373** (0.000)
12. Encourage pupils' creativity	0.365** (0.000)	0.420** (0.000)
13. Help pupils to improve their spatial skills	0.249* (0.012)	0.314** (0.000)
14. Make preparing for lessons more time-consuming***	0.348** (0.000)	0.141 (0.092)
15. Require additional training on my part***	0.323** (0.001)	0.130 (0.124)
16. Require that I acquire knowledge in problem-solving techniques***	0.333** (0.001)	0.133 (0.101)
17. Require time for pupils to become familiar with the drone***	0.151 (0.115)	0.092 (0.267)
18. Infringe personal data***	0.025 (0.792)	0.014 (0.862)
19. Make me anxious***	0.169 (0.069)	0.091 (0.265)
20. Require additional attention to avoid pupils' injuries***	0.145 (0.124)	-0.088 (0.281)

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)
*** Items for which the scoring was reversed

14.6 Discussion and Conclusions

Aerial robotics and, particularly, one of its categories, i.e., drones, constitute a new research field in education, which has begun approximately one decade ago. Given that teachers play a key role both in the introduction and in the implementation and continuation of every educational change and innovation (Byker et al., 2017;

Table 14.6 Kendall's correlation for pre-service and in-service teachers' intention and control beliefs

What factors or circumstances make it easier for you to use drones in your teaching?	Pre-service teachers	In-service teachers
	Intention	Intention
1. My training in the use of drones	0.412** (0.000)	0.387** (0.000)
2. My training on how to integrate drones into my teaching	0.125 (0.215)	0.002 (0.984)
3. Cost reduction of drones	−0.028 (0.764)	−0.041 (0.683)
4. Creation of a repository of good practices of drone utilization	0.083 (0.378)	−0.009 (0.927)
5. Establishment of a legal framework regarding the use of drones in school	−0.087 (0.356)	−0.033 (0.744)
6. Time availability for the preparation of my lesson	0.274** (0.004)	−0.029 (0.771)
7. Support from the school's head teacher	0.313** (0.000)	0.036 (0.717)
8. Support from my colleagues at school	0.216* (0.012)	−0.008 (0.939)
9. Availability of drones in school	−0.064 (0.502)	0.227* (0.022)

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 14.7 Median (Mdn), Means (M), standard deviations (SD) and Mann–Whitney U test of pre-service and in-service teachers' perceptions regarding the skills that pupils can develop using drones

Drone use facilitates the development of	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
1. Digital skills	5.00	5.00	4.68	0.546	4.50	0.559	3361.000	0.023*
2. Spatial skills	5.00	5.00	4.70	0.560	4.62	0.526	3676.500	0.199
3. Basic programming principles	5.00	5.00	4.58	0.689	4.41	0.737	3508.000	0.081
4. Problem-solving skills	5.00	4.00	4.49	0.746	4.38	0.646	3531.000	0.103
5. Critical thinking skills	5.00	4.00	4.51	0.693	4.34	0.697	3429.500	0.051
6. Social skills	4.00	4.00	4.08	0.883	4.00	0.812	3807.500	0.480
7. Pupils' self-motivation	4.50	4.00	4.35	0.781	4.25	0.607	3512.000	0.092
8. Creativity	5.00	4.00	4.61	0.684	4.42	0.621	3225.000	0.008*

* The mean difference is significant at the 0.05 level

Table 14.8 Median (Mdn), Means (M), standard deviations (SD) and Mann–Whitney U test of pre-service and in-service teachers' perceptions regarding the subjects in which drones can be used

In which of the following subjects do you believe drones can be used to further assist your teaching?	Pre-service teachers	In-service teachers	Pre-service teachers		In-service teachers		U	*p*
	Mdn		M	SD	M	SD		
Physics	5.00	4.00	4.75	0.436	4.28	0.736	2620.000	0.000*
Mathematics	5.00	4.00	4.31	0.894	4.30	0.807	3901.000	0.663
Geography	5.00	5.00	4.68	0.497	4.61	0.509	3789.000	0.386
Technology	5.00	5.00	4.71	0.455	4.58	0.621	3721.000	0.263
Physical Education	3.00	3.00	3.41	1.229	3.20	0.980	3691.500	0.297
History	4.00	4.00	3.66	1.102	3.70	1.005	3958.000	0.807
Arts	4.00	3.00	3.66	0.993	3.42	0.941	3435.500	0.069
Theatre Education	4.00	3.00	3.63	1.023	3.22	1.055	3103.000	0.005*
Environmental Education	5.00	5.00	4.78	0.551	4.53	0.687	3262.500	0.005*

* The mean difference is significant at the 0.05 level

Fullan, 2015; Harris & Jones, 2019; Vandeyar, 2017), the current study—through utilization of the theoretical framework of the Theory of Planned Behavior (TPB) (Ajzen, 1991)—has focused on how the potential use of drones in education is viewed by two different groups of participants: in-service teachers and pre-service teachers as future teachers. The results of the study have been encouraging regarding the use of drones in the future, since both groups have positive perceptions towards them. What follows is a discussion on the main results of the study based on its research questions.

14.6.1 *Pre-service and In-service Teachers' Intention and Attitude*

Concerning the first research question, one important finding is that pre-service and in-service teachers had a strong intention regarding the use of drones in teaching as well as positive attitudes towards said use. According to TPB and TAM, these two variables are among the key factors regarding the acceptance of any technology in education (Gómez-Ramirez et al., 2019; Opoku et al., 2020; Scherer et al., 2019; Scherer & Teo, 2019). The fact that there was a positive correlation between these two variables in the present study suggests that, when pre-service and in-service teachers' attitudes towards using drones in their teaching increases, then their intention to use drones also increases. Therefore, future attempts to integrate aerial robotics in education through drones should focus, among other things, on shaping positive attitudes among teachers towards this use. This finding is in accordance with the results of previous studies regarding the acceptance of various digital technologies in education (Scherer & Teo, 2019; Scherer et al., 2019) as well as regarding the use of ground robots by teachers in education (Bazelais et al., 2017; Schina et al., 2021; Weng et al., 2018).

14.6.2 Pre-service and In-service Teachers' Behavioral and Control Beliefs

Regarding the second research question and the participants' behavioral beliefs, one important finding is that these beliefs relate more to the potential advantages rather than the disadvantages of using drones in teaching and learning. For example, among the advantages which the participants mentioned are that the use of drones in their teaching will make their lessons more fun and pleasant for them, make lessons more interesting for their pupils, and increase pupils' motivation and interest for learning. These beliefs are also supported by previous ICT studies (e.g., Sadaf & Johnson, 2017; Sadaf et al., 2012). Also, another important finding that concerns the third research question is that the majority of these beliefs was correlated with the participants' intention. According to TPB (Ajzen, 1991), the behavioral beliefs result in an either unfavorable or favorable attitude which in turn affects intention. Subsequently, the results of this study suggest that, to improve both the intention of pre-service teachers as future teachers as well as the intention of in-service teachers to use drones in teaching in the context of aerial robotics, educational policy should enhance their attitudes as well as their behavioral beliefs towards the use of drones in schools. In particular, educational policy should focus on the behavioral beliefs that are related to the advantages of drones. Teachers should be encouraged to view drones as making their lessons more beneficial to them and to their pupils.

One more important finding concerning the second and third research question regarding control beliefs is that the participants will use drones in their teaching if they believe that there are conditions and factors which will facilitate said use. According to Ajzen (1991), the control beliefs result in self-efficacy or perception of control over the performance of a specific behavior. Based on the present study's results regarding control beliefs, the most important factors, which are also positively correlated with their intention, are the training in the use of drones and how to integrate them into their teaching, the support from the school's head teacher, and the availability of drones in schools. This finding is similar to that of previous ICT (Sadaf et al., 2012; Smarkola, 2008) and STEM (Castro et al., 2018; Knauder & Koschmieder, 2019; Pimthong & Williams, 2018) studies which indicated that the training and the availability of resources (e.g., hardware, infrastructure) as well as the head teacher's support were positively correlated with educators' stronger intentions to use technology in their teaching. Therefore, the most efficient way to increase pre-service and in-service teachers' intention to use drones in their future classrooms is to provide them with all the facilitating factors and conditions which will be identified by their control beliefs.

14.6.3 Pre-service and In-service Teachers' Perceptions on Skills

Regarding the fourth research question, the results showed that participants believe that drones in the context of aerial robotics can enhance various skills of pupils. Among the skills which they believe can be enhanced more are: spatial skills, digital skills, problem-solving skills, critical thinking skills, skills of basic programming principles, and creativity skills. Similar skills have been found in previous studies on both robotics and STEM (Atmatzidou et al., 2017; Çalişkan, 2020; Di Battista et al., 2020). Therefore, educational policy regarding aerial robotics in schools should focus on how teachers can be trained to develop the above skills in their pupils.

14.6.4 Pre-service and In-service Teachers' Perceptions on Subjects

The results that relate to the fifth research question showed that the participants believed that the use of drones could be implemented either in STEM-related subjects or in Humanities-related subjects. The aforementioned results are in line with those of earlier studies regarding teachers' perceptions on the use of ground robots (Khanlari & Mansourkiaie, 2015; Reich-Stiebert & Eyssel, 2016). These results show that drones could be used in almost every subject of primary education and possibly by all teachers depending on their interests and specialization. More specifically, all the characteristics of drones relate to Science, Technology, Engineering and Mathematics (STEM) (Chen et al., 2019; Chou, 2018; Goodnough et al., 2019). They can be constructed, assembled, and programmed to fly and collect various data through their technical affordances and sensors (Bermúdez et al., 2019; Carnahan et al., 2016; Ng & Cheng, 2019). Therefore, teachers should be encouraged to integrate drones either in STEM-related subjects or in Humanities-related subjects and be provided with specific teaching examples and best teaching practices.

14.6.5 Differences Between Pre-service and In-service Teachers' Intentions, Attitudes, Beliefs and Perceptions

Another important finding of this study, which concerns the sixth research question, is that pre-service teachers had a statistically significant stronger intention and more positive attitudes and behavioral beliefs regarding the use of drones in education compared to in-service teachers. They also had more positive perceptions on the skills that can be developed through the use of drones as well as the subjects in which they can be used. This may be due to the fact that today's generation of pre-service teachers is more accustomed to digital technologies and emerging technologies compared to today's in-service teachers (Chiner et al., 2019; Papadakis et al., 2021; Saltan & Arslan, 2017). Another explanation is that in-service teachers have more teaching experience and, very often, their attempts to use digital technologies in their classrooms are related to various factors (e.g., time, resources, support). This means that experienced teachers have a better understanding of how difficult it is to integrate an intervention in schools. Therefore, one would not expect in-service teachers to be more enthusiastic regarding the use of drones compared to pre-service teachers, who are not familiar with real school situations.

In addition, this study showed significant differences between pre-service and in-service teachers in terms of their control beliefs. More specifically, the results indicated that pre-service teachers need more training than in-service teachers. Therefore, training programs for pre-service teachers should assist them not only in how to use drones but also in how to integrate them effectively in their teaching practices. Furthermore, the results showed that in-service teachers need more support from head teachers as well as a greater availability of drones in schools. This finding agrees with the findings of previous studies in education which showed that the role of head teachers is significant regarding the integration of any innovation and change in schools (Fullan, 2015; Jogezai et al., 2021; Mei Wei et al., 2016; Tondeur et al., 2008).

14.6.6 Limitations and Future Research

The present research is the first to study the intention, attitudes, beliefs and perceptions of two different groups of teachers regarding the use of drones in education in the context of aerial robotics. The results enrich the existing literature and open new avenues of research in aerial robotics and the use of drones in schools. Given that the research sample was convenient, the results of this study should be interpreted with caution. Future studies should investigate the aim and the objectives of this study with the use of a more representative sample which will consist of teachers of various subjects. Moreover, future studies should examine the aim and the objectives in a real-life learning environment where drones are used by both in-service teachers in their teaching and pre-service teachers within the context of their in-school practicum.

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