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Drone STEM Education: Revolutionizing Learning for the Future

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Abstract
Drones as game-changers in STEM education: bridging theory and practice. Furthermore, drones provide dynamic, hands-on learning experiences that enhance critical thinking, creativity, and technical skills across STEM disciplines, including aerodynamics, programming, environmental monitoring, and data analysis. Integrating drones into curricula promotes disciplinary styles of learning as students actively participate and interact with difficult concepts of science, engineering, and mathematics. Case studies from Malaysia, Brazil, and the United States highlight the positive impact of drone initiatives on student engagement, comprehension, and interest in pursuing STEM careers. One point that would often arise would be implementation costs, safety and the other needs of its human resources such as teachers training and aligning your curriculum. Proposed solutions are also shared, including partnerships with industry, workforce development or educational programs, plus open-source software and inexpensive drone models. In the future, the combination of drones and new technologies such as artificial intelligence, virtual reality, and e-learning platforms have the potential to advance STEM education even more by enabling immersive and globally accessible learning opportunities. This paper ultimately provides insight into how drones are enabling the next generation of scientists, engineers, and technologists and helping to prepare them for success in a world that is becoming more driven by technology each day.
Keywords: Drone-Based Learning, STEM Education Innovation, Hands-On Technology Integration, Interdisciplinary Learning Tools, Educational Technology in STEM

Introduction

Drones are the new trend setters; new agrochemicals, new recession tides, high scalability, and the diversity in flagging the creepy projects are helping industries from agriculture, to logistics, constructions, and defense, to power up (Edulakanti & Ganguly, 2023; Emimi et al., 2023; Stierlin et al., 2024). However, beyond these domains, drones are also emerging as a powerful educational resource; one of the fields affected is STEM (Science, Technology, Engineering, and Mathematics) education. As such, drones can serve as an inclusive instrument across the STEM spectrum and promote creativity, critical thinking, and technical skills across a wide range of learners (Bolick et al., 2022; Jemali et al., 2022; Yasin et al., 2024; Yeung et al., 2024).

Drone-based STEM education is framed within Kolb's Experiential Learning Theory, which defines four stages of the learning cycle: 1) concrete experience, 2) reflective observation, 3) abstract conceptualization, and 4) active experimentation (Haritha & Rao, 2024; Wijnen-Meijer et al., 2022). This process of adaptive learning not only cultivates a more in-depth understanding but also increases long-term skill retention through hands-on drone programming, flight simulations, and real-world problem-solving exercises. In addition, Constructivist Learning Theory highlights active learning, social collaboration, and scaffolding as contributing factors to the acquisition of knowledge (Do et al., 2023; Wibowo et al., 2025). Constructivist approaches promote learners as active creators of their knowledge through investigation, social interaction, and iterative discovery, which lie at the heart of drone-based learning. Most importantly, (Do et al., 2023) points out that Design Science Approach, which emphasizes problem-solving through iterative learning and can offer students applications in real-world STEM settings through drone-based projects throughout the curriculum. With the incorporation of these learning approaches, drone education becomes not just an exciting project for students but also a step toward their career in a tech-powered world.

This paper discusses how the multi-layered nature of drone or also known as UAV (Unmanned Aerial Vehicle) use in STEM education can span an abstract theoretical concepts to tangible real-world embodied applications. Through exploring curriculum integration, hands-on exercises, and transdisciplinary approaches, this research seeks to illustrate the ways in which drones can enable students to be really immersed in STEM content, while building the skills needed to succeed in a fast-changing technological environment. Additionally, the paper highlights the difficulties of deploying education around drones and gives suggestions on how to optimize it within heterogeneous educational contexts.

The Role of Drones in STEM Education

STEM Drones are potent devices that merge disciplines and make opportunities for experiential learning with artistry; They transcend their original purpose and serve as facilitators of experiential learning by allowing students to wrestle with complex concepts through practical usage and hands-on experience. As a teaching and learning tool, drones offer students an exciting space to think critically, collaborate, push their boundaries, and master the technological skills currently pervasive in the tech-bedecked society in which we live (Ng & Cheng, 2019; Reddy et al., 2019; Slater, 2024; Yeung et al., 2024).

From a science perspective, drones can teach students about the principles of aerodynamics, weather patterns, and physics. Students themselves practice applying real-world uses for scientific theories, e.g. studying flight dynamics or analyzing environmental data collected by drones (Gholami, 2024; Janke et al., 2022). Similarly, drones, their sensors and cameras, their communication systems give students a way in to the world of technology. Students learn about fundamental principles including data transmission, GPS work, and remote sensing devices through the knowledge of these components (Bhat et al., 2024; Choi et al., 2023; Rogers et al., 2022; Tuğrul, 2023).

Engineering students can also learn hands-on by building, designing and programming their own devices with the help of drones (Akasheh et al., 2022; Al-Haddad et al., 2024; Dayakar et al., 2024). According to studies, construction of drones, or programming them with autonomous routes, allows students to engage in hands-on learning, and helps develop engineering skills and creativity and innovation (Abbass & Kang, 2023; Bermúdez et al., 2019; Rahman et al., 2024; Voštinár, 2023). Finally, drone-based education exhibits strong integration of mathematics as students need to apply geometry, trigonometry and algebra when calculating their flight trajectories, optimizing their movements and solve real world problems (Duraj et al., 2021; Pergantis & Drigas, 2024). Drones do not restrict only to technology but also build the connectivity for embracing a complete STEM education (Yasin et al., 2024).

Curriculum Design

Constructing a concrete STEM curriculum with solid drone integration involves drawing on both formal and general STEM constructs through an experiential method (Ng & Cheng, 2019; Yepes et al., 2021; Yeung et al., 2024). Starting with the most basic elements, students can get acquainted with rigid-body programming and assembly of drones. These academic opportunities afford the students with critical technological skills while allowing them to experience how they need to interact to construct functionality (Chou, 2018; Yamish et al., 2024).

Simulations are a big part of curriculum, giving students a chance to optimize their flight paths, or predict how a drone will behave across a range of conditions — all without crashing physical hardware. In this way, virtual environments simulation can simulate situations in the real world (e.g. delivering resources in an emergency environment or mapping an urban area), so learners can learn valuable skills in a safe environment (Koç et al., 2021; Somerville et al., 2024; Toribio et al., 2019).

A second essential aspect of drone-based STEM education is solving real-world problems. Given the potential impact of drones, whether for tracking environmental changes, generating agricultural maps or surveying disaster-affected areas, these hands-on tasks help students make connections between what they learn in class and the issues faced by society. These also empower students with a sense of purpose and social responsibility, as their skills can positively affect the real-world (Abbas et al., 2023; Abichandani et al., 2024; Djatmiko et al., 2021; Mohd Daud et al., 2022).

Practical Applications

For example, they offer students several real-world opportunities inside the classroom where they can put their STEM learning to use to better the world (Yunus & Techanamurthy, 2023). For example, drones are being used in environmental monitoring, where they are analyzing ecosystems, tracking wildlife, and even checking the condition of natural resources like forests and water bodies. These activities expose students to real-world cases of environmental science, emphasizing sustainability and conservation (Buchelt et al., 2024; Jiménez López & Mulero-Pázmány, 2019; Maina Mwaura, 2024).

Drones also enable students to gain experience in precision agriculture and to learn how technology can aid improved farming practices. For example, students are learning about how scientific concepts and technology can synergistically enhance agricultural efficiency and productivity when they utilize drones to acquire information about the status of soil, health of plants, or needs for irrigation (Abd Kharim et al., 2024; Aliloo et al., 2024; Hafeez et al., 2023).

The drones for emergency response is yet another powerful application that students learn with how drone can used in different disaster management. For example, they may map out the areas that need help, kiosk survivors or deliver pathology and logistics supplies via drones in hard-to-reach terrains. But these simulations go beyond developing technical and problem-solving abilities; they also serve as evidence for the humanitarian capacity of technology (Mohd Daud et al., 2022; Nair et al., 2024; Unger et al., 2024; Yucesoy et al., 2025).

Benefits of Drone-Based STEM Education

In the last years, they have been used to have a broad STEM education, where students learn about technology, solving real-life problems, and developing their creativity. Educators can engage students, build critical skillsets, prepare young people for emerging careers and increase equity in education through the integration of drones into the curriculum. The benefits above clearly facilitate the innovative way to teach STEM subjects (Ng & Cheng, 2019; Yasin et al., 2024; Yepes et al., 2021).

Engagement is one of the main advantages which drones provide education. This is because drones offer some hands-on interactive activities and engages student interests capturing their interest and motivation to learn in a way that cannot be accomplished in traditional methods in the classroom. Active involvement for learners comes through the excitement of flying drones, programming their movements, or experimenting with them (Lu et al., 2024b; Pergantis & Drigas, 2024; Yeung et al., 2024). This type of engagement is vital to keeping students interested in STEM topics, particularly amongst those individuals who could be intimidated by what they view as abstract academic disciplines (Jemali et al., 2022; Marzuki et al., 2024). The nature of the technology itself (drones) helps present learning concepts in unexpectedly exciting and interesting ways (Jiang et al., 2024; Zamiri & Esmaeili, 2024), transforming the classroom into an exciting place of discovery and invention.

Another huge advantage is skill development. The innovative pedagogy behind the drone-based activities facilitates critical thinking and problem-solving as students study mechanics of flight, troubleshoot technical problems, and improve performance through inquiry-based activities (Bhuyan et al., 2020; Pergantis & Drigas, 2024; Yepes et al., 2021). For instance, having students design and program drones for defined specific target tasks as team or group projects fosters collaboration and communication skills (Bhuyan et al., 2020; Demetroulis et al., 2023; Lobo et al., 2021). Moreover, doing work with drones provide technical proficiencies like coding, engineering design, and data analysis (Choi et al., 2023; Voštinár, 2023). These skills, which cross disciplines, equip students not only to build an academic foundation but also to wield tools they can employ in the workplace (Hussain et al., 2024; Lobo et al., 2021; Yasin et al., 2024).

Due to ever-increasing industry demands for drone activity and relevant technologies (Lobo et al., 2021; Yasin et al., 2024; Zakaria et al., 2023), a significant component of drone-based STEM education is career preparation. The growing adoption of the use of drones for various purposes such as agriculture, logistics, environmental science, and public safety has created a demand for personnel skilled in drone technology (Askerbekov et al., 2024; Ayamga et al., 2021; Halin & Abd. Manan, 2024; Marzuki et al., 2021). Early access to drones through education programs is a firm foot-hold on learning these in-demand skills. Such early exposure may kindle their interests in follow-on careers in a range of areas such as engineering, robotics, data science, and even other technology-themed domains, and thus prepare them for a job market in transition (Kalyani, 2024; Ng & Cheng, 2019; Slater, 2024).

Drones also improve equity in education, whereby leading-edge technology becomes available to a diverse array of student populations (Lindgren & Ljungblad, 2024). Previously only high-resourced schools presented exposure to cutting-edge tools and technologies. Cheap drone models combined with open-source software democratized drone access, making it possible for schools in the underprivileged areas to introduce drones to their STEM programs. These initiatives help make STEM education more accessible, reaching students from all backgrounds and maximizing their potential in these fields. Drones help close the technological gap, ultimately leading to an equitable and inclusive education landscape (Jemali et al., 2022; Palid et al., 2023; Sze et al., 2025; Yeung et al., 2025).

Challenges in Implementation

Although they offer incredible potential, the integration of drones into STEM has introduced challenges that educators and institutions must navigate to achieve excellent integration. Challenges in finance, logistics, or pedagogy have to be appropriately planned and resourced (Jiang et al., 2024; Slater, 2024).

The most significant obstacles are the expensive cost of drone educational use. The initial costs of drones, associated equipment, and software can be significant, especially for schools with fewer funds (Slater, 2024). Very high quality drones with advanced features (camera, GPS system, programmable interface) are usually expensive. Furthermore, the service downtime, repair, and equipment replacement costs incurred over time also contribute to the long-term expenses (Askerbekov et al., 2024). Underserved schools may struggle to devote resources to such programming, which presents a barrier to equitable implementation (Bolick et al., 2022). Fortunately, collaborative efforts with tech companies, grant funding, and relatively inexpensive basic drones may be a solution to address these concerns (Bai et al., 2021; Dieker et al., 2021).

Another major issue when entering drones into a classroom based environment is the safety (Bolick et al., 2022). The use of drones is also strictly regulated and requires appropriate safety measures to protect students and staff members from risk. Larger model drones, in particular, can be subject to physical hazards if they are mismanaged or wrongly flown (Zenz, 2023). They also must comply with aviation regulations; drones are frequently subject to constraints on where and how they can be flown (Lee et al., 2022; Rahmani & Weckman, 2024; Tran & Nguyen, 2022). They should follow local and national regulations, looking at what permits to apply for and what guidelines to follow when using drones in education. Six factors including verified distance learning systems (Ng & Cheng, 2019; Yeung et al., 2024).

One of the biggest barriers is teacher training. STEM programs that include drones should include educational personnel that have a deep knowledge of about drone technology and applications. Teaching drones will require professional development that many educators likely have never received. Drone-specific training includes hands-on training sessions, workshops, and certification programs that help educators to feel confident in using the drones for the lesson. Beyond resources, teachers face the need for training so they do not use drones as a gimmick (Ng & Cheng, 2019; Slater, 2024; Yeung et al., 2024).

Another challenge is the integration with curriculum. In order to get the most out of drones in STEM education, drone usage needs to be in conjunction with established curricula and learning targets. While drones are an engaging way to learn and explore, designing lesson plans and activities that include drones and that meet state or national academic requirements can be quite a conundrum (Rahman et al., 2024; Yeung et al., 2024). Educators need to explore how they can make drone-based experiences fit into mandated subjects such as physics, mathematics or environmental science without requiring commentary (Janke et al., 2022; Kuzma et al., 2018). Such concerted efforts can enhance partnerships among educators, curriculum developers, and industry experts to develop cohesive, standards-aligned programs (Hussain et al., 2024; Moon & Ock, 2023).

Strategies for Success

There are a few ways these types of challenges can be overcome. Policy update schools, educators, policymakers, and industry partners to financial, logistical and educational barriers (Arafat et al., 2024). By implementing collaboration, safety, educational independence, and innovative technology, these schools could create a drone education program that will lead to sustainability with a big footprint.

Thus among the most significant tactics for balancing the provision of education via drones with the implicit investment is to offer these services with industry partners. Schools could collaborate with drone manufacturers, technology companies and business in the area to develop co-costing projects (Haruna, 2015). Such partnerships can encompass equipment discounts, donations of drones and accessories, and pilot program sponsorships (Mathieson et al., 2023; Vuoriainen et al., 2024). In addition, financial support may be available through grant funding from educational foundations and government programs focused on STEM innovation (Li et al., 2020; Marshall & Galey-Horn, 2024). Such collaborations not only relieve financial pressure on educational institutions but also create connections between education and industry, because students get the chance to see how drone technology can be applied in practice.

Schools, therefore, will need to craft detailed safety protocols and training modules to facilitate the safe integration of drones in classrooms. The guidelines must address the operational, maintenance, and storage aspects of the drone while providing information on emergency or accidents (Mendes et al., 2022; Tran & Nguyen, 2022; Vidović et al., 2024). Required safety training for students and teachers to understand the risks of liability from drone use and how to mitigate them. Schools must also stay aware of the current local and national regulations for drone operations and keep up with aviation laws and restrictions (Hall & Wahab, 2021; Kutynska & Dei, 2023; Lee et al., 2022). Institutions can focus on creating safe environments, which also minimize risks and enhance returns.

Another significant step towards successful implementation is the empowerment of educators through interdisciplinary workshops and certification programs. Once again this will only come if teachers are confident and competent; confident that drones can work in their setting and competent in their use as an educational tool (Pergantis & Drigas, 2024; Yeung et al., 2025). The programs could provide technical training, such as drone assembly, drone programming, and drone troubleshooting, in combination with pedagogical strategies on how to integrate the drones into classes (Rahman et al., 2024; Slater, 2024). Interdisciplinary workshops can also facilitate collaboration between educators from different STEM disciplines, leading to innovative lesson design and project-based learning strategies (Wang et al., 2020; Wu et al., 2024). As a result, the certification programs not only contribute to improving the skills and knowledge of teachers but also strengthen the credibility and trust of the program (Dahri et al., 2023; de Koff, 2023; Sholihah et al., 2020).

Drone-based education is still more widely ignored, but it can easily be made more doable through open-source software, and low-cost models of drones in such institutions that work on tight budgets. Existing platforms for open-source provide free or low-cost programming and simulation of drone operations, limiting the purchase of costly proprietary software (Pereyra Irujo et al., 2023; Pergantis & Drigas, 2024; Sørensen et al., 2017). Drones at the educational level are commonly cheaper and more robust than high-end drones, and as such can be used in school environments (Sadiku et al., 2024). Implementing cost-effective means of drone technology allows for a growing availability of technology to the students who may not have the best opportunities due to their socioeconomics (F. Yasin et al., 2024).

Case Studies and Success Stories

In fact, drones in STEM education have created tremendous success stories across the globe, highlighting their transformative power in driving student engagement and learning. They are informative cases on how drone associated platforms can be adapted for wide-ranging educational contexts, from high-tech ecosystems to low-resource communities. This can lead to various implications on how drones influence STEM education.

Malaysia: The Drone@School initiative engaged students in rural communities and increased interest and knowledge in STEM subjects. Initial interest in STEM was low; just 54.3% of participants indicated STEM careers as areas of interest before they heard the drone modules, compared to 89.8% who did so after. These sessions, aimed at helping close the gap for deprived students, provided practical opportunities to work with drones for operation and programming, thus making STEM subjects more accessible and relevant (Jemali et al., 2022).

Likewise, the Drone Education Program in Sarawak, Malaysia affected 16 schools and emphasized its far-reaching consequences for students aged 5 to 16. This program developed technical skills, as well as redefined how students saw drone technology and multimedia edits. The robustness of these wide-ranging findings across different ages, populations, and cultures confirmed the reliability of the program and offered hope for a promising model for future educational applications. This success can be partly attributed to novel feedback approaches, including emoji-focused evaluations, which performed particularly well with younger participants (Sze et al., 2025).

A US initiative, Idaho Drone League (iDrone), aimed to introduce drone technologies to the doors of elementary and high school students. The initiative successfully sparked interest and awareness in the STEM disciplines and taught a technologically adept next generation of drone programmers and operators. Thereby, the active learning approach of this program enriched young learners with both technical skills and passion for STEM careers (Ryu et al., 2020).

This was further supported by the data collected from Brazil indicating that the introduction of drones into STEM courses increased understanding and deep engagement among students. Driving the need for a new pedagogical model, a study conducted with high school students showed that drone-based workshops enable a deeper understanding of STEM concepts when they are grounded in active methodologies and meaningful learning theories. The findings showed that students were learning not only technical skills, but also critical thinking and problem-solving skills fundamental to future STEM careers (Yepes et al., 2021).

Finally, a study conducted by Clemson University (United States) illustrated that a UAV (drone)-based education module for natural resource science students significantly enhanced their knowledge retention and application skills. There was a 92% average on quiz scores from the students post-module indicating even complex subject such as remote sensing and GIS have been successfully taught using UAVs. While some students reported a stronger inclination towards hands-on learning experiences, the investigation most notably concluded that even simulation-based learning techniques of UAV education could positively impact learning outcomes on a significant scale (Bolick et al., 2022).

Future Prospects

STEM education will never be the same again, too, as new technologies like artificial intelligence (AI), virtual reality (VR), and e-learning platforms come together and continue to reshape the future of drone-based lessons. These technologies have the potential to transform student learning and provide greater depth of engagement, immersion, and accessibility in education. The technology of the future If combined with the latest developments, a drone program is capable of preparing students for an improving complex world.

One of the most interesting advancements is the union of AI with drones that creates new abilities and analytics. AI-media drones could autonomously navigate through environments, comprehend metrics, dimensions, datasets, and other parameters to make decisions dynamically (Obiuto et al., 2024; Pal et al., 2024; Soori et al., 2023). In STEM education, this means students can get to work with bleeding edge topics like machine learning, computer vision, and autonomous systems. The latest and most practical could be the development of academic drone detectors' patterns based on environmental data, or AI algorithms to optimize the path of drone flight. Such experiences help them not only to deepen their understanding of STEM-related principles but also to develop skills that are increasingly sought after in robotics, logistics, and environmental science (Amenyo et al., 2023; Ching Wang et al., 2024; Kabashkin et al., 2023).

A second creative method of enhancing drone-education is by using VR (Marougkas et al., 2023; Szóstak et al., 2024). VR technology has much more to offer than a basic simulator — Integration of VR along with drone simulators offers an immersive education where students can experience and engage with techs hands-on, which was not even possible in the older times. New example scenarios could include piloting drones in twilight zones between virtual and non-virtual realities, including mapping a dynamic disaster zone, exploring the geobiological waterfalls in a simulated remote ecosystem, or inspecting aerial structures. Simulation at that level can and should be used to help safeguard students to experiment with real-life applications of what they learn in a secure and supervised environment and bridge the gap between theoretical knowledge and practical skills. In addition, VR has a potential role in making drone education more accessible and equitable by empowering schools with limited physical space to provide high-quality, simulated learning opportunities (Jin et al., 2024; Lu et al., 2023, 2024a, 2024b).

The proliferation of e-learning platforms can help democratize drone education because it can reach more people around the world (Burgett, 2023; Velasco & Valente, 2020). Today, students in remote or underfunded areas can gain unparalleled access to courses on drone technology, programming, and applications through online courses and virtual labs. Gamified tutorials, challenges and virtual simulations can be implemented on those platforms with which students can interact and actively encourage students with different profiles and skills (Cardona Reyes et al., 2021; Toribio et al., 2019). Also, cloud-powered drone software can enable students to collaborate on projects, analyze data and program drones from different locales, building a global community of learners and creators (Cañas et al., 2020; Chan et al., 2024).

Moreover, alongside their pairing with other new technologies (e.g., Internet of Things (IoT), augmented reality (AR)), the education process in the STEM area may be further transformed and adapted (Hasan, 2024; Stavropoulos et al., 2022; Zen et al., 2023). IoT-equipped drones can also communicate with the connected devices to pull real time data for the projects, such as those for monitoring smart farms or urban infrastructure (Bine et al., 2024; Rajak et al., 2023). In particular, a real-time data overlay system based on AR is a possible potential that could help users visualize the complexities of drone formation flying during a drone flight (Konstantoudakis et al., 2022; Singh et al., 2024).

Conclusion

Stem education is being revolutionized by: Using drones to make complex concepts engaging and interactive to get students excited about how things work. Unlike traditional instructors, drone technology provides a viable means to actually linking these new abilities to classroom learning with real-world applications. Drones encourage critical thinking, creativity, and technical skills to address real-world issues and tackle interdisciplinary projects. Not only are these tools making STEM more engaging to learn about, they are inspiring students to imagine and prepare for a future that includes tech and innovation.

Yet there are challenges to the successful integration of drones into education. Prohibitors remain high initial costs, safety concerns, training teachers, and matching drone-based activities to existing curricula. Joining forces among schools, policymakers, employers, and the wider education community to tackle these challenges is key. Ensuring sustainability and inclusivity for drone-based programs require strategic investments in professional development for teachers, the development of cost-effective solutions, and the establishment of safety protocols.

Drones can do so much more than just act as flying robots hiding at the corner of your classroom. With the continuous integration of technology into our lives, the educational applications of this technology will only continue to evolve, especially in the realms of artificial intelligence, virtual reality, and e-learning platforms. Despite this, early experiments suggest that drones could contribute a lot to STEM education, and innovations could lead to even more immersive, engaging and accessible drone-based STEM education for students around the world — opening international lines of learning and physically transcending borders.

We are seeking this change in education, either by the way we invest as well as or in the higher education industry, innovation, and by the amazing change of methods of education using the drones. Not only will these efforts inspire the next generation of scientists, engineers, and technologists, they will also provide them with the skills and vision necessary to address the complex challenges of tomorrow. Beyond being an educational tool, drones are engines for change, helping to build a cutting-edge, inclusive future.

References

Abbas, A., Zhang, Z., Zheng, H., Alami, M. M., Alrefaei, A. F., Abbas, Q., Naqvi, S. A. H., Rao, M. J., Mosa, W. F. A., Abbas, Q., Hussain, A., Hassan, M. Z., & Zhou, L. (2023). Drones in Plant Disease Assessment, Efficient Monitoring, and Detection: A Way Forward to Smart Agriculture. *Agronomy*, *13*(6), Article 6. https://doi.org/10.3390/agronomy13061524

Abbass, M. A. B., & Kang, H.-S. (2023). Drone Elevation Control Based on Python-Unity Integrated Framework for Reinforcement Learning Applications. *Drones*, *7*(4), Article 4. https://doi.org/10.3390/drones7040225

Abd Kharim, M., Mokhtar, S., Kayat, F., Ywih, C., Wahab, I., Mohamed Redwan, R., Mahmud, M., Amsyar, S., Mat, K., Md Zain, N., Rusli, N. D., Harun, H., Bakar, T., Mohamad Nor, M., & Zakaria, S. (2024). Agrotechnology Students' Acceptance on Agriculture Drones Spraying as Practical Tool in Class using the Knowledge, Attitude and Practice (KAP) Model. *International Journal of Advanced Research in Food Science and Agriculture Technology*, *1*, 31–44. https://doi.org/10.37934/fsat.1.1.3144

Abichandani, P., Lobo, D., Dimitrijevic, B., Borgaonkar, A., Sodhi, J., Kabrawala, S., Brateris, D., & Kam, M. (2024). Competition-based active learning instruction for drone education. *Interactive Learning Environments*, *32*(5), 1795–1813. https://doi.org/10.1080/10494820.2022.2128821

Akasheh, F., Shannon, D., Pippins, R., Thompson, E., Carter, A., Baker, S., & Guiseppi, B. (2022, July 27). Additive Manufacturing-Enabled Modular Drone Design Development by Multidisciplinary Engineering Student Team Additive Manufacturing-Enabled Modular Quadcopter Drone Design Development by Multidisciplinary Engineering Student Team. *ASEE Annual Conference & Exposition*. https://doi.org/10.18260/1-2--42122

Al-Haddad, L. A., Jaber, A. A., Giernacki, W., Khan, Z. H., Ali, K. M., Tawafik, M. A., & Humaidi, A. J. (2024). Quadcopter Unmanned Aerial Vehicle Structural Design Using an Integrated Approach of Topology Optimization and Additive Manufacturing. *Designs*, *8*(3), Article 3. https://doi.org/10.3390/designs8030058

Aliloo, J., Abbasi, E., Karamidehkordi, E., Ghanbari Parmehr, E., & Canavari, M. (2024). Dos and Don'ts of using drone technology in the crop fields. *Technology in Society*, *76*, 102456. https://doi.org/10.1016/j.techsoc.2024.102456

Amenyo, J.-T., Kpo, W., Amenyo, J.-T., & Kpo, W. (2023). Leveraging Programmable Educational Drones, Robots and AI for Learning STEM, Computational Thinking and Higher Order Thinking in Schools in Rural Villages. In *Drones—Various Applications*. IntechOpen. https://doi.org/10.5772/intechopen.1002465

Arafat, M., Budiyanto, C., Yuana, R., & Fenyvesi, K. (2024). Implementation of Integrated STEM Learning in Educational Robotics towards 21st Century Skills: A Systematic Review. *International Journal of Education in Mathematics, Science and Technology*, *12*, 1127–1141. https://doi.org/10.46328/ijemst.4271

Askerbekov, D., Garza-Reyes, J. A., Roy Ghatak, R., Joshi, R., Kandasamy, J., & Luiz de Mattos Nascimento, D. (2024). Embracing drones and the Internet of drones systems in manufacturing – An exploration of obstacles. *Technology in Society*, *78*, 102648. https://doi.org/10.1016/j.techsoc.2024.102648

Ayamga, M., Akaba, S., & Nyaaba, A. A. (2021). Multifaceted applicability of drones: A review. *Technological Forecasting and Social Change*, *167*, 120677. https://doi.org/10.1016/j.techfore.2021.120677

Bai, O., Chu, H., & Al, E. (2021). Drones in Education: A Critical Review. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(11), Article 11. https://doi.org/10.17762/turcomat.v12i11.6107

Bermúdez, A., Casado, R., Fernández, G., Guijarro, M., & Olivas, P. (2019). Drone challenge: A platform for promoting programming and robotics skills in K-12 education. *International Journal of Advanced Robotic Systems*, *16*(1), 1729881418820425. https://doi.org/10.1177/1729881418820425

Bhat, G. R., Dudhedia, M. A., Panchal, R. A., Shirke, Y. S., Angane, N. R., Khonde, S. R., Khedkar, S. P., Pansare, J. R., Bere, S. S., Wahul, R. M., & Gawande, S. H. (2024). Autonomous drones and their influence on standardization of rules and regulations for operating–A brief overview. *Results in Control and Optimization*, *14*, 100401. https://doi.org/10.1016/j.rico.2024.100401

Bhuyan, J., Wu, F., Thomas, C., Koong, K., Won Hur, J., & Wang, C. (2020). Aerial Drone: An Effective Tool to Teach Information Technology and Cybersecurity through Project Based Learning to Minority High School Students in the U.S. *TechTrends : For Leaders in Education & Training*, *64*(6), 899–910. https://doi.org/10.1007/s11528-020-00502-7

Bine, L. M. S., Boukerche, A., Ruiz, L. B., & Loureiro, A. A. F. (2024). Connecting Internet of Drones and Urban Computing: Methods, protocols and applications. *Computer Networks*, *239*, 110136. https://doi.org/10.1016/j.comnet.2023.110136

Bolick, M., Mikhailova, E., & Post, C. (2022). Teaching Innovation in STEM Education Using an Unmanned Aerial Vehicle (UAV). *Education Sciences*, *12*, 224. https://doi.org/10.3390/educsci12030224

Buchelt, A., Adrowitzer, A., Kieseberg, P., Gollob, C., Nothdurft, A., Eresheim, S., Tschiatschek, S., Stampfer, K., & Holzinger, A. (2024). Exploring artificial intelligence for applications of drones in forest ecology and management. *Forest Ecology and Management*, *551*, 121530. https://doi.org/10.1016/j.foreco.2023.121530

Burgett, J. (2023). An Online Drone Course for Construction Management Students: Curriculum, Simulation, and Certifications. *Proceedings of 59th Annual Associated Schools of Construction International Conference*, 65–55. https://doi.org/10.29007/4cj8

Cañas, J. M., Martín-Martín, D., Arias, P., Vega, J., Roldán-Álvarez, D., García-Pérez, L., & Fernández-Conde, J. (2020). Open-Source Drone Programming Course for Distance Engineering Education. *Electronics*, *9*(12), Article 12. https://doi.org/10.3390/electronics9122163

Cardona Reyes, H., Trujillo-Espinoza, C., Mercado, C., & Muñoz-Arteaga, J. (2021). Training of Drone Pilots through Virtual Reality Environments under the Gamification Approach in a University Context. *Interaction Design and Architecture(s)*, 64–83. https://doi.org/10.55612/s-5002-049-004

Chan, J. H., Liu, K., Chen, Y., Sagar, A. S. M. S., & Kim, Y.-G. (2024). Reinforcement learning-based drone simulators: Survey, practice, and challenge. *Artificial Intelligence Review*, *57*(10), 281. https://doi.org/10.1007/s10462-024-10933-w

Ching Wang, S. I., Zhi Feng Liu, E., Huang, Y. Y., & Yu Sang, H. (2024). When Drone Meets AI Education: Boosting High School Students' Computational Thinking and AI Literacy. *2024 Pacific Neighborhood Consortium Annual Conference and Joint Meetings (PNC)*, 45–52. https://doi.org/10.23919/PNC63053.2024.10697362

Choi, H.-W., Kim, H.-J., Kim, S.-K., & Na, W. S. (2023). An Overview of Drone Applications in the Construction Industry. *Drones*, *7*(8), Article 8. https://doi.org/10.3390/drones7080515

Chou, P.-N. (2018). Smart Technology for Sustainable Curriculum: Using Drone to Support Young Students' Learning. *Sustainability*, *10*(10), Article 10. https://doi.org/10.3390/su10103819

Dahri, N. A., Al-Rahmi, W. M., Almogren, A. S., Yahaya, N., Vighio, M. S., & Al-Maatuok, Q. (2023). Mobile-Based Training and Certification Framework for Teachers' Professional Development. *Sustainability*, *15*(7), Article 7. https://doi.org/10.3390/su15075839

Dayakar K., H. Kajol, & Karthik Reddy. (2024). Modeling And 3D Printing Of Drone Frame. *International Advanced Research Journal in Science, Engineering and Technology*, *11*(10). https://doi.org/10.17148/IARJSET.2024.111029

de Koff, J. P. (2023). Effectiveness of a remote pilot certification training for agricultural professionals. *Natural Sciences Education*, *52*(2), e20121. https://doi.org/10.1002/nse2.20121

Demetroulis, E. A., Theodoropoulos, A., Wallace, M., Poulopoulos, V., & Antoniou, A. (2023). Collaboration Skills in Educational Robotics: A Methodological Approach—Results from Two Case Studies in Primary Schools. *Education Sciences*, *13*(5), Article 5. https://doi.org/10.3390/educsci13050468

Dieker, L. A., Butler, M. B., Ortiz, E., & Gao, S. (2021). Reflecting upon 30 Years of STEM Partnerships between Industry, University, and Public Schools: Past Lessons, Current Successes, and Future Dreams. *Education Sciences*, *11*(12), Article 12. https://doi.org/10.3390/educsci11120760

Djatmiko, I., Yatmono, S., & Nugraha, A. (2021). Development and Effectiveness of Drone as a Learning Media in Islamic Boarding School. *Journal of Physics: Conference Series*, *2111*, 012011. https://doi.org/10.1088/1742-6596/2111/1/012011

Do, H.-N., Do, B. N., & Nguyen, M. H. (2023). 3How do constructivism learning environments generate better motivation and learning strategies? The Design Science Approach. *Heliyon*, *9*(12), e22862. https://doi.org/10.1016/j.heliyon.2023.e22862

Duraj, S., Pepkolaj, L., & Hoxha, G. (2021). Adopting Drone Technology in Mathematical Education. *3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, 7. https://doi.org/10.1109/HORA52670.2021.9461297

Edulakanti, S. R., & Ganguly, S. (2023). Review article: The emerging drone technology and the advancement of the Indian drone business industry. *The Journal of High Technology Management Research*, *34*(2), 100464. https://doi.org/10.1016/j.hitech.2023.100464

Emimi, M., Khaleel, M., & Alkrash, A. (2023). The Current Opportunities and Challenges in Drone Technology. *International Journal of Electrical Engineeringand Sustainability (IJEES)*, *1*, 74–89.

Gholami, A. (2024). Exploring Drone Classifications and Applications: A Review. *International Journal of Engineering and Geosciences*, *9*, 418–442. https://doi.org/10.26833/ijeg.1428724

Hafeez, A., Husain, M. A., Singh, S. P., Chauhan, A., Khan, Mohd. T., Kumar, N., Chauhan, A., & Soni, S. K. (2023). Implementation of drone technology for farm monitoring & pesticide spraying: A review. *Information Processing in Agriculture*, *10*(2), 192–203. https://doi.org/10.1016/j.inpa.2022.02.002

Halin, A., & Abd. Manan, Mohd. S. (2024). Drones and Technopreneurship in Malaysia: Unlocking the Economic Potential of Drones in Built Environment Development. *International Journal of Business and Technopreneurship (IJBT)*, *14*, 283–302. https://doi.org/10.58915/ijbt.v14i3.1041

Hall, O., & Wahab, I. (2021). The Use of Drones in the Spatial Social Sciences. *Drones*, *5*(4), Article 4. https://doi.org/10.3390/drones5040112

Haritha, D. G., & Rao, D. R. (2024). A Holistic Approach to Professional Development: Integrating Kolb\'s Experiential Learning Theory for Soft Skills Mastery. *Journal of Engineering Education Transformations*, *37*(Special Issue 2). https://doi.org/10.16920/jeet/2024/v37is2/24069

Haruna, U. I. (2015). The Need for an Effective Collaboration across Science, Technology, Engineering & Mathematics (STEM) Fields for a Meaningful Technological Development in Nigeria. *Journal of Education and Practice*, *6*(25), 16–21.

Hasan, M. (2024). *Applications of Virtual Labs in Engineering* (SSRN Scholarly Paper 4795012). Social Science Research Network. https://doi.org/10.2139/ssrn.4795012

Hussain, A. H., Ummihusna, A., Wahi, W., Eni, S., & Mohamed Sultan, A. A. (2024). Droneducation: Empowering Tomorrow's Workforce through IR4.0-based Curriculum. *International Journal of Academic Research in Business and Social Sciences*, *14*. https://doi.org/10.6007/IJARBSS/v14-i1/20583

Janke, C., Lin, Y., Luthi, K., & Kleinke, S. (2022, May 22). Using Small UAS for STEM Education: Introducing Robotics and Mechatronics with Drones. *Florida Conference for Recent Advances in Robotics 2022*. https://doi.org/10.5038/QQGN3785

Jemali, N. J. N., Rahim, A. A., Rosly, M. R. M., Susanti, S., Daliman, S., Muhamamad, M., & Karim, M. F. A. (2022). Adopting drone technology in STEM education for rural communities. *IOP Conference Series: Earth and Environmental Science*, *1064*(1), 012017. https://doi.org/10.1088/1755-1315/1064/1/012017

Jiang, M., Jong, M., Chai, C., Huang, B., Chen, G., Lo, C. K., & Wong, F. (2024). They believe students can fly: A scoping review on the utilization of drones in educational settings. *Computers & Education*, *220*, 105113. https://doi.org/10.1016/j.compedu.2024.105113

Jiménez López, J., & Mulero-Pázmány, M. (2019). Drones for Conservation in Protected Areas: Present and Future. *Drones*, *3*(1), Article 1. https://doi.org/10.3390/drones3010010

Jin, Z., Bai, Y., Song, W., Yu, Q., Yue, X., & Jia, X. (2024). DVRT: Design and evaluation of a virtual reality drone programming teaching system. *Computers & Graphics*, *125*, 104114. https://doi.org/10.1016/j.cag.2024.104114

Kabashkin, I., Misnevs, B., & Zervina, O. (2023). Artificial Intelligence in Aviation: New Professionals for New Technologies. *Applied Sciences*, *13*(21), Article 21. https://doi.org/10.3390/app132111660

Kalyani, D. (2024). The Role of Technology in Education: Enhancing Learning Outcomes and 21st Century Skills. *International Journal of Scientific Research in Modern Science and Technology*, *3*, 05–10. https://doi.org/10.59828/ijsrmst.v3i4.199

Koç, D., Seçkin, A. Ç., & Satı, Z. E. (2021). Evaluation of Participant Success in Gamified Drone Training Simulator Using Brain Signals and Key Logs. *Brain Sciences*, *11*(8), 1024. https://doi.org/10.3390/brainsci11081024

Konstantoudakis, K., Christaki, K., Tsiakmakis, D., Sainidis, D., Albanis, G., Dimou, A., & Daras, P. (2022). Drone Control in AR: An Intuitive System for Single-Handed Gesture Control, Drone Tracking, and Contextualized Camera Feed Visualization in Augmented Reality. *Drones*, *6*(2), Article 2. https://doi.org/10.3390/drones6020043

Kutynska, A., & Dei, M. (2023). Legal Regulation of the Use of Drones: Human Rights and Privacy Challenges. *Journal of International Legal Communication*, *8*, 39–55. https://doi.org/10.32612/uw.27201643.2023.8.pp.39-55

Kuzma, J., Robinson, A., Dobson, K., & Law, J. (2018). Practical Pedagogy for Embedding Drone Technology into a Business and Computing Curriculum. *Journal of Education and Human Development*, *7*, 1–9. https://doi.org/10.15640/jehd.v7n3a1

Lee, D., Hess, D. J., & Heldeweg, M. A. (2022). Safety and privacy regulations for unmanned aerial vehicles: A multiple comparative analysis. *Technology in Society*, *71*, 102079. https://doi.org/10.1016/j.techsoc.2022.102079

Li, Y., Wang, K., Xiao, Y., Froyd, J. E., & Nite, S. B. (2020). Research and trends in STEM education: A systematic analysis of publicly funded projects. *International Journal of STEM Education*, *7*(1), 17. https://doi.org/10.1186/s40594-020-00213-8

Lindgren, P., & Ljungblad, S. (2024). Drones as Accessibility Probes in Able-Bodied Norms: Insights from People with Lived Experiences of Disabilities. *Designing Interactive Systems Conference*, 2946–2957. https://doi.org/10.1145/3643834.3661580

Lobo, D., Patel, D., Morainvile, J., Shekhar, P., & Abichandani, P. (2021). Preparing Students for Drone Careers Using Active Learning Instruction. *IEEE Access*, *9*, 126216–126230. IEEE Access. https://doi.org/10.1109/ACCESS.2021.3110578

Lu, J., Dawod, A., & Ying, F. (2023). From traditional to digital: The impact of drones and virtual reality technologies on educational models in the post-epidemic era. *Sustainable Engineering and Innovation*, *5*, 261–280. https://doi.org/10.37868/sei.v5i2.id233

Lu, J., Dawod, A., & Ying, F. (2024a). Transformation of Digital Innovation in Education in the Post-covid Era: An Exploration Centered on Drones and Virtual Reality. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *8*, 436–451. https://doi.org/10.22437/jiituj.v8i2.37133

Lu, J., Dawod, A., & Ying, F. (2024b, March 15). Effects of Drone Technology and Virtual Reality on Student Engagement, Visual Attention, and Learning Experience. *Proceedings of the*

1st International Conference on Artificial Intelligence, Communication, IoT, Data Engineering and Security, IACIDS 2023. https://doi.org/10.4108/eai.23-11-2023.2343184

Maina Mwaura, F. (2024). The Use of Drones in Environmental Monitoring and Conservation. *Research Invention Journal of Biological and Applied Sciences*.

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13), Article 13. https://doi.org/10.3390/electronics12132832

Marshall, S. L., & Galey-Horn, S. (2024). STEM leaders promoting resilience within equity-centered K-12 STEM education organizations. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1331358

Marzuki, O. F., Lih, E., Abdullah, W., Khairuddin, N., Inai, N., MD Saad, J., & Aziz, M. (2024). Innovating Education: A Comprehensive Review of STEM Education Approaches. *International Journal of Academic Research in Progressive Education and Development*, *13*. https://doi.org/10.6007/IJARPED/v13-i1/20490

Marzuki, O. F., Teo, E., & Rafie, A. (2021). The Mechanism of Drone Seeding Technology: A Review. *Malaysian Forester*, *84*, 349–358.

Mathieson, D., Cotrupi, C., Schilling, M., & Grohs, J. (2023). Resiliency through partnerships: Prioritizing STEM workforce pathways amid macro challenges. *School Science and Mathematics*, *123*(3), 137–149. https://doi.org/10.1111/ssm.12575

Mendes, E., Albeaino, G., Brophy, P., Gheisari, M., & Jeelani, I. (2022). Working Safely with Drones: A Virtual Training Strategy for Workers on Heights. *Construction Research Congress 2022*, 622–630. https://doi.org/10.1061/9780784483985.063

Mohd Daud, S. M. S., Mohd Yusof, M. Y. P., Heo, C. C., Khoo, L. S., Chainchel Singh, M. K., Mahmood, M. S., & Nawawi, H. (2022). Applications of drone in disaster management: A scoping review. *Science & Justice*, *62*(1), 30–42. https://doi.org/10.1016/j.scijus.2021.11.002

Moon, S., & Ock, J. (2023). Developing the Framework of Drone Curriculum to Educate the Drone Beginners in the Korean Construction Industry. *Drones*, *7*(6), Article 6. https://doi.org/10.3390/drones7060356

Nair, V. G., D’Souza, J. M., S, A. C., & Rafikh, R. M. (2024). A Scoping Review on Unmanned Aerial Vehicles in Disaster Management: Challenges and Opportunities. *Journal of Robotics and Control (JRC)*, *5*(6), Article 6. https://doi.org/10.18196/jrc.v5i6.22596

Ng, W., & Cheng, G. (2019). Integrating Drone Technology in STEM Education: A Case Study to Assess Teachers’ Readiness and Training Needs. *Issues in Informing Science and Information Technology*, *16*, 061–070. https://doi.org/10.28945/4288

Obiuto, N. C., Festus-Ikhuoria, I. C., Olajiga, O. K., & Adebayo, R. A. (2024). Reviewing the Role of AI in Drone Technology and Applications. *Computer Science & IT Research Journal*, *5*(4), Article 4. https://doi.org/10.51594/csitrj.v5i4.1019

Pal, O. K., Shovon, M. S. H., Mridha, M. F., & Shin, J. (2024). In-depth review of AI-enabled unmanned aerial vehicles: Trends, vision, and challenges. *Discover Artificial Intelligence*, *4*(1), 1–24. https://doi.org/10.1007/s44163-024-00209-1

Palid, O., Cashdollar, S., Deangelo, S., Chu, C., & Bates, M. (2023). Inclusion in practice: A systematic review of diversity-focused STEM programming in the United States. *International Journal of STEM Education*, *10*(1), Article 1. https://doi.org/10.1186/s40594-022-00387-3

Pereyra Irujo, G., Bernaldo, P., Velazquez, L., Pérez, A., Molina Favero, C., & Egozcue, A. (2023). Open Science Drone Toolkit: Open source hardware and software for aerial data capture. *PLOS ONE*, *18*, e0284184. https://doi.org/10.1371/journal.pone.0284184

Pergantis, P., & Drigas, A. (2024). The Effect of Drones in the Educational Process: A Systematic Review. *Education Sciences*, *14*(6), Article 6. https://doi.org/10.3390/educsci14060665

Rahman, M. J. B. A., Hashim, H. B. N., Ensimau, N. K., & Majid, M. Z. A. (2024). Application of Drone Technology in Learning Process Strategies. *International Journal of Academic Research in Business and Social Sciences*, *14*(8), 784–791.

Rahmani, H., & Weckman, G. R. (2024). Working under the Shadow of Drones: Investigating Occupational Safety Hazards among Commercial Drone Pilots. *IISE Transactions on Occupational Ergonomics and Human Factors*, *12*(1–2), 55–67. https://doi.org/10.1080/24725838.2023.2251009

Rajak, P., Ganguly, A., Adhikary, S., & Bhattacharya, S. (2023). Internet of Things and smart sensors in agriculture: Scopes and challenges. *Journal of Agriculture and Food Research*, *14*, 100776. https://doi.org/10.1016/j.jafr.2023.100776

Reddy, E., Hoople, G., & Choi-Fitzpatrick, A. (2019). Drones for good: Interdisciplinary project-based learning between engineering and peace studies. *International Journal of Engineering Education*, *35*, 1378–1391.

Rogers, S. R., Singh, K. K., Mathews, A. J., & Cummings, A. R. (2022). Drones and Geography: Who Is Using Them and Why? *The Professional Geographer*, *74*(3), 516–528. https://doi.org/10.1080/00330124.2021.2000446

Ryu, J., LaPaglia, S., & Walters, R. (2020). Idaho Drone League (iDrone) to Stimulate STEM workforce. *Journal of STEM Education: Innovations and Research*, *21*(2). https://www.jstem.org/jstem/index.php/JSTEM/article/view/2384

Sadiku, M. N. O., Oteniya, M., Sadiku, J. O., & Abunene, S. (2024). Drones in Education. *International Journal of Latest Engineering Research and Applications (IJLERA)*, *9*(8).

Sholihah, M., Ratnasari, K., Permatasari, Y., Muawanah, U., & Fajri, A. (2020). The policy of educators' certification: An effort to improve quality, qualification, and teachers' competence. *IOP Conference Series: Earth and Environmental Science*, *485*, 012130. https://doi.org/10.1088/1755-1315/485/1/012130

Singh, P., Murthy, V., Kumar, D., & Raval, S. (2024). A comprehensive review on application of drone, virtual reality and augmented reality with their application in dragline excavation monitoring in surface mines. *Geomatics, Natural Hazards and Risk*, *15*(1), 2327399. https://doi.org/10.1080/19475705.2024.2327399

Slater, T. F. (2024). Identifying Implementation Strategies for Integrating Drones into STEM and Career Technology Education CTE Programs. *Education Sciences*, *14*(1), Article 1. https://doi.org/10.3390/educsci14010105

Somerville, A., Lynar, T., Joiner, K., & Wild, G. (2024). Use of Simulation for Pre-Training of Drone Pilots. *Drones*, *8*, 640. https://doi.org/10.3390/drones8110640

Soori, M., Arezoo, B., & Dastres, R. (2023). Artificial intelligence, machine learning and deep learning in advanced robotics, a review. *Cognitive Robotics*, *3*, 54–70. https://doi.org/10.1016/j.cogr.2023.04.001

Sørensen, L. Y., Jacobsen, L. T., & Hansen, J. P. (2017). Low Cost and Flexible UAV Deployment of Sensors. *Sensors*, *17*(1), Article 1. https://doi.org/10.3390/s17010154

Stavropoulos, P., Athanasopoulou, L., Papacharalampopoulos, A., Kanellopoulos, I., & Mourtzis, D. (2022). Augmented Reality tool for the facilitation of the UAV flight inspection process during aircraft de-icing as a maintenance procedure. *IFAC-PapersOnLine*, *55*(10), 976–982. https://doi.org/10.1016/j.ifacol.2022.09.480

Stierlin, N., Risch, M., & Risch, L. (2024). Current Advancements in Drone Technology for Medical Sample Transportation. *Logistics*, *8*(4), Article 4. https://doi.org/10.3390/logistics8040104

Sze, S. N., Phang, P., Tiong, W. K., Chiew, K. L., Wee, B. L., Goh, S. L., Bakar, S. A. A., & Hardi, R. (2025). Digital Drone Education in Sarawak: Enhancing STEM Learning through Hands-on Training for School Students. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *53*(2), Article 2. https://doi.org/10.37934/araset.53.2.19

Szóstak, M., Mahamadu, A.-M., Prabhakaran, A., Caparros Pérez, D., & Agyekum, K. (2024). Development and testing of immersive virtual reality environment for safe unmanned aerial vehicle usage in construction scenarios. *Safety Science*, *176*, 106547. https://doi.org/10.1016/j.ssci.2024.106547

Toribio, C. B., Chua, A., Espinola, J., Lacaden, J., & Ignacio, J. (2019). Virtual Simulations for Drone Education of Senior High School Students. *International Journal of Engineering and Advanced Technology (IJEAT)*, *8*(6S3tori), 220–226. https://doi.org/10.35940/ijeat.F1036.0986S319

Tran, T.-H., & Nguyen, D.-D. (2022). Management and Regulation of Drone Operation in Urban Environment: A Case Study. *Social Sciences*, *11*(10), Article 10. https://doi.org/10.3390/socsci11100474

Tuğrul, K. M. (2023). Drone Technologies and Applications. In *Drones—Various Applications*. IntechOpen. https://doi.org/10.5772/intechopen.1001987

Unger, D. R., Kulhavy, D. L., Hung, I.-K., Williams, V., Zhang, Y., Viegut, R., Unger, D. R., Kulhavy, D. L., Hung, I.-K., Williams, V., Zhang, Y., & Viegut, R. (2024). Use of Drones to Monitor and Aid Disaster Management Efforts of Natural Resources. In *Revolutionizing Earth Observation—New Technologies and Insights*. IntechOpen. https://doi.org/10.5772/intechopen.1004598

Velasco, O., & Valente, J. (2020). Online Drone Education, a Mapping Review. *2020 IEEE Global Engineering Education Conference (EDUCON)*, 1286–1289. https://doi.org/10.1109/EDUCON45650.2020.9125268

Vidović, A., Štimac, I., Mihetec, T., & Patrlj, S. (2024). Application of Drones in Urban Areas. *Transportation Research Procedia*, *81*, 84–97. https://doi.org/10.1016/j.trpro.2024.11.010

Voštinár, P. (2023). *Using Drones in Teaching Computer Science* (p. 904). https://doi.org/10.23919/MIPRO57284.2023.10159850

Vuoriainen, A., Rikala, P., Heilala, V., Lehesvuori, S., Oz, S., Kettunen, L., & Hämäläinen, R. (2024). The six C’s of successful higher education-industry collaboration in engineering education: A systematic literature review. *European Journal of Engineering Education*, *0*(0), 1–25. https://doi.org/10.1080/03043797.2024.2432440

Wang, H.-H., Charoenmuang, M., Knobloch, N., & Tormoehlen, R. (2020). Defining interdisciplinary collaboration based on high school teachers’ beliefs and practices of STEM integration using a complex designed system. *International Journal of STEM Education*, *7*. https://doi.org/10.1186/s40594-019-0201-4

Wibowo, S., Wangid, M. N., & Firdaus, F. M. (2025). The relevance of Vygotsky’s constructivism learning theory with the differentiated learning primary schools. *Journal of Education and Learning (EduLearn)*, *19*(1), Article 1. https://doi.org/10.11591/edulearn.v19i1.21197

Wijnen-Meijer, M., Brandhuber, T., Schneider, A., & Berberat, P. O. (2022). Implementing Kolb´s Experiential Learning Cycle by Linking Real Experience, Case-Based Discussion and Simulation. *Journal of Medical Education and Curricular Development*, *9*, 23821205221091511. https://doi.org/10.1177/23821205221091511

Wu, X., Yang, Y., Zhou, X., Xia, Y., & Liao, H. (2024). A meta-analysis of interdisciplinary teaching abilities among elementary and secondary school STEM teachers. *International Journal of STEM Education*, *11*(1), 38. https://doi.org/10.1186/s40594-024-00500-8

Yamish, S., Rajanarasimha, S., & Abhijeet, K. (2024). Assembly and Programming of Hexacopter Drone for Surveillance and Medical Kit Delivery Purposes. *International Research Journal on Advanced Engineering Hub (IRJAEH)*, *2*(6). https://doi.org/10.47392/IRJAEH.2024.0246

Yasin, F., Hamid, S., Phang, F., & Pusppanathan, J. (2024). Empowering Student with Drone: A DDR Approach to Expanding the Physics Body of Knowledge and Enhancing Stem Education. *International Journal of Academic Research in Progressive Education and Development*, *13*. https://doi.org/10.6007/IJARPED/v13-i4/23793

Yasin, F. M., Fatin Aliah Phang Abdullah, Nazri Nasir, & Jaysuman Pusppanathan. (2024). Drone Technology in Education: A Bibliometric Analysis. *International Journal of Education, Psychology and Counselling (IJEPC)*, *9*(55). https://gaexcellence.com/ijepc/article/view/4244

Yepes, I., Barone, D., & Porciuncula, C. (2021). Use of Drones as Pedagogical Technology in STEM Disciplines. *Informatics in Education*. https://doi.org/10.15388/infedu.2022.08

Yeung, R. C. Y., Sun, D., & Yeung, C. H. (2025). Integrating drone technology in STEM education: Curriculum, pedagogy and learning outcomes. *Education and Information Technologies*. https://doi.org/10.1007/s10639-025-13368-0

Yeung, R. C. Y., Yeung, C. H., Sun, D., & Looi, C.-K. (2024). A systematic review of Drone integrated STEM education at secondary schools (2005–2023): Trends, pedagogies, and learning outcomes. *Computers & Education*, *212*, 104999. https://doi.org/10.1016/j.compedu.2024.104999

Yucesoy, E., Balcik, B., & Coban, E. (2025). The role of drones in disaster response: A literature review of operations research applications. *International Transactions in Operational Research*, *32*(2), 545–589. https://doi.org/10.1111/itor.13484

Yunus, S. N. M., & Techanamurthy, U. (2023). Students' acceptance of drones using the Knowledge, Attitudes, and Practice (KAP) model. *Jurnal Kejuruteraan*, *SI-6*(2), Article 2.

Zakaria, A. F., Mohd Zulfadli Rozali, & Mohd Syafiq Syazwan Mustafa. (2023). A preliminary discussion on STEM-drone sport's athlete development program toward career relevance. *Jurnal Kejuruteraan*, *SI-6*(2), Article 2.

Zamiri, M., & Esmaeili, A. (2024). Methods and Technologies for Supporting Knowledge Sharing within Learning Communities: A Systematic Literature Review. *Administrative Sciences*, *14*(1), Article 1. https://doi.org/10.3390/admsci14010017

Zen, I. S., Nour, A., & Nurhaqeem, M. A. (2023). Utilising Smart Technology for Heritage Preservation: A Systematic Review Case Study Malaysia and Türkiye. *Journal of Architecture, Planning and Construction Management*, *13*(2), Article 2.

Zenz, A. (2023). Safety first: Analysing the problematisation of drones. *Griffith Law Review*, *32*(3), 310–334. https://doi.org/10.1080/10383441.2024.2303937