education sciences

Systematic Review

The Effect of Drones in the Educational Process: A Systematic Review

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Abstract: Due to COVID-19, Industry 4.0 technologies have been deeply integrated into our lives, making it possible to interact, learn, and be productive. The rise of ICT has been established for a lot of years, transforming the educational process of many students with more and more educators applying them in school settings and considering them an essential part of teaching. ICT constantly evolves incorporates and utilizes all the recent and cutting-edge technology to help learners interact and learn in the most engaging and motivating way. The purpose of this literature review is to investigate a very fascinating and promising piece of robotic technology called a drone or unmanned aerial vehicle and how it has been integrated and utilized in the educational process of students to date. In the introduction, the main adoptions of ICT and drones are discussed. In the main part, we explore the possibilities and the applications of drone technology in the educational path from analysis of included studies and research, as well as discussing the students' and teachers' perceptions of their use. The results of this study of the application of drones in education show promising effects among students and teachers, but several limitations were identified, making it still difficult to generalize their use in the educational process. Furthermore, a need for a unified framework for reference is needed to be able to accommodate their use in school and academic environments.

Keywords: drones; flying drones; unmanned aerial vehicles; education; students; STEM

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1. Introduction

The development of ICT is gradually replacing traditional teaching with every aspect of life now related to science and technology [1]. Face-to-face interaction in the classroom is being replaced by online communication, the interactive whiteboard is replacing the traditional classroom blackboard, and online resources are replacing textbooks or print resources. Many people believe that technology can revolutionize the education sector. This is because applying ICT in schools can bring some potential benefits. Information and technology are widely used in the educational field to make the process of teaching and learning successful and interesting for both students and teachers. However, to achieve these benefits, enormous difficulties have to be overcome. These difficulties may present differences from school to school, region to region, and country to country [2].

The future is moving toward an advanced educational environment in which each student will be connected via the internet to a vast learning network where they can search for knowledge, examples, answers, and solutions to the assigned topic, find students studying the same topics, and join groups and working groups that have something in common. There also have been a lot of changes in the perspectives of teachers and students due to robotics, new and assistive technologies [3–5], and the constant development of future work such as learning coding and building robots [6].

Teachers play a vital role in the teaching and learning process. The introduction of ICT in teaching has been essential for teachers as ICT makes it easier for them to share teaching resources [7] and knowledge more generally [8]. ICT tools allow them to perform all teaching and learning activities in a flexible way [9]. With the implementation of ICT, teachers' skills, confidence in their abilities, and enthusiasm increase. ICTs in education serve as a powerful tool for teachers to integrate students with difficulties and disabilities through their teaching. The integration of ICT in teaching and learning processes requires teachers to acquire a certain level of different skills to handle all the challenges associated with their integration in educational processes [10]. Drones are an emerging ICT [11,12] that have many capabilities, making them a pioneer technology in many areas of interest.

Drones are flying robots, including unmanned aerial vehicles (UAVs) that can travel thousands of kilometers and small drones that fly in confined spaces. Aerial vehicles carry no operator, fly remotely or autonomously, and may carry lethal or non-lethal payloads. Advances in manufacturing, navigation, remote control capabilities, and energy storage systems have facilitated the development of a variety of drones that can be used in a variety of situations where human presence is difficult, impossible, or dangerous. Flying robots serving purposes including military surveillance, planetary exploration, and search and rescue have received the greatest attention in recent years [13]. The size and type of drive used in drones are not predetermined. They are often accompanied by accessories for monitoring and control such as optoelectronic heads. The most important feature of drones is that they do not need any additional infrastructure to quickly record and monitor a specified area or object [14].

The use of drones has very recently expanded into educational environments, attracting significant attention. Due to their potential to support student learning, the use of drones is often considered an alternative educational strategy to innovate learning environments. Drones are suitable and can benefit learning activities that include logic and deductive reasoning, debate, geography, advanced math, electronics, and eye-hand coordination. Students can also benefit from drone capture-imaging in both speaking and writing classes. This also applies to physical education classes, where students are required to perform exercises (Figure 1) [15,16]. In their research, Joyce et al. [17] discussed the conceptual themes for implementing drones in the educational process. These procedures referred to safety checks, the creation of a flight plan, the evaluation of the planning, and the quality of the process. Moreover, several aspects were targeted, with an emphasis on the educational process, including the expertise and skills of the teachers in implementing the educational program, taking into account all the risk factors. Drones have many benefits and many applications, allowing them to attract educators to using them in their process of teaching. Forestry, geography, and wildlife biology through remote sensing [18] (refers to the ability of the drone to carry sensors and transmit data of audio-visual input) allow for observations of the environment. This offers educational possibilities to teach data analysis and critical thinking, allowing the learners to analyze data received from outdoor areas not otherwise accessible. It can also provide data for analysis regarding possible feedback following a gym class lesson, allowing the learners to benefit from analytical observation of the whole procedure followed by the instruction of their teachers [19]. According to engineering, physics, and mathematics [20–22], drones can also be beneficial to learners as tools to aid their process analysis (assembling, following the knowledge of the educator, or coding analysis) to showcase problem-solving, data analysis, and research skills.

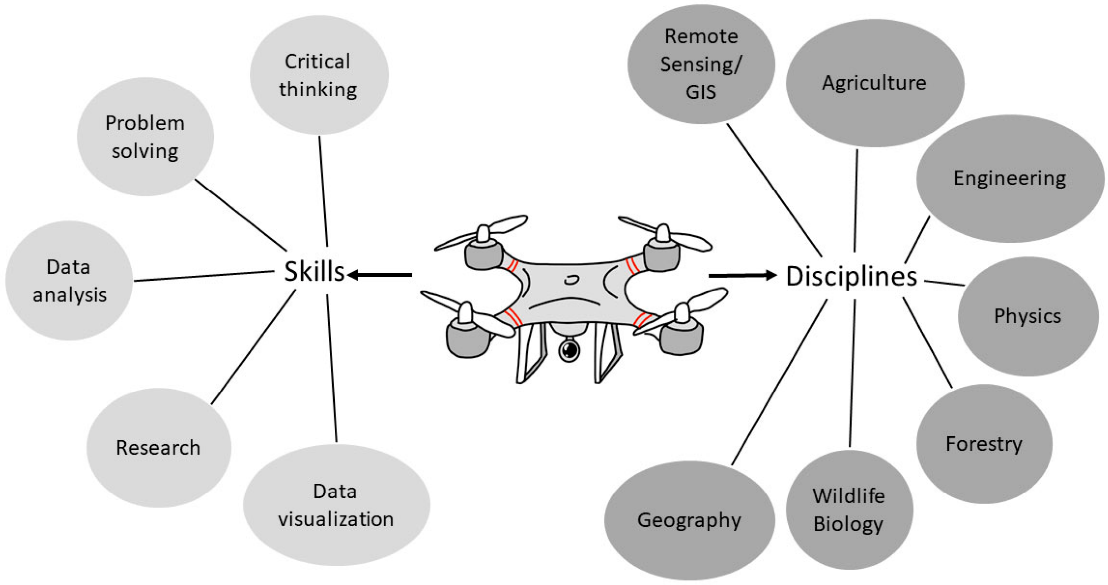

Figure 1. Drone skillsets in different educational disciplines [16].

2. Materials and Methods

The purpose of this literature review is to gather recent data on the use of drones as promoters of the educational process and document how they are integrated and perceived by educators, teachers, and students. This research through the review of the literature attempts to answer the following research questions.

- RQ1. How are drones used for educational purposes?
- RQ2. What types of drones have been studied and used in research for educational purposes?
- RQ3. How are drones perceived by students and teachers?
- RQ4. What are the limitations of the studies?
- RQ5. What are the educational methods applied?
- RQ6. Is there any established framework for drone usage in education?

The inclusion criteria for the main part were the following:

- IC1. Research articles dating from 2015 to present, after the price drop of drones that made it easy and affordable to incorporate them into study designs in schools, colleges, and universities [23].
- IC2. Be experimental, observational, or both including quantitative, qualitative, or mixed methods.
- IC3. Include the use of drones only for educational purposes.
- IC4. Include children, adolescents, adults, and their teachers-educators through their academic path (kindergarten through university) as a part of their curriculum or by offering educational outcomes to support their academic skills.
- IC5. Was written in English.

Accordingly, the exclusion criteria were as follows:

- EC1. Research articles before 2015.
- EC2. Literature reviews, systematic reviews, or metanalysis.
- EC3. Include the use of drones for other than educational purposes.
- EC4. Including children, adolescents, and adult populations outside of the academic curriculum path or not providing academic skill improvement
- EC5. Was not written in English.

The methodology performed to conduct this literature review was based on PRISMA 2020 principles (Figures 2 and 3), guiding the search of the literature across multiple platforms including PubMed, Web of Science, and Google Scholar using the snowball research method for the selection of the articles. Some of the following core keyword definitions that were used for the search process were "drones", "flying drone" "unmanned flying vehicle", "education", "students", "teachers", "educators" and combinations of these terms. A detailed analysis follows in Table 1.

Table 1. Research data entry strings.

Research Data Entry Search
("unmanned aerial devices"[MeSH Terms] OR ("unmanned"[All Fields] AND "aerial"[All Fields] AND "devices"[All Fields]) OR "unmanned aerial devices"[All Fields] OR "drone"[All Fields] OR "drones"[All Fields]) AND ("educability"[All Fields] OR "educable"[All Fields] OR "educates"[All Fields] OR "education"[MeSH Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[MeSH Terms] OR "education s"[All Fields] OR "educational"[All Fields] OR "educative"[All Fields] OR "educator"[All Fields] OR "educator s"[All Fields] OR "educators"[All Fields] OR "teaching"[MeSH Terms] OR "teaching"[All Fields] OR "educate"[All Fields] OR "educated"[All Fields] OR "educating"[All Fields] OR "educations"[All Fields]) AND ("student s"[All Fields] OR "students"[MeSH Terms] OR "students"[All Fields] OR "student"[All Fields] OR "students s"[All Fields]) AND ("teacher"[All Fields] OR "teacher s"[All Fields] OR "teachers"[All Fields])

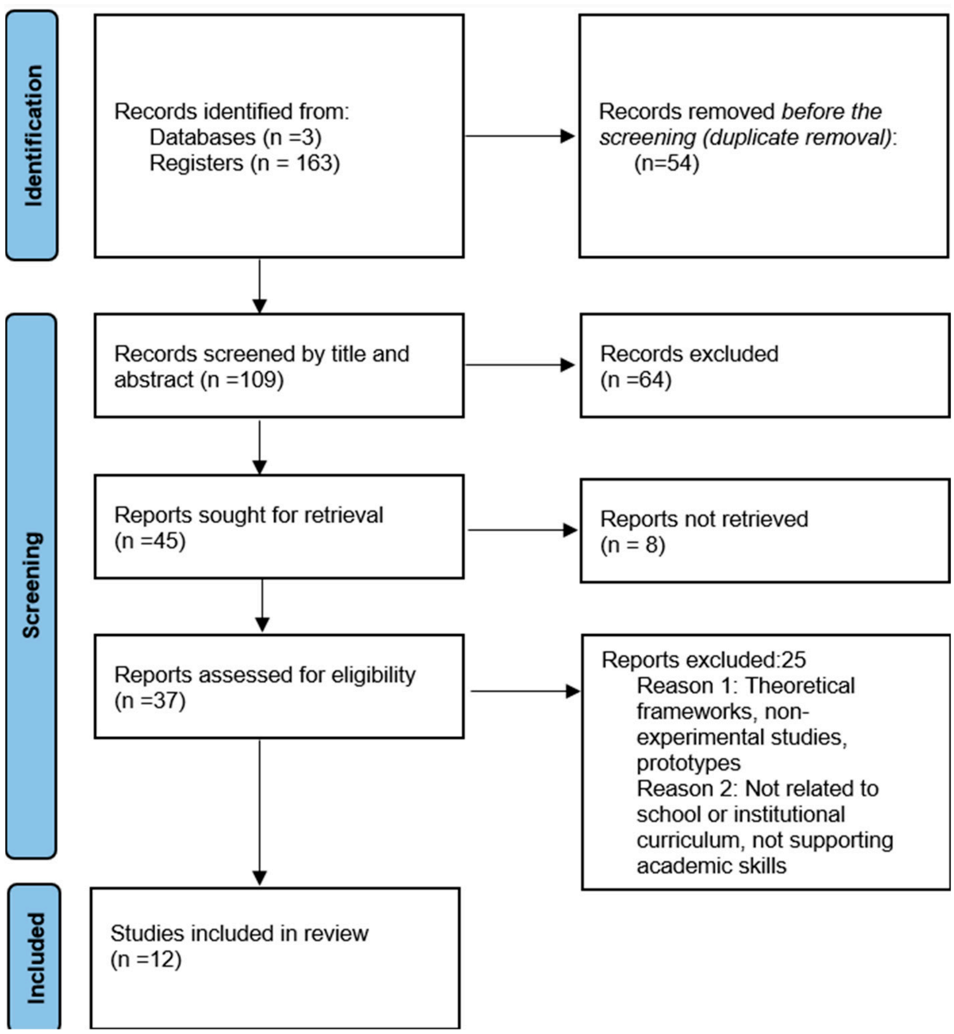

Figure 2. The PRISMA flow diagram.

PRISMA 2020 for Abstracts Checklist

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	YES
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	YES
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	YES
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	YES
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	YES
Synthesis of results	6	Specify the methods used to present and synthesise results.	YES
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	YES
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	YES
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	YES
Interpretation	10	Provide a general interpretation of the results and important implications.	YES
OTHER			
Funding	11	Specify the primary source of funding for the review.	NO
Registration	12	Provide the register name and registration number.	NO

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Figure 3. PRISMA 2020 abstracts checklists [24].

A total of n = 163 articles were identified and screened for the final selection of the included articles, which concluded after processing and inclusion and representative criteria for the main part (n = 12) in the final selection for further investigation and analysis. The research of the literature was performed between January 2015 and December 2023.

For the selection process, eligibility criteria were determined as the first step of the process. Additionally, a list of keywords was established to initiate the search in the databases, using Boolean operators and various search filters to produce the most results. After removing duplicate studies (n = 54), the selection was made according to the eligibility criteria (n = 109) through title and abstract screening. The next stage of the process included the full text screening after the exclusion of (n = 64) articles. The remaining studies (n = 45) were processed in detail. Unfortunately, n = 8 articles could not be retrieved for full text screening. For the final selection process, two independent reviewers participated in the procedure, analyzing the full text of n = 37 articles and discussing the applicability of the eligibility criteria. The remaining (n = 25) articles were removed because they did not meet the eligibility criteria (theoretical frameworks, non-experimental studies, prototypes, not related to a school or institutional curriculum, not supporting academic skills). This left n = 12 articles included in the final selection. Details of the results are summarized in Figures 2 and 3.

3. Results

3.1. Participants and Study Characteristics

According to the included studies, we gathered data from n = 12 studies from the year 2015 to 2023. The research protocols of the included studies were allocated to several locations including n = 4 from Greece [25–28], n = 1 from Thailand [29], n = 1 from China [30], n = 1 Taiwan [12], n = 1 South Korea [31], n = 1 Croatia [32], n = 1 USA [33], n = 1 Brazil [34], and n = 1 non-specified [35]. For the children, adolescents, and adults examined, we collected data from n = 994 subjects ranging from 3rd grade to university students and graduates [12,25,26,31,33–35]. For the teachers' or educators' performance, perception, or point of view, we collected data from $n = 509$ subjects, including different academic positions from school to university [27–30]. According to the characteristics of the population of children, adolescents, and adult students, we observe that in most of the studies males and females were examined, the only exception being Lee et al. [31], who examined only male subjects. Accordingly, referring to the cohort of teachers/educators examined, both genders were examined without a particular specification made by the searchers.

Most of the experimental processes referring to the use of drones for students were conducted in real-world contexts [12,25,26,33]. Finally, about the authors' methodology, most of them utilized a mixed method of collecting quantitative and qualitative data for analysis. Most of them used the questionnaire method to collect data about the perceptions of students [12,25,31,32] and teachers/educators/professors [27–30].

3.2. RQ1. Uses of Drones in Education

Despite the enthusiasm around the use of drones in the educational process, it seems that there are still very limited available studies that explore using them to facilitate teaching (Figure 2). More specifically, the pilot study by Fokides et al. [25] explored the integration of drones into the curriculum of 40 5th-grade elementary students who were divided into two groups to study the effects of learning math, geography, and physics. The first group learned through the use of drones while the second group was taught conventionally. Results indicated that students in the drone group outperformed students in the conventional instruction group on math assessments and all delayed post-tests.

Chou [12] examined the impact of drone use on the development of students' spatial visualization and sequencing skills and the teaching tasks associated with their use through the development of an after-school drone program. Ten third-grade students volunteered to participate in a six-week educational experience. The results showed that drone programming significantly improved students' learning of spatial visualization and sequencing skills.

In the study designed by Ng and Cheng [30], the researchers tried to explore the potential use of drones in the educational process by utilizing a group of pre-service teachers. The methodology followed by randomly allocating the subjects into three groups in which they were asked to develop teaching plans with the use of drone technology, and analysis was made through the TPCK framework to identify the readiness and need for training of the participants. The results implied that despite the capabilities of the subjects to show competence and knowledge about this technology, they needed to increase their knowledge to increase the effects and benefits of the learners.

The purpose of the study by Lee et al. [31] was to explore whether drone-based video feedback could enhance primary school students' satisfaction with soccer after school and evaluate its efficacy. Ninety male 4th-grade students who attended after-school soccer classes at three elementary schools in Seoul, South Korea were the selected participants. They were separated into three groups including an experimental group (a visual feedback group using a drone), a comparison group (a visual feedback group using a mobile phone), and a control group (a visual feedback group using only oral feedback). The study revealed that the group receiving drone feedback experienced greater levels of physical, educational, and psychological satisfaction than those receiving oral or mobile feedback.

The study by Yepes et al. [34] was conducted with 30 high school students and followed a qualitative analysis, in which quantitative data was collected from results obtained during pre-and post-tests and qualitative data was collected from notes to determine whether the use of drone-based platforms benefits the educational process in STEM. During the intervention, the researchers observed a semi-structured press interview. The results found that workshops with drone-based platforms helped in understanding, elaborating, and explaining the content covered, and it can be concluded that there was a significant relationship between the use of technology packages provided in the educational process and the students' ability to learn meaningfully in STEM fields.

Another use of drones in education is to help establish social connections among students, helping them engage more and assisting the educational process. In the study by Johal et al. [35], the researchers explored the application of the human–drone interaction domain by conducting seven remote online workshops with 20 participants. The results revealed many implications for the design of an applicable drone that can be used in the classroom, including aspects of noise, fear, lack of social cues, and teachers' cognitive load management.

An additional application has also been reported referring to the integration of virtual reality and drone usage. The study by Palaigeorgiou et al. [26] investigated participants in the elementary education department's sustainability education course. The students were randomly divided into two groups. Twenty-six students from the first group visited a predetermined city while the second group of 15 students followed their route through the city by watching live video broadcasts from drones in the university laboratory. Students argued that the two methods were equally valid, each with its advantages and problems. Students reported that drone-based virtual field trips (VFTs) provided a fun and engaging method of learning, while also offering several advantages over actual field trips, such as more detailed views at higher altitudes and a more general view of the area being examined. However, drone-based VFTs did not provide full field detail at human eye level and failed to convey the non-visual and auditory sensations of being on-site. Figure 4 illustrate, and Table 2 summarize the findings.

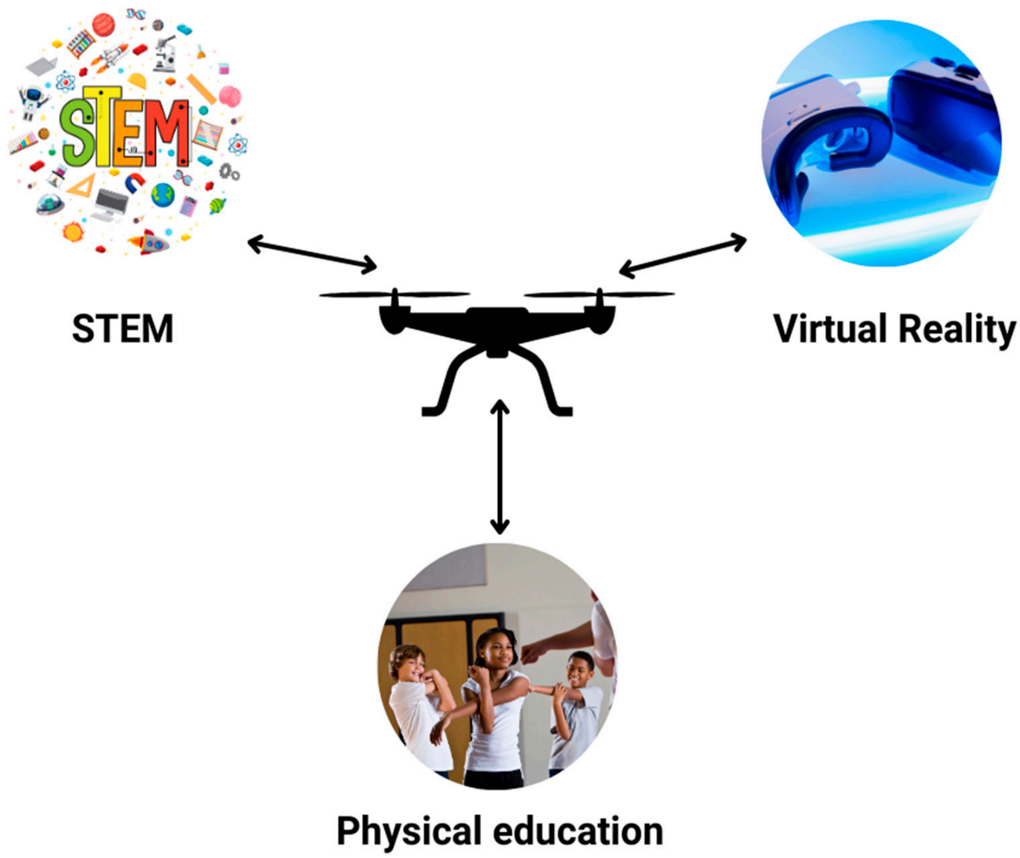

Figure 4. Uses of drones in students' education.

Table 2. Characteristics of the studies.

Studies	Participants/Academic Status	Context	Purpose	Results
Chou [12]	*n* = 10, 3rd grade Students	After School program	Spatial visualization, sequencing skills, and the teaching tasks associated with their use in the classroom	The use of drone programming might support the students' sequencing skills and spatial visualization. Major improvements in spatial visualization were recorded. Students were motivated to participate in learning activities
Fokides et al. [25]	*n* = 40, 5th grade students	Primary school	Learn math, geography, and physics	In the drones group the students outperformed students in the comparison group only in mathematics. Highly positive attitude over the use of drones in the educational process
Palaigeorgiou et al. [26]	*n* = 41 elementary school students	Elementary education department	Explore field trips using VR and drones	Students reported that drone-based virtual field trips (VFTs) provided a fun and engaging method of learning, while also offering several advantages over actual field trips, such as more detailed views at higher altitudes and a more general view of the area being examined
Ng and Cheng [30]	*n* = 10 Pre-service teachers	Teacher training institute	Readiness and training needs regarding using drone technology in STEM education	Despite the capabilities of the subjects to show competence and knowledge about this technology they needed to increase their knowledge to increase the effects and benefits to the learners
Lee et al. [31]	*n* = 90 4th grade students	After-school soccer classes	If Drone-based video feedback could enhance primary school students' contentment of soccer	The group receiving drone feedback experienced greater levels of physical, educational, and psychological satisfaction than those receiving oral or mobile feedback.
Isingizwe et al. [33]	*n* = 11 middle school students	Summer youth camp	Explore attitudes and concerns toward construction	Students across all majors positively evaluated various aspects of using drones and virtual reality in their education
Yepes et al. [34]	*n* = 30 high school students	Computer lab	Use of drone-based platforms for Educational process in STEM	Results found a significant relationship between the use of technology packages provided in the educational process and students' ability to learn meaningfully in STEM fields.
Johal et al. [35]	*n* = 20 university students and graduates	Online platforms Zoom and Miro	Establish social connections among students helping them engage more and assisting the educational process	Highlighted several implications considering their use in the classroom

3.3. RQ2. Types of Drones Used

Several researchers did not provide specific information about the drones they used in their studies. More specifically, in the study conducted by Fokides et al. [25], the type of drone selected to run the experimental process was not specified and no specific information was provided about the design or brand used, but the researchers took into consideration several factors to determine the final choice. Some of them referred to low-cost, high-definition cameras, small sizes for indoor and outdoor usage, ease of use, and safety. Also, in the study by Palaigeorgiou et al. [26], there was a lack of information about the drone that was used and its particular characteristics. Furthermore, in Ng and Cheng's [30] study as well there was no reference to the specific type or brand of drone that they used to run their experiment, so the authors did not provide us with enough information about either the size or the weight of the drone that was used.

In contrast, Chou [12] in his research referred specifically to the type of drone he used. It was a lightweight type of drone called Mambo by Parrot Co., Ltd., (Paris, France) which was operated by a virtual remote control in the app or by using a programming language.

Lee et al. [31] provided us with detailed information about the specific type and characteristics of the drone they used in their experiment. More accurately, the type they used is called Phantom 4 Pro by SZ DJI Technology Co., Ltd., (Shenzhen, China) weighing 1.3 kg and having a maximum flight time of 27 min and a flight distance of 7 km. The video resolution capabilities state that the camera can capture in H.264 4K/60 fps, H.265 4K/30 fps MP4/MOV (MPEG-4 AVC/H.264, HEVC/H.265).

Voštinár [32] in his investigation used four different types of drones to address his research questions. Analytic detail was provided by the author about the specific details of the different types of drones that were used. In detail, an Airblockdrone by Makeblock (Shenzhen, China), LiteBee wing by Makerfire Technology Co., Ltd. (Shenzhen, China), Ryze tech-tello by SZ DJI Technology Co., Ltd. (Shenzhen, China), and Elecfreaks micro: bit dron: bit kit (Shenzhen, China) were analyzed in detail, providing information about their characteristics, use, and advantages and disadvantages. According to the author's findings, the participants of this research favored the Ryze Tello most because of its size and speed; it was also mentioned that it had the best camera. Yepes et al. [34] likewise used a Ryze Tello for their experimental study. They gave details about additional items that were purchased, such as four additional batteries, an additional set of propellers, a charger for three batteries simultaneously, a PGY-Tech protective cage, a set of propeller guards, and a landing pad drone. Ryze tech-tello was also found to be accessible and simple to use in the research established by Isingizwe et al. [33]. Their research explored attitudes toward and concerns about construction among 11 middle school students enrolled in a summer youth camp at Michigan Technological University (Figure 3). Similar findings were also reported in Lu et al. [29] about their use (Figure 5). Table 3 displays the findings about the type of drones used.

Table 3. Drones used for research.

Studies	Drones
Chou [12]	Parrot Mambo
Fokides et al. [25]	Non-specified
Palaigeorgiou et al. [26]	Non-specified
Lu et al. [29]	Ryze tech-Tello, Sky Viper e 1700, and Parrot Mambo
Ng and Cheng [30]	Non-specified
Lee et al. [31]	Phantom 4 pro
Voštinár [32]	Airblock drone, LiteBee wing, Ryze tech-Tello, and Elecfreaks micro: bit dron
Isingizwe et al. [33], Yepes et al. [34]	Ryze tech-Tello

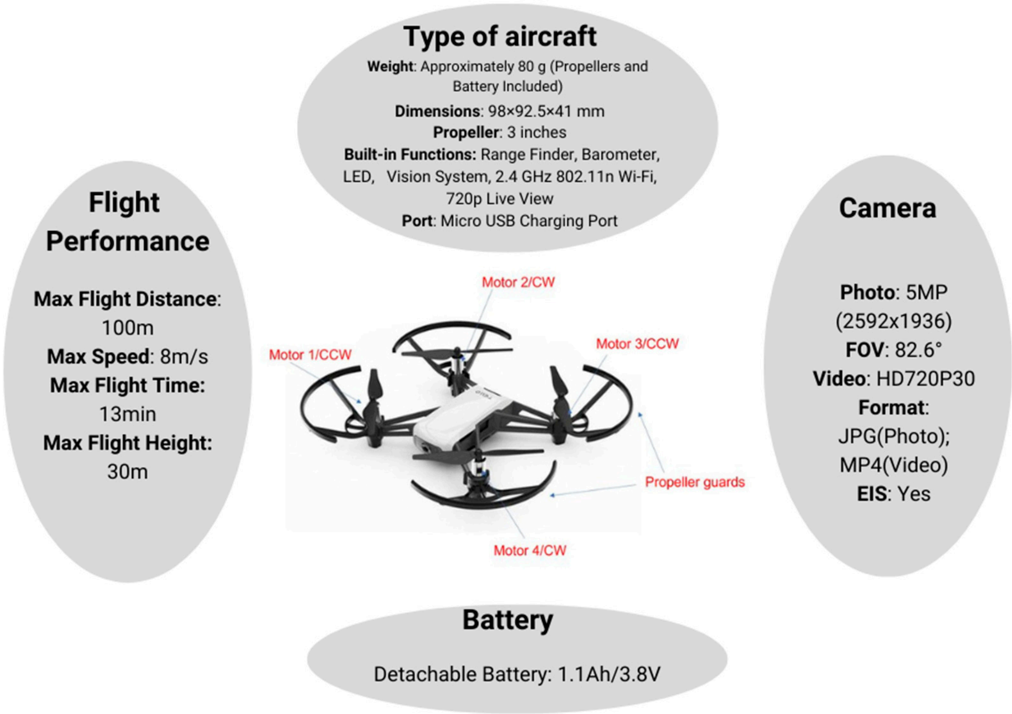

Figure 5. Ryze tech-Tello drone motor components and specifications [36,37].

3.4. RQ3. Teachers' and Students' Perceptions about the Application of Drones

Until now, there has been very limited evidence on the subject of teachers' and students' perceptions of the use of drones. More specifically, Sivenas and Koutromanos [27] examined the perceptions of pre-service (n = 80) and in-service teachers (n = 101) regarding the use of drones in teaching. Results indicated that pre-service and in-service teachers demonstrated positive attitudes, intentions, and behavioral beliefs toward the use of drones in teaching. The results that arose from the beliefs of teachers also implied that some students' skills and subjects would improve by using drones in the classroom. The same authors also performed another study using a research design that explored the perception of (n = 60) in-service teachers about the use of mobile apps in the use of drones. The results regarding the perceived usefulness showed that teachers believed the use of drones through mobile applications would be useful to improve their students' learning and would help students develop their skills [28].

Teachers surveyed in the Lu et al. [29] research revealed (through a questionnaire) a positive attitude toward the impact and effectiveness of teaching using virtual reality and drones, but also revealed a desire to improve the methods used, develop infrastructure, and increase the teachers' readiness for the use of virtual reality and drones in the educational process. This need for educators to be appropriately prepared was also observed in Ng et al.'s [30] research, which despite the positive attitudes presented toward drones, supported the statement that teachers had to improve their pedagogical knowledge, subject content knowledge, and technological content knowledge about drones. Table 4 summarizes the findings on teachers' perceptions of drones.

According to the perception of the students who used drones for the educational process, the findings indicate positive effects. In detail, the participants of the Fokides et al. [25] study responses positively characterized the drones as "fun, and a great experience", "something new, different from normal lessons", "like a game, but we also learned", "Interesting, wonderful, amazing, fun!". Similar findings were implied in Choo's research [12], with all the participants demonstrating a strong drive for learning.

Table 4. Teachers' perception of drones' use.

Studies	Participants/Academic Status	Method	Perception
Sivenas and Koutromanos [27]	*n* = 80 pre-service teachers, *n* = 101 in-service teachers	Via online questionnaire using variables and questions adapted from the Theory of Planned Behavior	Pre-service and in-service teachers demonstrated positive attitudes, intentions, and behavioral beliefs toward the use of drones in teaching
Sivenas and Koutromanos [28]	*n* = 60, in-service	Via an online questionnaire using open-ended questions adapted from the Technology Acceptance Model, namely perceived ease of use, perceived usefulness, and facilitating conditions	Teachers believed the use of drones through mobile applications, would be useful for their students' learning and would help students develop their skills
Lu et al. [29]	*n* = 258 university teachers	Via Likert scale questionnaire	Positive attitude toward the impact and effectiveness of teaching using virtual reality and drones but revealed a desire to improve the methods used, develop infrastructure, and increase their readiness for the use of virtual reality and drones in the educational process.
Ng and Cheng [30]	*n* = 10 Pre-service teachers	Qualitative method, case study	Positive attitude but needed to increase their knowledge to increase the effects and benefits to the learners.

The results of the study by Lee et al. [31], which measured the educational satisfaction of the participants, presented positive effects, and were characterized by the biggest difference in their analyses, highlighting that the effect on the group that received feedback including the use of drones was higher than on the traditional oral feedback group.

Voštinár [32] used four types of drones to teach programming as part of an extracurricular computer science activity to increase the learners' interest. The results of this study indicated that the use of drones increased their interest.

In an application of drone use similar to that found in Palaigeorgiou et al. [26], Lu et al. [29] intended to explore the impact of using drones and virtual reality on students' educational learning patterns in the post-pandemic period. The participants consisted of fourth-year students studying in various specialties including geography and ecology (n = 119), engineering and, robotics (n = 135), architecture and urban planning (n = 120), agriculture, and agronomy (n = 118), information technology (computer science) (n = 139), journalism (n = 117), and teachers (n = 258) with more than 5 years of experience. Next, students were surveyed using a questionnaire tailored to explore their attitudes toward virtual reality technology and drones for learning. Students across all majors positively evaluated various aspects of using drones and virtual reality in their education (Table 5).

3.5. RQ4. Studies Limitations

Regarding the limitations of the included studies, several elements have been identified due to the sample sizes, design methodology, lack of length of the effects, and lack of the use of drones in the actual context of school. More specifically, a common phenomenon that was observed in several of the included studies was the fact that authors did not address or identify the limitations of their research [26,30,32]. Another issue that was detected referred to the lack of the type and the specifics of the drones used to gather data from the participants [25,26,30]. The most common limitation among the studies was the small sample sizes, found in most of them [12,25,27,30,32,34]. Other limitations recorded referred to the lack of representativity of the collection sample [25], no follow-up, non-gender representativity [31], experiments not carried out in the actual setting or with the actual use of drones [33,34], and online questionnaires used while gathering data for teachers' perceptions [27,28]. Table 6 displays the limitations of the studies.

Table 5. Students' perception of drone use.

Studies	Participants/Academic Status	Method	Perception
Choo [12]	n = 10, 3rd grade Students	Design-based research method and a mixed method using qualitative triangulation to analyze class observation, work and interviews	All the participants demonstrated a strong drive for learning.
Fokides et al. [25]	n = 40, 5th grade students	Via means of evaluation sheets and a questionnaire	Highly positive, outperforming students in math in the comparison group
Lu et al. [29]	n = 748 4th year university students	Via questionnaire	Students across all majors positively evaluated various aspects of using drones and virtual reality in their education
Lee et al. [31]	n = 90 4th grade students	Via questionnaire 23 items tested	Participants presented higher positive effects on educational satisfaction than the comparison group
Voštinár [32]	n = 24 primary school children	Via questionnaire of 11 questions	The use of drones increased their interest of the participants

Table 6. Studies limitations.

Studies	Limitations
Chou [12]	No comparison group was identified, small sample size
Fokides et al. [25]	Sample size, not representative (gathered from one city), time restrictions, use of drones lacked educational interest and designed for amateurs
Palaigeorgiou et al. [26]	Not identified by the authors
Sivenas and Koutromanos [27]	Data collected from online questionnaires
Sivenas and Koutromanos [28]	Data collected from online questionnaires
Lu et al. [29]	Not identified by the authors
Ng and Cheng [30]	Not identified by the authors
Lee et al. [31]	Study conducted only on boys, brief study exam (4 lessons), no follow up, examined only class satisfaction, only qualitative data examined and only soccer, not other sports
Voštinár [32]	Not identified by the author
Isingizwe et al. [33]	Small sample size, no diversity to sample, limited exposure time, lack of real drone exposure, not in real-world situation
Yepes et al. [34]	Not performed in a school setting, sample size, gender comparison
Johal et al. [35]	Some of the students had teaching experience

3.6. RQ5. Educational Methods Applied

Putting it into perspective, most of the included studies used a variety of learning models to actively engage the learner in the whole process. The most common finding was that most of the studies used a motivational type model of learning to encourage learners to become involved. More specifically, Choo [12] applied a three-stage learning progression model for the students in his experimental process related to copying programming examples for practice reasons, modifying these examples, adding more of their own, and finally creating their programming design. Fokides et al. [25] based their work on Driver & Oldham's model [38], encompassing active learning and collaboration as the core of their program. They also applied the Predict-Observe-Explain model [39] and the Conceptual Change Model [40]. They summarized using a five-stages teaching perspective, including orientation of the students for motivational purposes, elicitation evaluating the students' previous concepts and knowledge, restructuring for brainstorming and new ideas formations with teachers and peers, and application for showcasing and testing their newly learned materials. Lu et al. [29] used principles based on the individualized aspect of learning, supporting that every individual learns in different ways, giving emphasis to communication and collaboration. Ng et al. [30] applied technological pedagogical content knowledge [41] to evaluate teachers' readiness for the use of drones. In their experimental process, they emphasized three main categories involving: (1) DIY drone STEM education on distinguishing, understanding, and identifying several aspects of drones including the components, the aerodynamics, and the flightpath. (2) Using programmable drones in STEM, teaching students how to identify the characteristics, demonstrate, and understand iteration in programming drones. (3) Using aerial photography and videography to teach students how to calculate the parameters of the selected area and perimeter (a real-world application of mathematics), and use drone control to foster growth of the students' know-how about technological tools. Lee et al. [31] used the method of visual feedback to support their learners in performing better in football, educating them about body movement and task performance. Voštinár [32] wanted to motivate the learners and applied the core principle of motivational theories to the learners. Isingizwe et al. [33] constructed a concept applying existing literature about STEM, based on understanding drone concepts, the use of drones for task completion, and reflection on the knowledge acquired. Through their workshops, they applied principles similar to those observed by Ng et al. [30] to introduce the subjects to programming, explore their previous knowledge, apply the selected program (Scratch), and lastly refine the trigonometric functions (Sine and Cosine) of the drones (applying new knowledge). Yepes et al. [34] performed their experiment using the revised Bloom's taxonomy [42] and the principles of Ausubel [43] for effective and meaningful learning. Johal et al. [35] took into consideration a learner-centered design similar to that used by Isingizwe et al. [33], employing multiple phases to support their learning experience.

3.7. RQ6. Framework for Integrating Drone Technology into Education

From the results drawn by this research, many have tried to highlight the importance of choosing the right type of drone to utilize most of their abilities. The specificity of the drone selection for producing the needed outcomes is needed. Depending on the environment of the use, the nature of the task, and the age of the learners the proper selection is needed to enhance learning outcomes [25,31,33–35]. Compact drones have been highly preferable in small places due to their compact size [12,32,35,36], larger drones offer longer battery life, and drones that have long range seem to fit tasks outside of the classroom [26,31,33]. Another aspect that improves the outcomes seems to be the motion capture camera of the drones. Highly capacity cameras capture more in-depth and detailed motion and landscapes [31,33]. Lastly, the knowledge of the educators as well as the learners is fundamental to securing the transfer of knowledge and the safety that follows the whole process. We have observed on several occasions that educators seem to lack in several cognitive aspects related to drone usage. They need to be highly trained to produce the necessary results [29,30]. From the findings, we suggest emphasizing four components that enable educators to introduce drones to their education process: Knowledge of the educators and learners, selection of the type of drone, safety, and reflection on the produced outcomes. Knowledge of the educators and the learners concerns the educators' know-how about the use and utilities of drones and furthermore the appropriate methods of introducing and teaching the learners to create a suitable human–drone interface. Regarding the selection of the appropriate learning models, following the selected articles we observe that there is a tendency to use motivational models as well as individualized and active learning, collaboration, and communication. Selection of the type of drone refers to choosing the appropriate model according to the environment that would be used and the task performed. Safety concerns all the factors that should be prepared and analyzed before and during the use of drones to eliminate injury or destruction of property. Finally, reflection from educators and learners would create perspective and prospects for better future outcomes, improving understanding and the validity of the process (Figure 6).

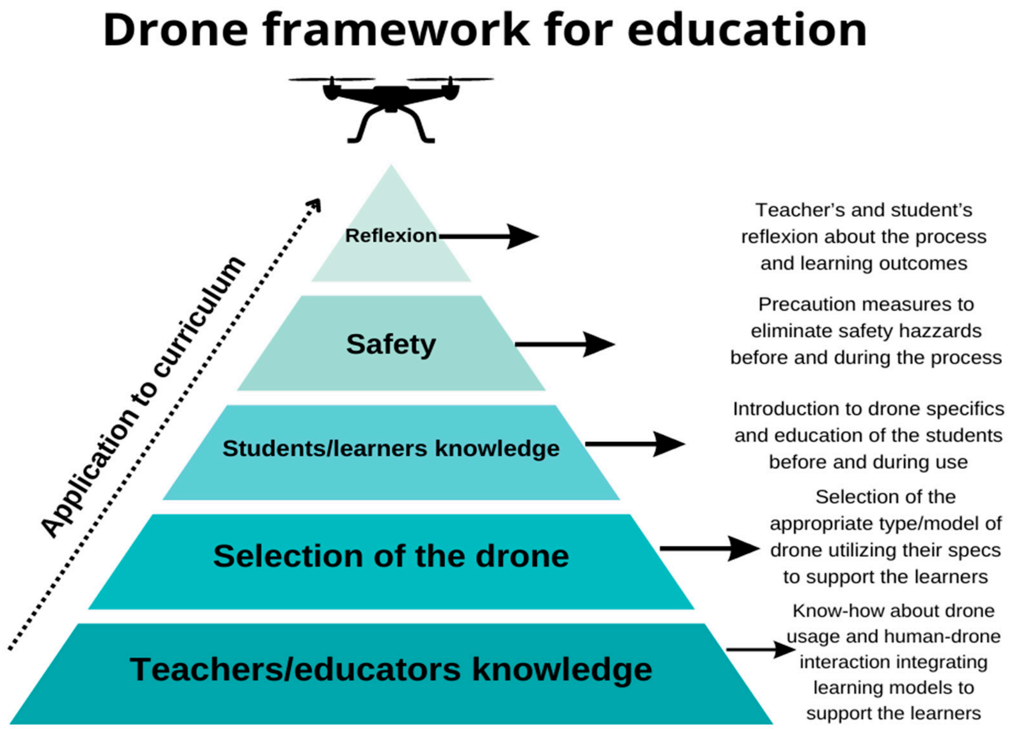

Figure 6. Drone framework for education.

4. Discussion

The use of drones offers an engrossing future for students and teachers. Integrating drones into the educational process has become more feasible since the major price drop of 2015, making drones accessible to use in many facilities [24]. However, despite all the positive attributes of drones, there are many factors we need to consider before we are ready to implement them in the process. An important issue is the safety aspect of their use. More specifically, if not used properly, drones can cause injuries to the users' eyes and skin through contact with propeller blades, to property of the institution or personal belongings, and also fire or explosion from the lithium in batteries [17]. Another issue we need to consider is the need for educators to be highly trained to eliminate possible negative outcomes of the given educational experience of the learners.

Reviewing the literature, we discovered many encouraging effects and applications for the use of them. Most of the studies used drones as part of STEM education, and others applied them in school environments to enhance the study process in class and physical education and help students develop spatial visualization, sequencing skills, and social interaction skills [12,31,34,35]. These results come in parity with the disciplines and skillsets we discussed before, utilizing the specification of the drones related to remote sensing, engineering, mathematics, and physics as well as geography.

Furthermore, we discovered that drones can be utilized in combination with VR in two studies, enhancing the student's attitude and engagement in the learning process [26,29].

Regarding the type of drones, the researchers in most studies unraveled that there is a preference for low-cost and lightweight technology types. The one that has been most frequently used and making an impression among the participants is the Ryze Tello model [29,33,34].

Additionally, we found limited studies investigating the teachers' and students' perceptions of drone use. Most of the studies we did find reported very positive attitudes due to the excitement, engagement, and positive effects on performance of the demanded educational tasks. Teachers found them useful and helpful for their students but expressed the need to develop their skills to be capable and ready for the proper application of drones in the process of education. Lastly, several factors were identified related to the complexity of using drones including noise, fear, lack of social cues, and the teacher's cognitive management load [25,27,29,32,35].

Several limitations were identified according to the selected research for analysis. The main findings concern the presence of small sizes, the lack of population diversity, short duration, and the absence of a detailed description of the selected drone in some of the cases. Finally, we came to the conclusion that there is an absence of a unified framework for reference regarding the use of drones for educational purposes.

Summarizing our findings, our framework model aligns with previous educational framework models for drone use such as SOAR [44] and the Dronagogy [45]. To address the safety hazards discussed in Joyce et al. [17], we provided an updated version of the model, adding more emphasis on teacher/educator knowledge as the basis of our pyramid, as it was observed that there was a lack of fundamental knowledge. We observed the need of the educators to improve their knowledge to be able to provide the most for the learners [17,29,30]. We also added two new concepts referring to the specifications of the drone, as different specs have different implications for the drone's use. We also include the reflection step to providing teachers/educators and learners feedback, feedforward, and new perspectives on the educational implementation of drones for better learning outcomes and future research.

This review adds valuable insights by highlighting the positive attributes of drones through analysis and by identifying the limitations of the studies for future research, providing a framework for their use in the educational process. Drones can be considered a valuable asset for motivating students, providing a whole new experience to the learner and offering a new perspective on objective learning.

5. Conclusions

To conclude, this literature review summarizes the findings of previous research focused on the application of drones for educational purposes. Despite the many uses of drones as emerging technological artifacts, embedding them in the educational process requires many attributes related to the teachers/educators as well as the users/students' knowledge and point of view.

Although many of the included studies yielded positive results, it is still difficult to completely integrate drones into the educational process. Many limitations were identified in most of the studies, including small sample sizes, limited exposure time, and no population diversity. For future purposes, it is suggested that larger sample sizes, gender representativity, longer duration interventions, and the inclusion of detailed descriptions of the drone selection and specifications and tasks, would allow educators to integrate drones into the educational process and take full advantage of their utilities.

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