Comunicar, n. 80, v. XXXIII, 2025 | Media Education Research Journal | ISSN: 1134-3478; e-ISSN: 1988-3478
www.comunicarjournal.com

Dronics in Higher Education and Inclusive Education: Proposal For Educational Innovation from above

Dr. Miriam Martínez Muñoz*. The Universidad a Distancia de Madrid (UDIMA), Spain (miriam.martinez.mu@udima.es) (https://orcid.org/0000-0001-7240-6681)

ABSTRACT

Access to quality higher education remains a challenge, especially for students with physical, sensory or cognitive disabilities, and those in remote communities. Higher education institutions face the need to offer inclusive solutions, taking advantage of technology to eliminate barriers. The use of drones has the potential to transform higher education, removing barriers and promoting the participation of students with diverse needs. This innovation fosters a more inclusive, collaborative and technologically advanced learning model. Unmanned aerial vehicles (UAV) can offer many advantages for higher education and research, especially in fields that require remote sensing, aerial mapping, environmental monitoring or disaster response. For example, UAVs can allow students and researchers to collect high-resolution images, videos, and sensor data from different perspectives and locations, which can improve their spatial awareness, analytical skills, and scientific research. UAVs can also facilitate collaborative and interdisciplinary learning and research, as they can be used to share data and ideas across disciplines, institutions and regions. Additionally, UAVs can foster creativity and innovation as they can be used to design and test new solutions, prototypes and methods for various problems and scenarios. Introduce gamification and other active drone learning methodologies, where students solve challenges related to their area of study (for example, aerial tracking of "treasures" in geology or rescue simulations in civil engineering). This work proposes the use of drones as an educational innovation focused on inclusion, by offering tools that complement teaching and learning models in higher education through an interdisciplinary approach. Drones can be used to help improve orientation skills, motor skills, and even give students a better understanding of how the world around us works.

RESUMEN

El acceso a una educación superior de calidad sigue siendo un desafío, especialmente para estudiantes con discapacidades físicas, sensoriales o cognitivas, y aquellos en comunidades remotas. Las instituciones de educación superior se enfrentan a la necesidad de ofrecer soluciones inclusivas, aprovechando la tecnología para eliminar barreras. El uso de drones tiene el potencial de transformar la educación superior, eliminando barreras y promoviendo la participación de estudiantes con necesidades diversas. Esta innovación fomenta un modelo de aprendizaje más inclusivo, colaborativo y tecnológicamente avanzado. Los vehículos aéreos no tripulados (UAV) pueden ofrecer muchas ventajas para la educación superior y la investigación, especialmente en campos que requieren teledetección, mapeo aéreo, monitoreo ambiental o respuesta a desastres. Por ejemplo, los UAV pueden permitir a estudiantes e investigadores recopilar imágenes de alta resolución, videos y datos de sensores desde diferentes perspectivas y ubicaciones, lo que puede mejorar su percepción espacial, habilidades analíticas e investigación científica. Los UAV también pueden facilitar el aprendizaje y la investigación colaborativos e interdisciplinarios, ya que pueden usarse para compartir datos e ideas entre disciplinas, instituciones y regiones. Además, los UAV pueden fomentar la creatividad y la innovación, ya que pueden utilizarse para diseñar y probar nuevas soluciones, prototipos y métodos para diversos problemas y escenarios. Introducir la gamificación y otras metodologías activas de aprendizaje con drones, donde los estudiantes resuelvan retos relacionados con su área de estudio (por ejemplo, el seguimiento aéreo de "tesoros" en geología o simulaciones de rescate en ingeniería civil). Este trabajo propone el uso de drones como una innovación educativa centrada en la inclusión, al ofrecer herramientas que complementan los modelos de enseñanza y aprendizaje en la educación superior a través de un enfoque interdisciplinario. Los drones pueden utilizarse para ayudar a mejorar las habilidades de orientación, las habilidades motoras e incluso dar a los estudiantes una mejor comprensión de cómo funciona el mundo que nos rodea.

KEYWORDS

Education, UAV, Innovation, STEM, Technology.

Received: 2024-11-28 | Reviewed: 2025-02-25 | Accepted: 2025-04-02 | Online First: 2025-04-18 | Published: 2025-04-20
DOI: https://doi.org/10.5281/zenodo.15565903 | Pages: 75-82

1. Introduction

Every day it is more common to find the use of drones in fields such as entertainment, medicine, agriculture, and also education (Gómez-Bustamante & Martínez-Cogollo, 2018). Reflecting critically and seeking answers or solutions to questions and challenges are essential accents for today's education. The idea is that students work, get motivated and get involved around real and meaningful situations for them, actively participating, applying different perspectives and areas of knowledge, until reaching a solution that is expressed in a product. To do this, two modalities are linked: Project Based Learning (PBL) and STEM (Science, Technology, Engineering and Mathematics). PBL involves students creating a project in response to a challenging and authentic question, together. It challenges them to find new answers, investigating on their own, and reflecting with their peers from diverse perspectives, in a framework of collaborative work, communication, critical and creative thinking, among others. STEM education integrates different knowledge and disciplines of science, mathematics, technology, and engineering to solve problems in real contexts in environments such as school, the community, and work. The STEM context is particularly revealing of the importance of the use of these UAVs. In many countries there are experiences of use for teaching mathematics, geography, natural sciences, etc. (Voštinár, Horváthová, & Klimová, 2018), allowing classes to be more dynamic and participatory, providing more motivation to students. Classrooms, since two aspects are added that are very striking for students: the principle of activity and technology. These programs demonstrated that these technologies captivated students, while allowing them to learn abstract concepts in the STEM framework in an unconventional way (Martin-Hansen, 2018; Sullivan & Bers, 2018).

This reality is based on a double argument: on the one hand, the existence of new and sophisticated technologies, dazzling in a certain sense for everyone who uses them and de facto connected with these sciences (Jovanović et al., 2019). On the other hand, some experiences show that, if a part of the students has no interest in areas such as mathematics or physics, it is possible to find an alternative path by teaching them from reality, in a practical and participatory way (De Loof et al., 2021). In this sense, Garcia-Bermudez et al. (2019) consider that students show enthusiasm for the idea of flying robots in class. Additionally, the use of UAVs presents a rich ecosystem for STEM subjects that allows capturing a wide spectrum of students' interests, abilities and skills. Like many new and cuttingedge technologies, UAVs raise some concerns. It is important to plan properly to achieve a positive result. Privacy, politics, and the negative connotation of the word drone are issues to consider. Many users of devices for commercial purposes prefer to call them by other names, such as flybot, helicopter, UAV (unmanned aerial vehicle), RPA (remotely piloted aircraft), UAS (unmanned aircraft system), unmanned aircraft or simply robot. Understanding the concerns and setting clear goals is key to successfully using UAVs in a classroom. UAVs can be used to help improve orientation skills, motor skills, and even give students a better understanding of how the world around us works.

The integration of UAVs into higher education and research also raises some ethical, legal and safety issues that need to be addressed and resolved (Kennedy & Odell, 2014). For example, unmanned aerial vehicles may pose risks to privacy, security, and property rights because they may capture and transmit personal or sensitive information; interfere with other airspace users, or cause damage or injury to people or objects. Therefore, users of unmanned aerial vehicles must comply with relevant laws and regulations, obtain necessary permits and licenses, and adhere to ethical principles and codes of conduct. Additionally, users of unmanned aerial vehicles must ensure that they operate them safely and responsibly, following best practices and standards and avoiding potential hazards and conflicts. Over the last decade, we have witnessed the rise of the modern maker movement; Driven by new technologies, a community of creators has established shared spaces and created web environments to share ideas and carry out innovative projects (Chounta, Manske, & Hoppe, 2017). In this philosophy, "making" generally refers to the construction of physical objects, combining various disciplines, from crafts to electrical engineering. While Do It Yourself (DIY) projects do not necessarily require group activities, one of the central aspects of the maker philosophy is the maker space. Maker space refers to a genuine physical location, which serves as a persistent place for the exchange of ideas and knowledge, planning, communication and carrying out DIY projects. This leads to a microcosm of manufacturing, consisting of a community willing to share ideas and tools.

It is evident that Spanish universities are committed to the European effort to guarantee more comparable, compatible, coherent and accessible higher education systems. This effort includes not only curricular design and quality procedures, but also the reinforcement of aspects of technical competencies between teachers and students (Cavalcante, Riberas, & Rosa, 2016; Martin-Hansen, 2018). The objective of this article is to discuss the use of UAVs in educational spaces within the framework of the STEM/PBL model, justifying key elements to ensure their integration and the importance and impact on teaching-learning processes in higher education.

2. Methodology

Project-based learning (PBL) is an educational approach that aims to teach students by engaging them in finding solutions to problems through investigation (Thomas, 2000). In that sense, learning activities are driven by projects that students carry out to answer a question or problem that they themselves choose or that is posed by a teacher or instructor (Blumenfeld et al., 1991). The outcome of these activities is typically a product or artifact that addresses the project goal. Projects are generally complex tasks that involve students in designing, problem-solving, decision-making, and resource management within a social context, that is, working together with their peers to achieve a common goal (Thomas, 2000). An interesting feature of PBL is that the learning process and the final outcome cannot be completely predetermined. This requires students and teachers to continually monitor, reflect, evaluate, and update their practice (Barron et al., 1998). Project-based learning moves away from the traditional teacher-centered model often adopted in education. Instead, students are encouraged to work and learn independently (Martín-Páez et al., 2019). Although not primarily dedicated to learning, the maker movement that is currently emerging is based on very similar principles. We see this as an opportunity to define new types of project-oriented learning scenarios in technology- rich contexts (Wang et al., 2011). The *STEAM method* is a teaching-learning method that is based on the idea of educating students in five specific disciplines; Science, Technology, Engineering and Mathematics (in English Science, Technology, Engineering, Arts and Maths; STEAM).

A methodology focused on problem solving, through which questions are asked, objects are examined, background information is tracked and needs are investigated. On the one hand, Morrison (2006), cited by Lantz Jr (2009), executive director of the Teaching Institute for Excellence in STEM (TIES), points out that STEM is the creation of a discipline based on the integration of others in a new "everything", thus building an interdisciplinary bridge with its own identity. Tsupros, Kohler and Hallinen (2009), cited by Lantz Jr (2009), specialist in the STEM curriculum for Intermediate Unit 1(IU1), define STEM education as an interdisciplinary strategy for learning where academically rigorous concepts like science, technology, engineering and mathematics, are put into practice in contexts related to school, society, work. Nadelson and Seifert (2017) also define STEM as a global initiative to face the future challenges, as a development with the ability to compete in the new economy. With this methodology, students get used to working as a team, making joint decisions in the face of research, carrying out collaborations and making hypotheses. Likewise, this educational system is capable of increasing creativity when it comes to solving problems, improves individual critical thinking, improves self-esteem and boosts communication skills (Kelley & Knowles, 2016).

Likewise, STEM helps individuals learn through first-person experimentation, which improves long-term retention of concepts in education and partnerships (Breiner et al., 2012). Learning science, engineering, technology, art and mathematics implies not only passively "receiving" the concepts constructed by science, engineering and mathematics but also "doing" science, engineering, art and mathematics, that is, actively engaging in the cognitive, social and discursive activities of the field (Thibaut et al., 2018). Students are challenged to build an FPV (first person view) drone to which three sensors will be added (temperature, humidity and dust) to measure several physical quantities that will allow us to determine certain variables and their influence on the climate, through PBL methodology. The construction of this drone the application of concepts developed in several subjects of the degree, such as Circuit Analysis, Basic Electronics and Instrumentation, Fundamentals of Programming, Physics, Digital Signal Processing. As a robot that has the peculiarity of moving through the air, its development requires specialized human teams in all areas of science and engineering. The drone will be flown in the lowest layer of the Earth's atmosphere, the so-called boundary layer, which will allow us to take meteorological data to monitor the climate in a geographical area.

Flights are made that cover an entire greenhouse in several minutes and maps of temperature, humidity, lighting and CO2 concentration are generated. It also allows us to carry out work in areas where fires can occur. These UAVs are capable of detecting calls. Even monitor the activity of a volcano. But one of the biggest applications that we are going to promote with the built drone is to take photos of a crop, which together with the obtained data by the sensors and the photos we can determine and analyze how the weather conditions influence that crop.

2.1. Sampling

There were members of the cooperative team to carry out this research with following roles:

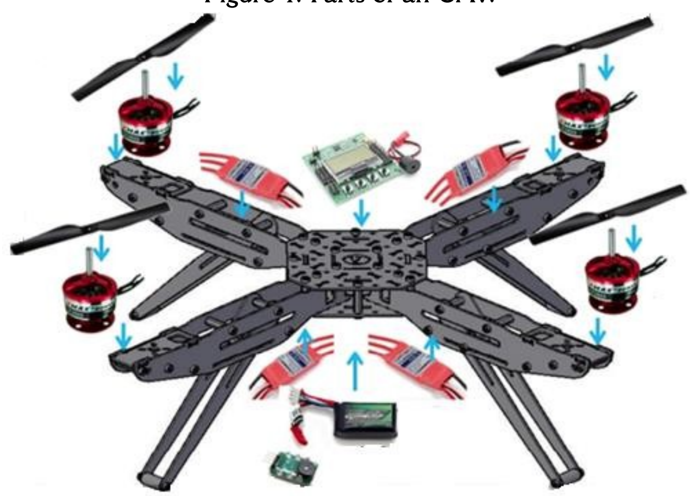
- Operations Manager: is the person who heads the project, reviews delivery dates, provides feedback and reflections on the work carried out, presents the progress, reviews pending tasks, supports other roles, distributes work with respect to the skills of others and has responsibility in all other fields or roles.
- Designer: is the person in charge of creating and designing prototypes or works that are in 2D or 3D, their strong point is being able to capture the ideas of others and your own, turning them into a tangible product. Helps solve qualitative problems.
- Scientific Advisor: his strength is logical-mathematical processes, performing mathematical operations, understanding scientific phenomena. Helps solve quantitative problems.
- Seeker: is the person who has great ability in searching and identifying valid and correct information from different reliable sources or resources.

During the first two weeks of class, what an UAV is, history, basic terms and the management of two web pages were explained (https://www.seguridadaerea.gob.es/es/ambitos/UAVs and https://drones. enaire.es/?locale=es). The first one, AESA, is the State Organism, attached to the Secretary of State for Transport of the Ministry of Transport and Sustainable Mobility, which ensures that civil aviation standards are met in all aeronautical activity in Spain. The second one offers help to pilots and operators of remotely controlled unmanned aircraft (RPAS) by making the necessary aeronautical information available to them.

2.2. Parts of a UAV

The basic parts of a UAV (Figure 1) are:

Figure 1: Parts of an UAV.



- Controller: is the brain of the drone. The basic function is to keep the Drone in stable flight regardless of the pilot's skill.
- Fuselage or Frame: skeleton of the drone. It needs to be strong enough to withstand the opposing forces of the engines without flexing and cope with hard landings without breaking. At the same time, it should also be light enough that its motors can easily lift it, and ideally have a small aerodynamic profile to avoid being too affected by the wind. The frames must be able to dampen vibrations and eventually have supports to place a camera or other equipment.
- Motors: the golden rule for choosing motors is to have twice the thrust of the Drone's weight.

- Electronic Speed Control (ESC): its function is to constantly supply current to the motor. 4 identical EESCs are needed.
- Propellers: The specifications for your motor should indicate roughly the size it needs to create the thrust you are looking for. They must have both directions of rotation to achieve stable balance of the UAV.
- Battery: Provides sufficient power to the UAV for operation. To choose an appropriate battery, you must take into account its capacity and weight.

Other elements that facilitate and ensure UAV flight are also important but are not strictly necessary.

2.3. Materials

A quadcopter-type drone was built. We needed the following materials:

- Structural Materials: Medium, Propellers (4 in total)
- Electronic Materials: Engines (4 in total); Variable speed drives (4 in total) Control card, Arduino, Inertial sensor Communication module Battery, Distribution card, Humidity, temperature sensors.

Apart from the above, which are properly components of the drone, the following additional materials and instruments for its construction were required for the integration of its components and for the respective tests.:

- Multimeter: Useful to verify continuity when making connections, to measure voltages and currents in the process.
- Soldering Iron and Tin Solder: They will be required precisely to solder some connections between components, such as the motors, the ESCs, the battery connectors and all the wiring to our frame or distribution board.
- Cables and Jumpers: Essential for connecting electronic components to the Arduino. Breadboard: It is not essential, but it can be useful for individual testing of some components, such as the IMU.
- Resistors: We will require some, specifically for battery level measurement and to limit the current to the LED.
- LED: It will provide a visual indication of the status of our drone.
- Diode: We will use it to isolate the battery power supply from other possible power sources, such as the USB port of the computer during testing and programming or the BEC of the ESCs.
- Basic and Essential Tools: Welder and accessories, Allen/Hexagon key set, Screwdrivers set, Hex wrench/spanner wrench, Cutting Pliers, Small Pliers, Insulating tape, Double sided tape, Scissors, Brush, Multimeter, Lighter, Cutter, LiPo battery tester

Once the drone was built, multidisciplinary activities were carried out related to Physics, Robotics, Digital Systems, Electronics, and Computer science (programming)

3. Results and Discussion

3.1. Inclusive Higher Education and Drone Technology

Incorporating UAVs into educational programs for students with visual and hearing disabilities can provide accessible, motivating, and enriching learning experiences. Here are some ideas and methodologies that could be effective in designing an inclusive program:

3.2. UAVs for Students with Visual Disabilities

Haptic and Audio Feedback: For visually impaired students, UAVs can include haptic (vibration) and audio feedback technology to help them understand the drone's actions. This can be applied through controllers that vibrate based on the drone's direction or altitude. Audio Descriptions of the Space: UAVs equipped with proximity sensors can translate spatial information into specific sounds, giving students an "image" of the environment through auditory cues. Voice-Guided Flight Models: Through headphones, students could receive step-by-step instructions for controlling the drone and understanding navigation concepts. Exploration of Open and Natural Spaces: Students can fly UAVs in environments like parks or rural areas, perceiving physical features of the space, such as trees, hills, or other elements, which expands their spatial understanding.

3.3. UAVs for Students with Hearing Disabilities

Visual Interfaces and Light Indicators: For students with hearing impairments, UAVs can be set up with colored lights or visual indicators. This setup allows for communicating instructions, alerts, and other relevant data visually. Sign Language Applications: Drone controllers or associated apps can include sign language video instructions to facilitate equipment use and explain activity concepts. Visual Programming: Incorporating visual programming tools like Blockly or Scratch allows students to create predefined routes or movements for the drone, demonstrating concepts like coordinates and velocity. Mixed-Ability Teamwork: Encouraging students with and without hearing impairments to work together on drone projects promotes inclusion and communication, where hearing-impaired students can lead with visual resources while others provide auditory support.

3.4. Educational Activities with UAVs

3D Flight Simulations: Before handling UAVs physically, students can explore flight simulations in 3D environments tailored to visual and hearing disabilities. These simulations can include haptic, audio, or visual feedback for each student to practice navigation concepts.

- Terrain Mapping: Students can use UAVs to capture images or maps of the terrain and analyze these images (using accessible software) to learn about geography, topography, and mathematics. Visually impaired students could receive audio or haptic feedback based on altitude and terrain geography.
- Environmental Science and Exploration: UAVs can collect real-time data on the flora and fauna of an area or even analyze air quality or temperature. This helps students understand ecosystems and natural processes, especially when accessible with auditory or visual tools.

3.5. Accessible Technological Resources

- Sensors and Adapted Software: UAVs with distance, altitude, and obstacle sensors can integrate with technologies like VoiceOver or TalkBack, where flight data is processed into audio for visually impaired students.
- Use of Augmented Reality (AR): Drone controls can incorporate AR to provide additional data like speed or altitude visually, accessible to students with hearing disabilities.
- Customizable Interface Apps: Developers of educational programs can create apps where students adjust alert and feedback types, allowing for a more comfortable and accessible experience.

3.6. Goals and Benefits of an Inclusive Educational Drone Program

- Development of Technical and Scientific Skills: These programs can spark interest in STEM subjects (science, technology, engineering, and mathematics) and make these concepts accessible and understandable for students with disabilities.
- Independence and Safety: Learning to use UAVs gives students a sense of independence and helps them navigate space, strengthening their confidence and autonomy.
- Teamwork and Leadership: Through drone activities, students develop communication, problem-solving, and leadership skills, working together in an inclusive environment.
- Implementation and Necessary Resources:

For these programs to be successful, educators need training in accessibility and educational technology. Additionally, programs must have adapted UAVs (ideally with accessible software), accessible controls, and a safe learning environment tailored to all students' needs. This integrative approach ensures that students with visual and hearing impairments benefit from technological advances, enjoy an equitable educational experience, and develop essential skills for the modern world.

4. Conclusion

What has been demonstrated is the motivating power for innovation that the drone provides, so the world of UAVs should be brought closer to young millennials, natives of the digital age, Generation Z, with the so that they find the necessary incentive to carry out studies in the area of science, since it will be necessary to have a large amount of highly qualified human capital to support the new era in which we are entering where continuous innovation and technological development will be the key to survival. Hobbies that combine technology and sport such as airplane modeling drone racing, etc., can successfully collaborate with this objective.

This study has the following implications and recommendations:

1. Strengthening Practical Learning. Students need to consolidate their theoretical knowledge through direct practical application. They should improve their technical skills in areas such as programming, electronics, control, sensors, robotics, and systems integration.
2. Development of Multidisciplinary Skills. Students are able to integrate diverse areas such as computer science, telecommunications, electronics, aerodynamics, and artificial intelligence, promoting comprehensive learning. It also fostered teamwork, project management, and problem-solving skills.
3. Increased Student Motivation. Practical projects involving drones generate interest and motivation, increasing active classroom participation and engagement with the subjects. It promotes a positive attitude toward subjects traditionally considered complex.
4. Fostering Innovation and Creativity. Students have the opportunity to develop innovative solutions by designing drones with specific applications, from surveillance to smart agriculture to rescue. Creativity was fostered in the search for innovative technological solutions to real-world problems.
5. Improvement in Advanced Technological Skills. Students strengthened their understanding of emerging technologies, such as IoT (Internet of Things), wireless networks (5G, LTE), embedded systems, cloud computing, and real-time data processing. Students developed skills in modern tools and platforms (ROS, Python, Arduino, MATLAB, etc.).
6. Professional Preparation Oriented to Industry 4.0. Students acquired skills aligned with current labor market demands, facilitating their job placement. They were able to develop highly specialized and competitive professional profiles in areas of technological innovation and digital transformation.
7. Strengthening Critical Thinking and Problem-Solving. By facing practical challenges in the construction and operation of drones, students will develop skills to identify, evaluate, and solve technical problems critically and autonomously.
8. Contribution to Technological Research and Development. Projects carried out by students could lead to academic research, scientific publications, and collaborations with companies and technological institutions.

Availability of Data and Material

Yes.

Funding

Not applicable.

Acknowledgements

Not applicable.

References

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., et al. (1998). Haciendo con comprensión: Lecciones de la investigación sobre aprendizaje basado en problemas y proyectos. *Journal of the Learning Sciences*, *7*(3-4), 271-311. https://doi.org/10.1080/10508406.1998.9672056

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivando el aprendizaje basado en proyectos: Sosteniendo la acción, apoyando el aprendizaje. *Educational Psychologist*, *26*(3-4), 369-398. https://doi.org/10.1080/00461520.1991.9653139

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What Is STEM? A Discussion About Conceptions of STEM in Education and Partnerships. *School Science and Mathematics*, *112*(1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Cavalcante, M. T. L., Riberas, G., & Rosa, G. (2016). Fomento de la innovación en los grados de trabajo social y educación social: entorno multilingüe y herramientas para el cambio social. *International Journal of Educational Technology in Higher Education*, *13*(1), 31. https://doi.org/10.1186/s41239-016-0031-0

Chounta, I.-A., Manske, S., & Hoppe, H. U. (2017). "De la creación al aprendizaje": presentación de los campamentos de desarrollo como paradigma educativo para reinventar el aprendizaje basado en problemas. *International Journal of Educational Technology in Higher Education*, *14*(1), 21. https://doi.org/10.1186/s41239-017-0061-2

De Loof, H., Struyf, A., Boeve-de Pauw, J., & Van Petegem, P. (2021). Teachers' Motivating Style and Students' Motivation and Engagement in STEM: the Relationship Between Three Key Educational Concepts. *Research in Science Education*, *51*(1), 109-127. https://doi.org/10.1007/s11165-019-9830-3

Garcia-Bermudez, J., Baudrier, L., Bayraktar, E. C., Shen, Y., La, K., Guarecuco, R., et al. (2019). Squalene accumulation in cholesterol auxotrophic lymphomas prevents oxidative cell death. *Nature*, *567*(7746), 118-122. https://doi.org/10.1038/s41586-019-0945-5

Gómez-Bustamante, J. A., & Martínez-Cogollo, A. L. (2018). Robótica educativa como propuesta de innovación pedagógica. *Gestión Competitividad e Innovación*, *6*(2), 1-12. https://pca.edu.co/editorial/revistas/index.php/gci/article/view/41

Jovanović, V. M., McLeod, G., Alberts, T. E., Tomovic, C., Popescu, O., Batts, T., et al. (2019). Exposing Students to STEM Careers through Hands-on Activities with Drones and Robots. *Engineering Technology Faculty Publications*, 132. https://digitalcommons.odu.edu/engtech_fac_pubs/132

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging Students in STEM Education. *Science Education International*, *25*(3), 246-258. https://www.icaseonline.net/sei/september2014/p1.pdf

Lantz Jr, H. B. (2009). Science, Technology, Engineering, and Mathematics (STEM) Education What Form? What Function? *Report*, *CurrTech Integrations*, *Baltimore*. https://www.uastem.com/wp-content/uploads/2012/08/STEMEducationArticle.pdf

Martin-Hansen, L. (2018). Examining ways to meaningfully support students in STEM. *International Journal of STEM Education*, *5*(1), 53. https://doi.org/10.1186/s40594-018-0150-3

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799-822. https://doi.org/10.1002/sce.21522

Morrison, J. (2006). TIES STEM Education Monograph Series: Attributes of STEM Education The Student The School The Classroom. *TIES (Teaching Institute for Excellence in STEM)*, *20*(2), 1-7. https://leadingpbl.pbworks.com/f/Jans%20pdf%20Attributes_of_STEM_Education-1.pdf

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research*, *110*(3), 221-223. https://doi.org/10.1080/00220671.2017.1289775

Sullivan, A., & Bers, M. U. (2018). Dancing Robots: Integrating Art, Music, and Robotics in Singapore's Early Childhood Centers. *International Journal of Technology and Design Education*, *28*(2), 325-346. https://doi.org/10.1007/s10798-017-9397-0

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., et al. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Journal of STEM Education*, *3*(1), 1-12. https://doi.org/10.20897/EJSTEME/85525

Thomas, J. W. (2000). *A Review of Research on Project-Based Learning*. California: Autodesk Foundation. https://tecfa.unige.ch/proj/eteach-net/Thomas_researchreview_PBL.pdf

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM Education: A Project to Identify the Missing Components*. Intermediate Unit 1: Carnegie Mellon University, Pennsylvania.

Voštinár, P., Horváthová, D., & Klimová, N. (2018). The Programmable Drone for STEM Education. In E. Clua, L. Roque, A. Lugmayr, & P. Tuomi (Eds.), *Entertainment Computing – ICEC 2018* (pp. 205-210). Springer International Publishing. https://doi.org/10.1007/978-3-319-99426-0_18

Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM Integration: Teacher Perceptions and Practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 2. https://doi.org/10.5703/1288284314636