Annales Universitatis Paedagogicae Cracoviensis 424

Studia ad Didacticam Scientiarum Socialium Pertinentia 15 ▪ 2025
ISSN 2083-7276
DOI 10.24917/20837276.15.10

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Implementing drones in mathematics teaching

Introduction

The following questions are investigated in the paper:

- General research question: how does the integration of drones influence the teaching-learning process of mathematics, especially in terms of understanding abstract concepts, developing skills and motivation of students?
- Specific research questions:
    1. How does the use of drones contribute to the understanding of spatial, geometric, and trigonometric concepts by students?
    2. To what extent does the use of drones develop problem-solving skills in mathematics lessons?
    3. How do collaborative activities based on drones influence the degree of involvement and motivation of students in learning mathematics?
    4. What technological and mathematical skills can be developed by using drone programming in educational activities?
    5. What are the perceptions of students and teachers regarding the integration of drones in teaching mathematics?

6. What methodological, logistical and legal difficulties may arise in implementing teaching activities with drones in mathematics lessons?
7. How can the didactic design of mathematics lessons be optimised by integrating drones to achieve STEAM curriculum objectives?

The proposed study has an empirical-conceptual character, that is:

- Conceptual, because it theoretically substantiates the idea of integrating drones into mathematics teaching through the analysis of specialised literature, pedagogical and technological arguments;
- Empirical, because it involves the practical testing of teaching scenarios, data collection, performance evaluation and analysis of participants' perceptions.

The implementation of drones in mathematics education can bring multiple benefits, significantly improving the educational process. Here are some essential reasons why it is important to use drones in mathematics learning:

- Concrete visualisation of abstract concepts: Drones enable students to visualise complex mathematical concepts, such as 3D geometry, trigonometry, and motion on a plane, in a practical, interactive way. For example, students can observe the trajectory of a moving object in real time and apply mathematical formulas to calculate distances, angles, and speeds. This helps to gain a deep understanding of mathematical theory through experiments and direct observations.
- Improving problem-solving skills: Using drones in educational activities stimulates critical thinking and problem-solving skills. Students are challenged to solve math problems by applying theory to real-world situations. For example, they can calculate flight paths, determine launch angles, or adjust flight parameters to better understand mathematical principles.
- Promoting active and collaborative learning: Drones can facilitate active learning, engaging students in a more dynamic and hands-on learning process. Students can work in teams to design routes, analyse drone-collected data, or solve complex problems, thereby developing collaboration and communication skills. This type of learning is more engaging and can increase motivation and interest in mathematics.
- Applying theory to real-world contexts: By using drones, students can experience how mathematical principles are applied in real life. For example, in calculating a drone flight, students can learn about speed, distance, and time by applying mathematical formulas to concrete, not just theoretical, situations. This allows them to understand the relevance of mathematics in the real world.
- Developing technological skills: Using drones helps students develop important technological skills, especially in the STEAM (Science,

Technology, Engineering, Arts and Mathematics) field. In a digital age, technological skills are essential, and drones offer a unique opportunity to learn how to use technology to solve mathematical problems and experience innovative learning processes.

- Motivating students: Drones are an attractive and engaging technology that can more easily attract students to mathematics learning. By integrating a playful and innovative element into mathematics lessons, students are more motivated to actively participate and explore the topics in a more enjoyable and interesting way.
- Improving spatial-temporal understanding: Drones are ideal for developing spatial and motion understanding skills. Students can apply geometry and trigonometry concepts to calculate height, distance, angles and trajectories. These skills are essential in fields such as engineering, architecture, and applied sciences.

A brief analysis of the specialised literature on the use of technologies in education reveals that it can be approached from several perspectives:

a. Technology in Education: Transforming Learning. Over the past few decades, technology has had a significant impact on education, transforming the way we teach and learn. According to studies, educational technologies can support more interactive and personalised learning, providing students with opportunities to learn through simulations, educational games, and digital resources (Diana, 2012).
b. Emerging Technologies in Education. In recent years, the use of emerging technologies, such as augmented reality (AR), virtual reality (VR), and drones, has been explored to support active and experiential learning. Studies by Bower et al. (2017) show that augmented reality can help students understand abstract and complex concepts, and interactive technologies can support collaborative and exploratory learning.
c. Technology and Mathematics Learning. In the field of mathematics, technology, especially educational software and online platforms, has been used to improve the understanding of mathematical concepts and skills. Alibali et al. (2000, p. 593–613) emphasise that digital tools, such as simulations and interactive applications, allow students to visualise and apply mathematical theory in a concrete way, providing more engaging and effective learning.
d. Replacing traditional methods with technologies. Various studies, including those conducted by Hattie (2009, p. 105–106), have analysed the impact of technology on student performance. Although technology does not completely replace traditional teaching methods, it can add an extra layer of interactivity and personalisation, adapting to students' individual needs and supporting active learning.

e. Use of drones in education. Drones are an emerging technology gaining popularity in education, with applications across various fields, including mathematics, science, technology, art, and engineering (STEAM). The scientific community argues that drones are a powerful educational tool for stimulating students' interest in technical fields and for providing hands-on learning experiences, especially in mathematics, through the concrete application of mathematical theory, such as path planning and 3D geometry.

The use of educational technologies is also not without challenges. For example, Ertmer and Ottenbreit-Leftwich (2010, p. 255–284) and Matt (2017) point out that while technology can enhance learning, its effective implementation in classrooms depends on factors such as continuous teacher training, technological accessibility and institutional support.

Description of the approach used

The approach used in the research "Implementation of drones in mathematics teaching" should include several key aspects related to the technology used, the didactic activities and the educational resources involved. Here we need to consider the following:

a. Types of drones used:

In the proposed research, several types of drones can be used, depending on the specific educational goals. Examples of drones that could be included are:

- Drones with simple control (quadcopters): These drones are the most common and easiest to handle, making them ideal for didactic activities that involve feeling and understanding movement in space. These drones can be used to demonstrate concepts such as trajectories, flight angles and distances.
- Drones equipped with cameras (drones with HD cameras): Drones with video cameras are excellent for recording flights and creating visual materials for analysing 3D geometry and trajectories. They can help visualise movements in a three-dimensional space and can be used in activities that study angles and distances.
- Drones with integrated GPS: These drones allow for more precise control of trajectories and positioning in space. They are useful for calculating distances, angles, and altitudes, making them a valuable resource for more complex mathematical applications (Elliot, 2016).

b. Educational software used:

- Drone programming software: Some research may involve using educational software that allows drones to be programmed to perform

specific movements. An example is Tynker or Scratch, visual programming platforms that allow students to write code for drones, applying mathematical concepts such as algorithms and coordinates.
- Trajectory simulation software: Simulation platforms, such as GeoGebra or Wolfram Mathematica, can be used to visualise drone movements in a virtual environment, allowing students to manipulate parameters such as flight angles or drone speed. These platforms can be used to analyse movement geometry and create graphs and diagrams of trajectories.
- Drone control applications: Most drones can be controlled through mobile applications, such as DJI GO or Litchi, which allow programming and controlling the drone, and the data obtained (such as speed, altitude, distance) can later be analysed using mathematical formulas.

c. Didactic activities carried out:

The didactic activities included in the research may vary depending on the mathematical concepts they target and the educational objectives. Examples of didactic activities could include:
- Calculating trajectories and distances: Students can use drones to fly predefined trajectories, measure distances and angles, and then calculate these values using mathematical formulas, such as the distance formula or the law of cosines. This activity helps students apply concepts of geometry and trigonometry.
- Studying motion in three-dimensional space: Drones can be used to demonstrate the principles of motion in 3D, and students can apply mathematical concepts to calculate the drone's coordinates as it moves through 3D space. This activity helps to consolidate the understanding of 3D coordinates and spatial geometry.
- Flight Simulation and Optimisation: Students can use drones to optimise flight paths, calculating the most efficient launch angles and trajectories using mathematical concepts such as angles and velocity. This allows students to apply mathematical theory to improve drone performance in real time.
- Group Projects: Collaborative activities are essential for developing teamwork skills. Students can work together to design flight paths or solve complex mathematical problems, combining their knowledge of math and technology. This can include using drones to collect motion data and analysing it in groups.

d. Student Performance Assessment:
- Practical Testing: After each teaching activity, students can be assessed on their practical performance, including the accuracy of measurements and the correct application of mathematical formulas. This may

include assessing the correctness of distance, trajectory, and angle calculations.

- Assessment based on group projects: Group projects, which involve both mathematical and technological aspects, can be used to assess students' ability to collaborate and apply mathematical concepts in a practical context.

e. eedback and improvements to the method:

The research should also include a continuous feedback component, in which students and teachers can provide feedback on how the use of drones has influenced their understanding of mathematics and learning experience. This will help to improve the teaching approach and adjust the activities based on the responses obtained.

Thus, we must:

- define the target group (e.g. high school students, university students, etc.).
- identify the data collection tools and techniques (questionnaires, interviews, direct observations).
- We explain the procedure for implementing drones in mathematics teaching.

Results:

- Presentation of data obtained from the implementation (graphs, tables, statistical analyses).
- Comparison of student performance under traditional conditions vs. using drones.

Discussions:

- Interpretation of the results: What did the data show? What impact did drones have on mathematics learning?
- Comparison with previous studies in the field.
- Possible explanations for the successes or difficulties encountered.

Conclusions:

- Summary of the main findings.
- Implications of the research for mathematics education and the use of technology in schools.
- Recommendations for future research or for the practical implementation of drones.

Annexes (if applicable):

- Additional materials, such as questionnaires, additional graphics, sample lessons or teaching activities implemented with the help of drones.

Challenges and limitations encountered in implementing drones in education

Although the use of drones in education can bring significant benefits, there are several challenges and limitations that can arise when they are implemented in schools and universities (Popescu, 2012), *Editura John Wiley & Sons Publication*, 2010, Афанас, 2025, p. 74–77, Бригалда, 2025, p. 242–245). These challenges can manifest in financial, logistical, methodological, and even teacher-training terms. In the following, we will explore the difficulties and obstacles that can arise in the integration of drones into education.

a. Financial challenges. One of the biggest challenges in implementing drones in education is their cost and the financial resources required to purchase the equipment. Here are some important aspects:
   - High initial costs: Drones can be quite expensive, especially advanced models that are needed for educational applications. Even basic drones, which can be used for educational purposes, require significant investment to purchase.
   - Maintenance and repair costs: Drones require regular maintenance, and spare parts can be expensive. In addition, because drones are susceptible to accidents, repairs can incur additional costs.
   - Limited financial resources: Many schools and educational institutions have limited budgets for the purchase of advanced technology. These financial resources can be more difficult to justify to educational decision-makers, especially given the funds needed for other fundamental educational needs, such as teaching staff or infrastructure.
   - Training costs: In addition to purchasing drones, it is also necessary to invest in training teachers, which adds cost to the implementation process.

b. Logistical challenges. Despite the great interest in implementing drones, their implementation in education can encounter significant logistical difficulties:
   - Space and appropriate learning environment: Drones require an open and safe space to fly. In many schools or universities, this type of space is not available, especially in urban environments where there are no sufficiently large courtyards or open fields. Even with outdoor space, adverse weather conditions (strong winds, rain, storms) can limit drone use.
   - Legal and regulatory restrictions: In many countries and regions, the operation of drones, including for educational purposes, is regulated by a strict legislative framework designed to ensure air safety, privacy protection, and the security of critical infrastructure. These regulations are issued by national civil aviation authorities (such as EASA in

the European Union, FAA in the United States, or AAC in the Republic of Moldova) and may be supplemented by local or institutional rules.

In the context of schools and universities, the use of drones is often subject to obtaining operating licenses, registering devices, and flight authorisations, depending on the geographical area and purpose of the activity. Institutions that do not hold these approvals risk legal sanctions or suspension of flight activities.

Among the most common restrictions imposed are:

- Altitude limitations: recreational or educational flights are usually not allowed to exceed a height of 120 meters above the ground, to avoid conflicts with civil air traffic.
- Exclusion of some geographical areas: flying is prohibited or severely limited in the vicinity of airports, military bases, dense urban areas or critical infrastructures (e.g. power grids, power plants, hospitals).
- Compliance with the "no-fly zones" regime: many countries have official digital maps with areas where drone flying is completely prohibited or requires special approval.
- Equipping with safety and geolocation systems: drones must be equipped with collision-avoidance functionality, automatic altitude limitation, and "geofencing" systems that prevent access to restricted areas.
- Rules on surveillance and data collection: video recording or data collection via sensors must comply with legislation on the protection of personal data (e.g., GDPR), especially if the flight takes place in areas where people are present.

There is also an important distinction between recreational flights and professional or educational flights, the latter requiring, in many cases, trained and certified operators, as well as a documented risk assessment (e.g. Specific Operations Risk Assessment – SORA, in the European context).

Thus, integrating drones into the educational process involves not only an innovative pedagogical approach but also a significant legal responsibility. Educational institutions must collaborate with the competent authorities to conduct flight activities in accordance with the legislation in force, thereby avoiding potential legal, technical, or safety risks.

- Equipment management: In the case of a large number of students or simultaneous courses, managing multiple drones, chargers, batteries, and other accessories can become a logistical challenge. This can involve more resources and the organisation of an efficient system to track and maintain the equipment in good working order.

c. Methodological challenges. Integrating drones into the educational process does not only mean purchasing modern equipment, but also implies a profound transformation of the didactic approach. For these technological tools to become truly pedagogically relevant, a rethinking of classroom methodological strategies is necessary. This transition involves a series of significant challenges:

– Lack of specific training for teachers: One of the most important obstacles is the lack of professional training for teachers in the field of emerging technologies, especially drones. Most teachers have not been exposed to modules dedicated to UAV (Unmanned Aerial Vehicles) technology during their pre-service or in-service training. The skills needed for effective integration include:
  · knowledge of the basic technical functioning of drones;
  · understanding of educational applications (e.g. mapping, applied physics, programming, mathematical measurements);
  · adaptive curriculum design skills, which allow the incorporation of technology in achieving educational objectives.

Educational policies must provide for multidisciplinary training programs that combine technical training with the development of pedagogical skills for active and contextualised digital learning.

– Rigidity of traditional teaching approaches: In many educational systems, teaching is still based on teacher-centred, transmissive methods, where the emphasis is on memorisation and reproduction of information. Interactive technologies, such as drones, SOPT a constructivist approach to learning, which promotes learning through discovery, problem-solving, collaboration and interdisciplinary exploration.

The integration of drones opens the door to Project-Based Learning, in which students work in teams to solve real problems (e.g., measuring the distance between two points using a drone), combining concepts from mathematics, science, technology, and even geography or civics.

This change requires a flexible pedagogical mindset open to innovation, which can be a challenge for teachers trained in traditional paradigms.

– Lack of standardised and contextualised teaching content: Another major obstacle is the absence of specialised teaching materials and pedagogical guides to support the integration of drones into regular lessons. In the absence of official programs and resources, teachers must create their own materials from scratch, which requires time, effort, and advanced interdisciplinary skills.

There is a need for:
  · Adapted lesson plans that include drones as a means of teaching, not just as an extracurricular activity.
  · Open Educational Resources (OER) developed collaboratively by educational communities of practice.
  · Digital platforms for sharing good practices, where teachers can access and contribute to validated educational scenarios.

In the absence of a coherent framework for curricular integration, there is a risk that drones will be used superficially, as a "show piece", without real impact on learning.

d. Technical and Security Challenges. The use of drones in education also comes with various technical and security challenges, including:
   - Technical Issues: Drones are sensitive equipment and can encounter technical issues related to batteries, control systems, GPS or software. These failures can disrupt lessons and require additional time to diagnose and repair the equipment.
   - Student and equipment safety: The use of drones in schools poses risks related to the safety of students and staff. For example, drones can hit people or objects, and their use in an educational environment must be strictly monitored to prevent accidents. In addition, the equipment must be protected (drones can be easily damaged, especially with frequent use and students' lack of experience).
   - Privacy and data protection: Drones can be equipped with cameras or sensors that collect visual and auditory data. It is important to comply with privacy regulations and ensure that collected data is not misused or violates students' rights.

e. Challenges of acceptance by the educational community. The adoption of new technologies in education, such as drones, extends beyond technical and logistical aspects. One of the most subtle but essential obstacles is the acceptance of these technologies by the entire educational community – teachers, students, parents, and decision-makers. Without an organisational culture conducive to innovation, even the most promising tools can fail to be implemented.
   - Resistance to change between perception and institutional culture. One of the main challenges is the reluctance to change, a well-documented phenomenon in educational theory and organisational management. Teachers, especially those with long experience in the system, may perceive the introduction of drones as a threat to traditional teaching methods, rather than as a pedagogical opportunity.

   This resistance is based on:
     - professional insecurity related to lack of familiarity with the technology;
     - the perception that drones are not directly related to theoretical subjects, such as mathematics, and that they can "dilute" academic content;
     - time pressure and professional overload, which reduce the availability for continuous training;
     - lack of good practice models or examples of success at the local level.

Some parents may also perceive drone use as frivolous or even risky, especially if the educational objectives and benefits of this technology are not clearly communicated.

Countering these perceptions requires a well-structured communication and awareness strategy that involves the entire school community and highlights how drones can support active learning, critical thinking, collaboration and the applicability of theoretical knowledge to concrete situations.

- Student engagement and diversity of interests: While drone use may seem like an exciting initiative for most students, the level of interest and engagement varies significantly depending on age, gender, educational background and learning style. There is a risk that some students may perceive drone activities as too technical, too "playful" or outside their personal interests.

To mitigate these differences, it is essential that:

  - Drone activities are interdisciplinary and inclusive, connected to relevant contexts for all students (e.g. ecology, architecture, visual arts, geography).
  - Teachers use personalised learning methods that allow each student to contribute with diverse skills – not only technical, but also analytical, creative, or communication skills.
  - Student-centred learning scenarios are created that stimulate curiosity, intrinsic motivation and autonomy in learning.

- Education for innovation as a foundation for cultural change: In order for drones – and other emerging technologies – to be accepted and exploited sustainably, an educational paradigm shift is needed that supports the development of a culture of innovation. This requires:
  - visionary educational leadership that encourages experimentation and tolerance for failure;
  - continuous professional development of teachers, not only from a technical point of view, but also methodologically and psycho pedagogically;
  - active partnerships with parents and the local community, to increase trust in the value of technological education;
  - creating an open, collaborative and future-oriented educational ecosystem, in which technology is not an end in itself, but a means to the formation of key skills of the 21st century.

To facilitate the authentic transition from technological innovation to profound educational transformation, the integration of drones in the educational environment must not be seen as a simple act of technological acquisition or as a form of superficial modernisation. The real acceptance of this technology by the school community involves a deep, gradual and essentially human process, in which the technical dimensions are inseparably linked to the cultural, organisational and pedagogical ones.

As studies in the field of digital education and change management have demonstrated, technology itself does not transform the school. What generates authentic transformation is the way educational actors interact with technology, the meaning they attribute to it, and the system's capacity to integrate it coherently into the educational mission.

Acceptance must be a systemic process, not a one-off outcome, meaning that accepting the use of drones involves not just becoming familiar with a new type of equipment, but also reconfiguring deeply rooted beliefs and teaching practices. Teachers must view drones as tools that support active, applied learning, not as mere gadgets or sources of distraction. Parents must understand the added value these technologies bring to the development of transdisciplinary skills. Students, in turn, must be guided to go beyond playful enthusiasm and discover the real potential for learning, research, and exploration.

In this context, the acceptance of technology reflects the school's organisational culture – the degree to which it values innovation, supports continuous learning, and promotes collaboration among all actors involved.

For drones to become an educational tool with real impact, a systemic, strategic and human-centred approach is necessary. This should include:

- Active institutional support: involving school leadership in promoting a modern vision of education, creating clear internal policies on the use of technology and facilitating access to resources.
- Continuing professional development: developing training programs for teachers, not only in the use of drones, but also in the design of innovative, student-centred teaching activities.
- Transparent and collaborative communication: building an open dialogue with parents and the local community, explaining the educational benefits of using drones and eliminating fears about safety or irrelevance.
- Curriculum integration strategies: using drones not as isolated activities, but as integrated parts of the STEM curriculum, project-based learning (PBL) or digital and scientific skills training.

Drones must be privatised as a symbol of future-oriented education. In a society characterised by accelerating technological progress and the increasingly acute need for digital skills, drones can become more than just educational tools. Used meaningfully, they can symbolise a modern, dynamic school, connected to reality, that trains students who are active, curious, and prepared for the challenges of the real world.

Integrating drones into mathematics education adds a practical, interactive dimension to the learning process, making mathematics more accessible and engaging for students while developing essential skills for the future.

The literature highlights that technology has the potential to revolutionise education, especially in mathematics, by creating an interactive, personalised, and engaging learning environment. The use of emerging technologies such as drones can enhance the understanding and applicability of mathematics, making lessons more interesting and compelling. However, success depends on how technology is integrated into educational curricula and on the appropriate training of teachers.

Therefore, the success of integrating drones into education does not lie solely in their use, but in the educational system's ability to incorporate them in a sustainable and valuable way, contributing to redefining school as a space of innovation, collaboration, and authentic learning.

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Abstract

This paper explores the implementation of drones as an innovative teaching tool in mathematics teaching, within secondary and higher education. In the context of modern education, where technology plays an essential role in developing students' skills, drones offer an interactive method of active learning that can improve understanding abstract mathematical concepts by applying them in practical scenarios and dynamic visualisations. The research aimed to evaluate the impact of drone use on students' performance in mathematical activities involving geometry, trigonometry and data analysis.

This research highlights the potential of relevant technologies, such as drones, to transform the educational process, providing a hands-on, engaging and relevant approach for today's digitally-savvy youth. The study concludes that integrating drones into mathematics curricula can significantly enhance problem-solving skills and improve student academic performance. Finally, it is recommended to continue research and expand their use in other areas of STEAM education.

Keywords: drones, STEAM education, mathematics teaching, active learning, educational technologies

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