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DRONE TECHNOLOGY IN EDUCATION: A BIBLIOMETRIC ANALYSIS

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Abstract:

Drone technology has shown a great deal of potential in transforming teaching and learning. In order to investigate the intellectual landscape around the integration of drone technology in education, this study undertakes a thorough bibliometric analysis. Various scholarly repositories were examined in detail to compile relevant papers. In the field of drone technology in education, this research presents a comprehensive bibliometric analysis, examining 1,147 papers indexed in Scopus. By utilizing VOSviewer for data visualization and analysis, the research identifies key trends, influential publications and collaborative patterns in the field. The data reveals an increasing interest in using drones in a variety of educational contexts with a focus on environmental studies, STEM education and experiential learning. Moreover, the study highlights significant contributions from interdisciplinary partnerships and specialized research groups, emphasizing the interdisciplinary character of integrating drone technology into educational practices. In summary, this bibliometric investigation offers valuable insights into the present status and future trajectories of research on harnessing drone technology to enhance educational methodologies. The outcomes of this study offer valuable guidance for researchers, educators, and policymakers seeking to integrate drones into curricula, equipping students with essential skills and competencies for future careers.

Keywords:

Bibliometric Analysis, Drone, Education, Technology, UAV

Introduction

Drone technology has surfaced as a transformative innovation capable of revolutionizing multiple fields including education. The incorporation of drones into educational environments has gained significant attention because of their potential to improve teaching methods, engage students in hands-on learning and promote interdisciplinary skills. However, integrating drone technology into the curriculum poses challenges. Educators need to find effective ways to incorporate drones into their lesson plans and ensure their use aligns with educational objectives which involves developing new teaching materials and methodologies. Additionally, while there is growing interest in the potential benefits of using drones for educational purposes, more research is needed to understand their impact on learning outcomes. Studies are necessary to evaluate how drone technology can enhance student engagement, motivation and knowledge retention. This paper aims to delve into the scholarly landscape surrounding the utilization of drone technology in education through a comprehensive bibliometric analysis.

The use of drones in education offers a wide array of opportunities for innovative pedagogical practices. By leveraging drone technology, educators can provide students with hands-on learning experiences that transcend traditional classroom boundaries. Drones have been particularly instrumental in enriching STEM (Science, Technology, Engineering and Mathematics) education by enabling students to apply theoretical concepts to real-world scenarios (Chou, 2018). Moreover, incorporating drones in educational curricula has enhanced students' spatial visualization, sequencing skills and overall engagement with the learning material (Naab & Weigel, 2021).

The interdisciplinary nature of drone technology integration in education is a key aspect that sets it apart from conventional teaching methods. Collaborations between educators, technologists and researchers have paved the way for innovative approaches to incorporating drones into educational practices. Studies have highlighted the positive impact of drone-based STEM learning approaches on students' enthusiasm, excitement and overall learning outcomes, particularly in underserved rural communities (Jemali et al., 2022). Furthermore, using drones to teach geospatial technology fundamentals has demonstrated the effectiveness of integrating cutting-edge technology to enhance students' understanding of complex concepts (Joyce et al., 2020).

As drone technology continues to evolve, it is essential to address the challenges and considerations associated with its implementation in educational settings. Issues such as privacy concerns, regulatory frameworks and ethical considerations need to be carefully navigated to ensure the responsible and effective use of drones in education (Ng et al., 2023). Additionally, exploring the readiness and training needs of educators to integrate drone technology into STEM education is crucial for maximizing the benefits of this innovative tool (Ng & Cheng, 2019).

The integration of drone technology in educational settings represents a significant advancement with the potential to transform teaching and learning practices. This paper embarks on a comprehensive bibliometric journey to trace the publications and research trends in the field of drone technology in education. By employing bibliometric methodologies, this study aims to identify research gaps, key themes, influential publications and the global distribution of research activities in this domain. The investigation delves into various

technology interventions, ranging from cutting-edge innovations like Artificial Intelligence (AI), machine learning and gamification in assessments to digital assessment platforms and learning analytics to shed light on their impact on instructional strategies, policymaking and educational outcomes.

The exploration of drone technology in education seeks to understand how these technological advancements have been embraced by educators and students alike and how they have enhanced the evaluation process. The study aims to provide a roadmap for future studies and advancements in this crucial field by focusing on the evolution and distribution of research on drone technology in education. The analysis will address key research questions, including the evolution and distribution of research on drone technology in education, the most productive countries, institutions, and authors in this field, common themes identified by scholars, and the most influential articles on drone technology in education studies.

Through a meticulous examination of the literature on drone technology in education, this study will utilize various metrics to evaluate research impact, analyze the productivity and effectiveness of countries, institutions, and authors, identify predominant themes in drone technology in education, and determine the articles that have had the most significant impact in this field. By comprehensively understanding the global impact and collaborative nature of drone technology integration in education, this research aims to equip researchers with the necessary knowledge to propel further inquiries into the development and utilization of drone technology in educational assessment methods.

The bibliometric analysis examined the literature on Drone Technology in Education to address these seven issues, taking into account the following aspects:

1. What are the trends? What are the research trends in online learning studies according to the year of publication?
2. Who writes the most significant number of articles?
3. What is the type of document used for the subject of research?
4. What are the research trends in drone education according to the country?
5. What are the popular keywords related to the study?
6. What are co-authorship countries' collaboration?

Literature Review
This research explores the exciting possibilities of drone technology in revolutionizing how we teach and learn around the world. Studies by Abichandani et al. (2022) and Yepes et al. (2022) advocate for using drones as teaching tools in STEM fields. They emphasize the need for innovative teaching methods and active learning approaches. These approaches create engaging learning experiences that allow students to apply STEM concepts to real-world situations (Abichandani et al., 2022; Yepes et al., 2022).

The research highlights the significant impact of integrating drone technology into education, particularly in developing skills required for the Industry 4.0 era (Phang et al., 2021). Phang et al. (2021) stress the importance of nurturing well-rounded graduates with a strong foundation in both technical and non-technical skills. Drone technology offers unique opportunities for students to develop competencies relevant to current and future job demands in an increasingly demanding job market. Bhuyan (2020) expands on this point by highlighting the effectiveness

of drones in teaching Information Technology and Cybersecurity. Drone technology suggests their potential to enhance learning across various subjects, even at the secondary school level. This literature underscores the need for improved access and training, particularly for underrepresented groups, to ensure everyone has the chance to participate in these innovative educational experiences (Bhuyan, 2020).The article further strengthens its argument by referencing a recent study by Slater (2021). Slater's (2021) research highlights the importance of practical experiences while acknowledging the logistical and technical challenges students face during drone projects. This study underscores the need for schools to provide adequate support to equip students with the resources and training to overcome these hurdles and effectively address real-world workplace challenges (Slater, 2021).

Building on this point, Lobo et al. (2021) highlight a critical gap in existing research identified by. While studies emphasize the importance of student exposure and practical experience with drone technology, most research focuses on skills and practical experiences rather than the physics or core STEM content knowledge associated with drone technology (Lobo et al., 2021; Ng et al., 2023). This study highlights the need for a stronger focus on integrating a robust physics framework within the context of using drones as a school learning tool.

Ng & Chu's (2021) study on integrating drones into STEM and Career and Technical Education (CTE) programs aligns with this gap. They emphasize the need for effective implementation strategies and equipping students with relevant drone-related skills to support industry growth (Ng & Chu, 2021). However, Ng et al. (2023) point out the limitations of solely focusing on theoretical knowledge. They advocate for incorporating active learning approaches, such as drone capstone projects, to ensure students acquire the necessary practical skills for drone-related careers (Ng et al., 2023). Table 1 summarizes the key findings from the literature review, highlighting the significant contributions and gaps in the research on drone technology in education.

Table 1: Summary of Past Findings on Drone Technology in Education

Author(s)	Year	Key Findings
Bhuyan	2020	Demonstrated the effectiveness of drones in teaching IT and Cybersecurity, advocating for improved access and training, especially for underrepresented groups.
Lobo et al.	2021	Identified a gap in research focusing more on practical experiences with drones rather than core STEM content, suggesting the need for a stronger physics framework.
Ng & Chu	2021	Emphasized integrating drones into STEM and CTE programs, focusing on equipping students with relevant skills to support industry growth.
Phang et al.	2021	Stressed the importance of integrating drone technology to develop Industry 4.0 skills,

		highlighting the need for a balance of technical and non-technical skills in graduates.
Slater	2021	Emphasized the importance of practical experiences with drones, noting the logistical and technical challenges and the need for adequate support in schools.
Abichandani et al.	2022	Advocated for using drones in STEM education, emphasizing innovative teaching methods and active learning to engage students in real-world applications.
Yepes et al.	2022	Highlighted the need for active learning approaches using drones to create engaging learning experiences in STEM fields.
Ng et al.	2023	Pointed out the limitations of theoretical knowledge, advocating for active learning approaches, such as drone capstone projects, to ensure practical skill acquisition.

In conclusion, the research underscores the transformative potential of drone technology in education. It equips students with practical skills and fosters a deeper understanding of STEM concepts. However, the article emphasizes the need to move beyond a purely skills-based approach. It calls for strengthening the STEM content learning aspects within drone education programs. This research article will ensure that students gain practical experience and a solid STEM foundation, leading to a comprehensive understanding of drone technology and preparing them for future workforce demands.

Methodology

This bibliometric study delves into the research landscape of a chosen field by analyzing high-quality publications curated from reputable databases like SCOPUS (Donthu et al., 2021; Farooq, 2021). To ensure the inclusion of impactful research, the study meticulously examines articles published in rigorously peer-reviewed academic journals, deliberately excluding books and lecture notes (Jain et al., 2021; Kumar et al., 2020). Leveraging the extensive coverage of SCOPUS, the study retrieves publications from a designated timeframe for further exploration (Farooq, 2021). By wielding a powerful combination of bibliometric analysis and content analysis, the study sheds light on influential aspects of published literature, identifies prominent research streams, and proposes future research directions to guide further exploration of the field (Bahuguna et al., 2023; Teixeira & Rodrigues, 2022; Zainuldin & Lui, 2021). To achieve this objective, the study implements a robust methodology incorporating document co-citation analysis, keyword analysis, and author co-authorship analysis (Fozaie, 2022; Kiss et al., 2022; Ullah et al., 2022). These techniques unveil predominant themes within the field, pinpoint the most influential articles shaping research, and identify the countries and institutions demonstrating the most significant research productivity (Luis & Celma, 2020; Pahlevi et al., 2023). Ultimately, this comprehensive bibliometric analysis strives to describe the various facets of scientific communication within the chosen field, paving the way for the development of a future research agenda (Luis & Celma, 2020; Pahlevi et al., 2023).

Data Search Strategy

The study determined the search terms for article retrieval using a screening sequence. The study was started by assembling 12,459 articles online and querying the Scopus database. Later, the query string was changed to concentrate on students as learners by using the search phrases "drone OR UAV OR unmanned aerial vehicle" AND "education." 1,147 articles from the final search string in Table 2 refinement were used for bibliometric analysis. All publications on drone technology in education found in the Scopus database as of April 2024 were included in the research as shown in Table 3.

Table 2: The Search String

Scopus	TITLE-ABS-KEY (drone OR uav OR "unmanned aerial vehicle") AND education) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English"))

Table 3: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Timeline	2000-2024	<2000
Language	English	Non-English

Data Analysis

VOSviewer, developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands, is a widely used bibliometric software known for its user-friendly interface and advanced visualization capabilities (Van Eck & Waltman, 2017). It is particularly adept at creating intuitive network visualizations, clustering related items, and generating density maps, making it a valuable tool for researchers seeking insights into complex research landscapes. One of the key features of VOSviewer is its ability to transform complex bibliometric datasets into visually interpretable maps and charts. By focusing on network visualization, the software excels in clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. This software allows researchers to explore research landscapes and efficiently identify emerging trends and patterns. The software's interactive interface makes it accessible to novice and experienced users, allowing for dynamic exploration of large datasets. Continuous updates ensure that VOSviewer remains at the forefront of bibliometric analysis, offering valuable insights through metrics computation and customizable visualizations.

VOSviewer is compatible with various bibliometric data sources, including co-authorship and citation networks, allowing researchers to analyze diverse types of data. Its versatility and adaptability make it an indispensable tool for scholars seeking deeper understanding and meaningful insights within their research domains. For data analysis, datasets comprising publication year, title, author name, journal, citation, and keywords were obtained from the Scopus database covering the period from 2000 to April 2024. These datasets were then analyzed using VOSviewer software version 1.6.19.

Through VOS clustering and mapping techniques, the software facilitated the examination and generation of maps, providing researchers with a comprehensive overview of the research landscape. Unlike the Multidimensional Scaling (MDS) approach, which primarily focuses on similarity metrics like cosine and Jaccard indices, VOSviewer places items within low-dimensional spaces based on the association strength (ASij). This index is calculated as the ratio between the observed number of co-occurrences of two items and the expected number of co-occurrences under the assumption of statistical independence (Van Eck & Waltman, 2007):

$$AS_{ij} = \frac{c_{ij}}{w_i w_j}$$

VOSviewer creates maps that accurately reflect the relatedness and similarity between items by reducing the weighted sum of squared distances between all item pairs. This approach allows researchers to identify clusters of related items and explore the connections between different research topics and themes.

In summary, VOSviewer is a powerful tool for visualizing and analyzing bibliometric data, offering researchers valuable insights into research landscapes and trends. Its intuitive interface, advanced visualization capabilities, and compatibility with various data sources make it an essential resource for scholars seeking to explore and understand complex research domains.

Results and Findings

What Are The Research Trends In Online Learning Studies According To The Year?
Figure 1 displays a line chart that analyses the trend over a period of ten years for a collection of 1147 publications in this field of study. Based on the Scopus search results, the publication trends related to drones or unmanned aerial vehicles (UAVs) in education reveal an overall upward trajectory in recent years. While the numbers fluctuated from 2001 to 2015, with relatively low counts ranging from 1 publication in 2001 to 35 in 2013, a significant publication surge was observed from 2016 onwards. The years 2021 (149 publications), 2023 (159 publications) and the partial year 2024 (49 publications) stand out as having the highest publication counts, potentially indicating an increased research focus and applications of drones/UAVs in educational contexts during this period. In 2017, we also witnessed a notable peak, with 101 publications. It is essential to note that the 2024 data is incomplete, and the final count may vary by the end of the year. Nonetheless, the consistent publication growth from 2016 to 2023 highlights the growing interest and advancements in this field, showcasing the relevance of drones/UAVs in educational research and practices.
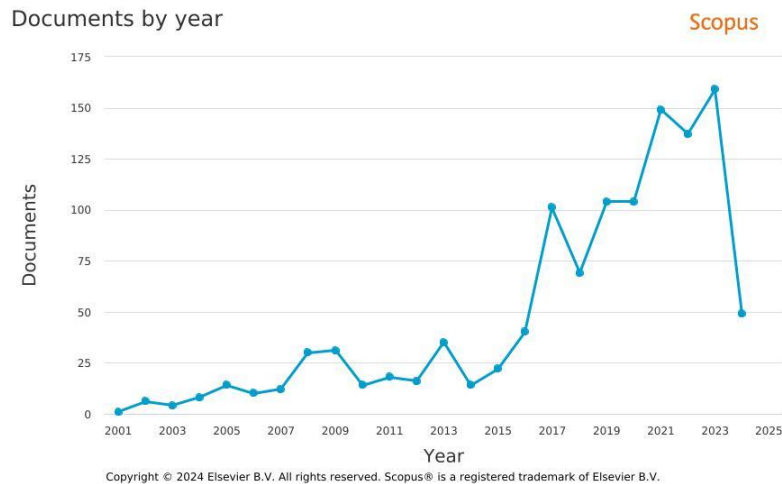
Figure 1: Total Publication by Year

The number of publications ranges from 1 to 159, with the highest number occurring in 2023. The percentage of publications ranges from 0.09% to 13.86% with the highest percentage also occurring in 2023. Overall, there is a significant increase in both the number and percentage of publications from 2014 to 2023 before experiencing a decline in 2024.

From 2001 to 2024, the number of publications and their percentages have been recorded. The number of publications ranges from 1 to 159, with the highest number occurring in 2023, while their percentages range from 0.09% to 13.86%, with the highest percentage also occurring in the same year. There is a significant increase in both the number and percentage of publications from 2014 to 2023 before experiencing a decline in 2024.

Thus, it can be concluded that there is a trend of increasing both the number of publications and their percentages from 2014 to 2023 before experiencing a decline in 2024. This finding indicates fluctuations in publication productivity from year to year that need to be understood in a broader context.

Who Writes The Greatest Number Of Articles?

Figure 2 shows the analysis of the Scopus search results for publications related to drones or unmanned aerial vehicles (UAVs) in education, revealing insights into the most prolific authors in this field. Among the retrieved results, Bhandari, S. stands out as the author with the highest number of publications, having contributed 7 articles. Bhandari S holds the position of Professor and Chair in the Aeronautical Engineering department at California State Polytechnic University, Pomona, Pomona, United States and is known for his significant contributions and active engagement in the field. Three authors, Caccamo, M., Dantsker, O.D. and Raheja, A., follow closely with 6 publications, each marking the second highest count. On the other hand, Caccamo, M is a professor in the Department of Mechanical Engineering at the Technical University of Munich (TUM), and he is known for his expertise in real-time and cyber-physical research. Meanwhile, Dantsker, O.D. is an Assistant Professor at Indiana University extensively involved in research on UAVs, Flight Testing, and Aerodynamics and also Raheja, A, who serves as a Professor of Computer Science at California State Polytechnic University,

is frequently engaged in studies revolving around computer image processing, applied vision, machine learning and precision agriculture.

Additionally, five authors, namely Aliyazicioglu, Z., Choi-Fitzpatrick, A., Gheisari, M., Hatfield, M.C. and Tang, F., have 5 publications each in this domain. Aliyazicioglu, Z presently serves as a Professor in the Department of Electrical and Computer Engineering at California State Polytechnic University-Pomona. His academic pursuits encompass Digital Signal Processing applications, Digital Image Processing and Communication Systems. Choi-Fitzpatrick, A affiliated with the University of San Diego, specializes in Social Movements, Human Rights, Political Sociology and Technology Innovation. Meanwhile, Gheisari, M, an Associate Professor at the University of Florida, focuses on Human-Technology Interaction in Construction. In addition, Hatfield, M.C. is an Assistant Professor of Electrical Engineering at the University of Alaska Fairbanks, specializing in Unmanned Aircraft Systems, Control Systems, Systems Engineering Design Process and Arctic Research.

It's fascinating to see a Malaysian author included in the Top 10 Authors Who Contributed to Drone Technology in Education. Howe Eng Tang, affiliated with the Faculty of Computer and Mathematical Science at Universiti Teknologi MARA in Mukah, Sarawak, Malaysia, focuses his research on a diverse array of topics ranging from Alpha Value and Concept Mapping to Electrical Engineering and Web-based Education. This study highlights the global impact and diverse expertise contributing to advancements in drone technology in education. The list continues with 14 authors having 4 publications each and a notable group of 24 authors contributing 3 publications each. The remaining authors in the search results have 2 publications, each within the specified criteria. This breakdown highlights the diverse range of researchers actively publishing in the field of drones or UAVs related to education, with Bhandari, S. emerging as the most prolific author based on the results retrieved.

Examining the biodata of the top 10 authors reveals a diverse range of research interests and affiliations, with none explicitly emphasizing education as their primary focus. Instead, these authors hail from fields such as engineering, computer science and mathematics, indicating a multidisciplinary approach to drone technology research. While education may not be their sole area of expertise, their contributions to the field of drone technology offer valuable insights and advancements that can benefit educational applications. This interdisciplinary collaboration underscores the importance of diverse perspectives and expertise in driving innovation and progress in integrating drone technology within educational contexts.
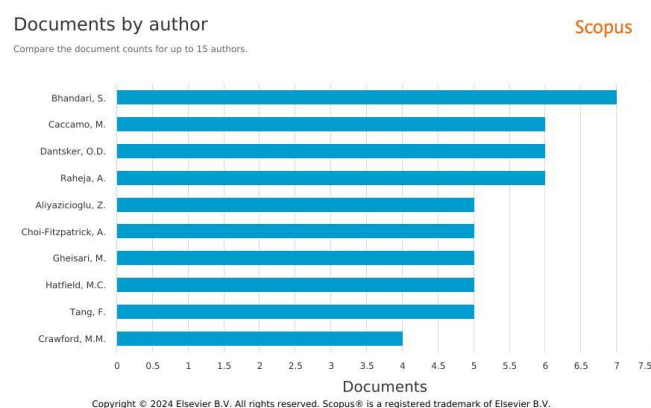
Figure 2: Top 10 Authors Who Contributed to Drone Technology in Education

What Is The Type Of Document Used For The Subject Of Research?
Figure 3 shows the publication analysis by subject area, which reveals a multidisciplinary landscape for research related to drone technology in education. The top subject areas are Engineering, with 609 publications (27%) and Computer Science, with 550 publications (24.4%), underscoring the technical foundations of drone development and operation. However, the analysis also highlights the broad applications of drones across diverse fields. Social Sciences, with 12.1% (273 publications), emerge as the third highest subject area, indicating the relevance of drones in educational contexts and social studies. Subjects like Earth and Planetary Sciences, Physics and Astronomy, Environmental Science and Materials Science showcase the use of drones in areas such as remote sensing, space exploration, and environmental monitoring. Additionally, fields like Medicine, Agricultural and Biological Sciences, Arts and Humanities, Economics and Psychology contribute to the interdisciplinary nature of drone research, exploring applications in healthcare, agriculture, arts, business and human behaviour. While the core technical disciplines dominate, the diversity of subject areas involved demonstrates the far-reaching impact and potential of drones in various educational and research domains.
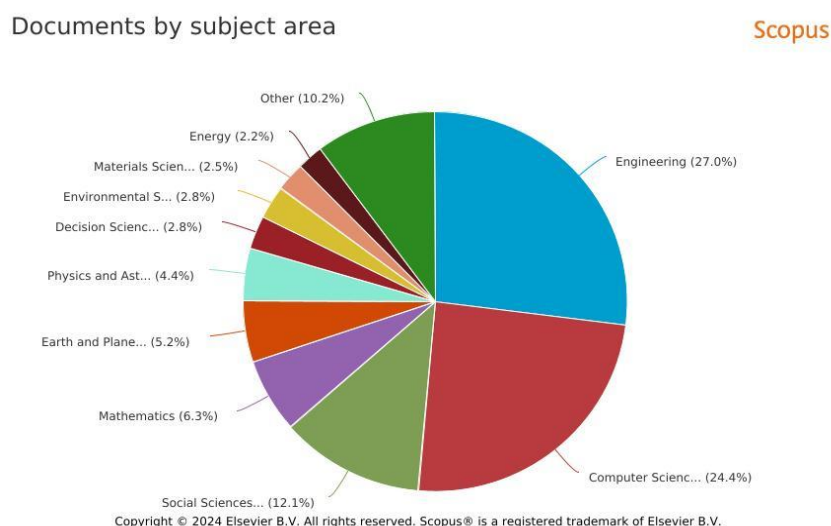

Documents by subject area — Scopus

Other (10.2%); Energy (2.2%); Materials Scien... (2.5%); Environmental S... (2.8%); Decision Scienc... (2.8%); Physics and Ast... (4.4%); Earth and Plane... (5.2%); Mathematics (6.3%); Social Sciences... (12.1%); Computer Scienc... (24.4%); Engineering (27.0%)

Figure 3: Type of Document by Subject

What Are The Research Trends In Drone Education According To The Country?
Figure 4 shows the analysis of publication counts by country and reveals a global landscape for research related to drones or unmanned aerial vehicles (UAVs) in education. The United States emerges as the leading contributor with 333 publications, showcasing its dominance in this field. China follows closely with 106 publications, indicating its growing emphasis on drone technology and educational applications. Several other countries, including India, the United Kingdom, Australia, Canada, Italy, Spain, Germany, and South Korea, have made substantial contributions, underscoring the widespread interest in this domain. European nations, such as France, Russia, Greece, Poland, and the Netherlands, have also actively participated in the research. Additionally, countries from various regions, including Mexico, Japan, Taiwan, Brazil, South Africa, and the Middle East, have contributed to the global publication landscape. While the data highlights the involvement of numerous countries, it is essential to note the presence of an "Undefined" category, which may represent publications

without specific country affiliations or incomplete metadata. Overall, the analysis demonstrates the multidisciplinary and international nature of research in the field of drones or UAVs related to education, with contributions spanning multiple continents and regions.
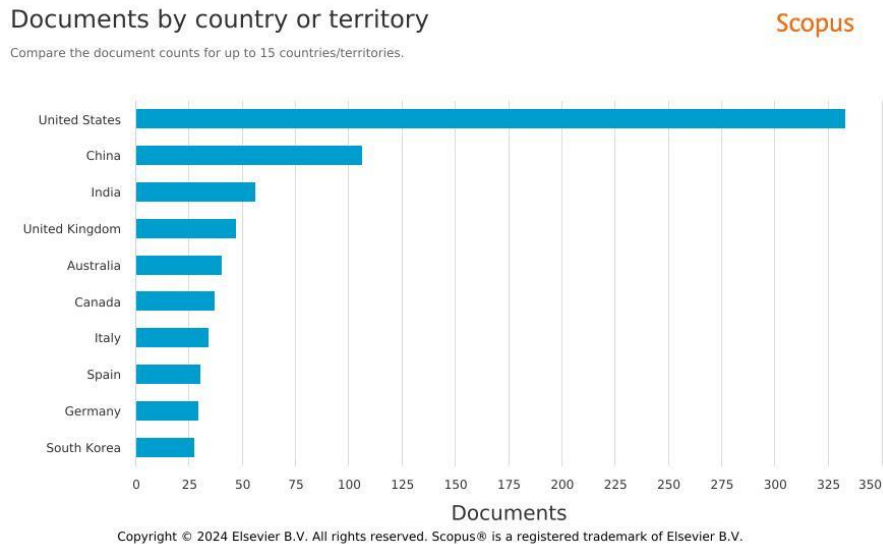
Figure 4: Top 10 Research Trends in Drone Education by Country

What Are The Popular Keywords Related To The Study?
The bibliometric analysis using the Vosviewer analyzer reveals several key insights into popular keywords based on occurrences and total link strength. Figure 5 shows the VOSviewer map demonstrates the interconnections between important subjects in Drone Technology in Education, highlighting "drones", "unmanned aerial vehicle", and "engineering education" as essential nodes in the discussion. These crucial terms connect to fundamental notions like "education", "uav", and "drone", as well as innovative components such as "deep learning" and "robotics." The document also touches on interdisciplinary aspects, object detection, and curriculum. Overall, the bibliometric analysis offers valuable insights into the patterns, areas of focus, and preferences within the scholarly community, which can inform future research efforts and educational initiatives.

Figure 5: Interconnectedness Of Key Themes Within Drone Technology In Education

What Are Co-Authorship Countries' Collaboration?

The co-authorship analysis using Vosviewer reveals the collaborative patterns among countries in academic research. Based on the network visualization in Figure 6, we can identify some of the prominent or popular countries in the research area of Drone Technology in Education by looking at the larger node sizes and their positions within the clusters. The node representing the United States appears to be one of the largest, indicating a significant number of publications or contributions from authors in this country. It is positioned within a distinct cluster, suggesting a strong research community focused on this topic. Similarly, the United Kingdom demonstrates strong collaboration with a high number of documents and citations suggesting active engagement in collaborative research endeavours. Australia, Canada and China also exhibit substantial collaboration, with notable contributions to research output and citation impact, reflecting their global influence in academia.

Furthermore, while some countries, such as India and China, show high research output but relatively lower citation impact, others, such as Germany and Spain, demonstrate a balanced combination of both. Interestingly, smaller countries like the Netherlands, Sweden and Switzerland exhibit high citation impact relative to their research output, indicating the quality and impact of their collaborative research efforts. Overall, this analysis provides valuable insights into the dynamics of international collaboration in academia, highlighting the key players and their contributions to global knowledge exchange and dissemination.

Figure 6: The Countries Whose Authors Collaborate on Drone Technology in Education

Discussion and Conclusion

As revealed by the bibliometric analysis, the dynamic landscape of drone education research underscores its transformative potential in shaping educational practices. The surge in research output since 2016, with leading countries like the US and China collaborating actively, reflects a global commitment to preparing students for the demands of Industry 4.0. Studies consistently emphasize drones' value in fostering technical and non-technical skills crucial for future jobs (Phang et al., 2021). Their effectiveness extends beyond STEM subjects, with research by Bhuyan (2020) demonstrating their potential in Information Technology and Cybersecurity. This versatility opens doors for integration across various disciplines, even at the secondary school level. However, ensuring equitable access and training for underrepresented groups remains a critical challenge (Bhuyan, 2020).

While the research overwhelmingly supports the benefits of practical experiences, it also acknowledges the hurdles students face. Slater's (2021) study highlights the importance of hands-on learning but recognizes the logistical and technical challenges that can arise during drone projects. This finding underscores the need for schools to equip students with the resources and training necessary to overcome these obstacles and prepare them for real-world workplace scenarios (Slater, 2021).

Lobo et al. (2021) and Ng et al. (2023) identified a critical gap in the current emphasis on skills development over core STEM content knowledge. While student exposure and practical experience with drones are crucial, a robust foundation in the underlying physics principles is equally important (Lobo et al., 2021; Ng et al., 2023). This gap aligns with Ng & Chu's (2021) study on integrating drones into STEM and Career and Technical Education (CTE) programs.

They advocate for effective implementation strategies that equip students with relevant drone-related skills while acknowledging the limitations of a purely theoretical approach (Ng & Chu, 2021; Ng et al., 2023). Here, incorporating active learning approaches, such as drone capstone projects, becomes essential to ensure students acquire both the theoretical knowledge and practical skills necessary for success in drone-related careers (Ng et al., 2023).

In conclusion, drone technology offers a powerful tool for revolutionizing education. It equips students with valuable skills, fosters a deeper understanding of STEM concepts, and prepares them for the future workforce. However, to fully harness this potential, future research and educational initiatives must move beyond a purely skills-based approach. A strong emphasis on integrating core STEM content knowledge alongside practical experiences is essential. This opportunity will ensure students develop a comprehensive understanding of drone technology, preparing them not only for the jobs of tomorrow but also for lifelong learning and innovation.

Additionally, continued international collaboration, as highlighted by the co-authorship analysis using VOSviewer, will be crucial for advancing the field through exchanging ideas and fostering innovation. Finally, addressing privacy, regulatory and ethical considerations emphasized by Ng et al. (2023) and Ng & Cheng (2019) remains paramount when integrating drone technology into educational settings. This comprehensive approach will ensure that drone education reaches its full potential and empowers all students to participate in this exciting and transformative learning experience.

Acknowledgements

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