

# ENGINEERING THE FUTURE OF HIGHER EDUCATION: A VOSviewer ANALYSIS OF SMART UNIVERSITY TRENDS IN THE DIGITALIZATION AND INDUSTRY 5.0 ERA

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## Abstract:

This manuscript aims to map the changing landscape of smart universities within the frameworks of digitalization and Industry 5.0, identifying key trends, challenges, and opportunities for observation. This study analyzes 8,061 Scopus database research papers from 2016 to 2024 by using VOSviewer for network visualization and bibliometric analysis. Centering around digitalization and Industry 5.0, the research explores literature that spans both the "smart" and "university" landscapes. The findings suggest a rich and fast-evolving field with a strong focus on the inclusion of advanced technologies, intelligent systems and intelligent pedagogies in higher education contexts, as well as significant international collaboration. Significant issues include the use of IoT, AI, and cloud computing for enhancing processes, learning environments, and safety on campus. This paper fills an important gap in the literature providing a thorough exploration of the smart university ecosystem through the lenses of digitalization and Industry 5.0, noting a significant point that technology will be an integral determinant in the future of higher education for both faculty and educational institutions. It sets out an exact blueprint for the way universities will become more responsive, efficient and networked institutions.

**Key words:** digitalization; industry 5.0; smart University, WOSviewer

*"We cannot solve our problems  
with the same thinking we used  
when we created them"*  
Albert Einstein

## INTRODUCTION

The current world is seeing an increasing influence of digital technology in professional and educational processes. The rapid advancement of information and communication technology has altered the nature of many facets of public life, much as the industrial revolution did in the 19<sup>th</sup> century [1]. The training of a contemporary expert includes the digitalization of education as a fundamental component. The significance and amount of information have been increasing steadily, and there are more multidisciplinary studies and initiatives as a result of these developments. Empirical research indicates that students nowadays are cognizant of the need to enhance their proficiency in artificial intelligence (AI), big data processing and analysis, and information and communication technologies (ICT) [2]. According to Chekanov and Neizvestny [3], the shift to a digital society places significant demands on the development of new specialized competences as well as the process of acquiring these competencies. According to Buryak [4], a specialist's "market value" in the job market is increased by education grounded on cutting-edge, future breakthrough technologies. In this context, the need of introducing and

analyzing novel ideas in the educational system as well as the modification of current forms, techniques, and training technology is becoming more pertinent [5]. Digitalization and industry 5.0 has had a significant impact on information technology, especially in the field of education [6, 7]. This trend of digitalizing education has been in trend for some time now. Nevertheless, we cannot overlook a significant increase in attention during the short-period communication constraints related to COVID-19 and the wider transition towards an entirely remote pattern of interaction for all the participants of educational process [8]. Digitalization has had a direct influence on the activities of students, teachers, administrators, and other stakeholders across all educational levels [9, 10, 11]. In addition to being a trend at the moment digitalization offers a bright future for development across many domains, including education [9]. Technological development will surely affect this route, albeit it may evolve in many ways. Higher education establishments have to not only accommodate the growing technology needs of Generation Z students, but also be ready for the oncoming wave of Generation Alpha. These and the COVID-19 problem in particular have caused most institutions to stick with hybrid models to varying degrees across all subject areas in their curriculum [10]. Industry 5.0 human-centered technical advancements enable the

conventional universities to be transformed into smart universities through the base layer of digitalization as follows:

1. Digitalization has a major impact on the functioning of the academic environment. Modern technologies significantly accelerate work from both the administrative and scientific side [11].
2. The human-centered strategy of Industry 5.0 focuses on the human-system cooperation explored during the digitalization process, which enabled technical innovations. Not only does this help embrace new technologies but it also allows smart universities to create conditions in which people and technology more completely operate in unison [12].
3. Smart universities indicate the ultimate stage of digitalization and Industry 5.0. Digitalization and Industry 5.0 together created smart universities, which utilize advanced technologies like AI, IoT, and big data to create a sustainable, flexible, and responsive learning environment [16, 17, 18].

To get to the next stage of university development – a smart university – we must create new conceptual models and pinpoint distinctive attributes, mechanisms, and technological advancements [13]. In an increasingly technologically advanced culture, smart classrooms, smart universities, and smart education are the way of the future. Ability to accommodate learners – one of the features that set a smart university apart is its potential to support a diverse set of students and learners. This ranges from normal and lifelong, in-classroom and online students and learners, to special students, that is, students having various disabilities (physical, visual, hearing, speech, cognitive, and other types of impairment) [14]. Smart universities are not only focused on teaching, but they also lead modifications in areas such as data-driven administration, safety, sustainability, environmental preservation. The constant influx of new technology affects itself how relevant activities can be executed in the fast-paced digital world we live in [15]. Smart Universities are characterized by several key features [22, 23, 24]. Cutting-edge tools like big data analytics to better decision-making, AI to customize learning, and IoT to improve campus operations are all used by them. Smart classrooms use virtual reality (VR), augmented reality (AR), and interactive technologies to create immersive learning environments, while e-learning platforms provide students flexible access to learning opportunities [16, 17]. Evaluating student achievement and enhancing institutional effectiveness are facilitated by data-driven decision-making. Personalized learning pathways powered by AI and intelligent coaching provide customized education [18]. While environmental sustainability is encouraged by green technology and practices, collaboration is enabled by digital tools, virtual laboratories, and international exchanges [19]. Even though the use of smart technologies, like AI, the Internet of Things (IoT), and big data analytics, in higher education has grown significantly, there is still a big knowledge gap about how these technologies can be fully utilized to improve campus operations, personalize learning, and enhance decision-making processes in smart universities. While a large number of institutions are using digital tools, there is still

variability in how these technologies are integrated across international educational systems, leading to differing degrees of success in terms of enhancing student results and operational effectiveness. Digital tool use is widespread, but there is still variation in how these tools are integrated into international educational systems, leading to differing degrees of success in terms of enhancing student results and operational effectiveness. Furthermore, little study has been done on how AI, IoT, and big data work together to create individualized learning environments and how this affects student engagement and administrative effectiveness. The intricacy of customizing learning experiences via data-driven insights is still a barrier, particularly when it comes to broad adoption in intelligent university systems. By methodically examining how these smart technologies are being used in the context of Industry 5.0 and placing an emphasis on technological integration and human-machine cooperation in academic settings, this research aims to close this gap. This manuscript intends to give a greater understanding of the revolutionary potential of AI, IoT, and big data in higher education by examining how these technologies shape individualized learning paths and streamline campus operations. Bibliometric analysis was the main technique used in this study to evaluate and analyze manuscripts on smart universities in a methodical manner. 8061 research publications were taken into consideration from the academic website Scopus from 2016 to 2024. This manuscript poses the following research questions:

1. What patterns of collaboration can be identified in the network visualization of co-authorships between different countries in smart university research, and how do these collaborations impact the adoption of key technologies like AI, IoT, and big data?
2. What are the most frequent terms found in the full scientific articles on smart universities, and what do these terms reveal about the key challenges and opportunities in the field?
3. Which keywords are most commonly used by authors in smart university research, and how do these keywords reflect the evolving technological trends and future directions of the field?
4. What are the most frequently used index keywords in smart university research, and what do they suggest about the focus, scope, and potential future growth areas in smart university studies?

This manuscript is organized as follows: Section 2 presents literature review. Section 3 demonstrates the research methodology. Section 4 explains the results. Section 5 further discusses of the findings; Section 6 gives conclusions and recommendations.

## LITERATURE REVIEW

The idea of a "smart university" is a new and rapidly developing field that embodies the clever fusion of cutting-edge ideas, intelligent hardware and software systems, smart classrooms outfitted with cutting-edge tools and technological platforms, smart pedagogy grounded in contemporary teaching and learning techniques, smart learning analytics and academic analytics, and numerous computer science and computer engineering specialties [20, 21]. The

authors [22] contend that the foundations of a smart university are found in the comprehension and critical awareness of fundamental information, in the identification of more practical competences, and in the exploration of the definitions of a "smart university community" that values excellence. The idea of a "smart university" entails completely updating every aspect of education [16]. A smart university is one that integrates cutting-edge technology into its operations to further its goals [23]. An institution that uses innovative technology (such as the IoT, smart gadgets, etc.) within its own walls in order to accomplish its strategic goals is known as a "smart university." Being at the forefront of technological breakthroughs and becoming a Smart University requires technical innovation, especially in the areas of computer innovation and data systems. Smart universities, which combine cutting-edge technology, creative pedagogies, and data-driven approaches to create adaptable, effective, and stimulating learning environments, are the vanguard of higher education. The goal of these institutions is to serve the changing demands of the

21st-century society, faculty, and students [33, 34, 35]. When compared to the traditional university model, e-learning reduces labor costs for administrators, executives, and students alike. As a result, astute universities adopt new technology that enables students, faculty, and administrative staff to use automated systems and tools, incorporating new technologies such as cloud computing, big data, e-learning, IoT or Green-ICT. A university is referred to be a "smart university" when these modern technologies are integrated. IoT is a component of new technology that a smart learning framework may work with to enhance the quality of its services by offering a customized learning environment [24]. Smart objects are becoming increasingly commonplace in many educational domains. Smart education is one of the key components in the implementation of IoT smart cities, which are made possible by digitalization and virtual learning, among the smart services facilitated by emerging technologies like IoT [25]. Table 1 present chosen studies concerning issues related to smart Universities.

**Table 1**  
***Chosen studies concerning issues related to smart Universities***

| Author(s) | Methods                                                                                                                                                                                                                                                                                  | Analysis aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [26]      | The manuscript has discussed the RFID issue and presented how the emerging technology of RFID can be used to build a smart university. A prototype is developed considering the major use cases involved in a smart university.                                                          | The system is taking care of maintaining attendance records, switching control of electrical items, and securing rooms. Results show that consumption of energy and object tracking time are decreased while security of rooms and credibility of attendance records are increased.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| [27]      | The manuscript does a literature study to provide context for the Internet of Things, emphasizing its critical role in the Smart Campus and its onnection to wireless sensor networks and cybersecurity.                                                                                 | The authors discuss the different linkages, trends, and potential growth of a smart campus in addition to highlighting the distinctions and parallels with the recently developed idea of a smart university. This analysis showed that the Internet of Things is pervasive across all domains and has the potential to enhance institutional procedures in order to support academic instruction, technology advancement, and decision-making.                                                                                                                                                                                                                                                                                                                                                                                                        |
| [28]      | The improvement of positioning, one of smart mobility's essential elements, is the main emphasis of this article.                                                                                                                                                                        | The authors created and implemented a unique indoor positioning system (IPS) that works in tandem with an outside positioning system to provide seamless wayfinding and navigation both inside and outside. The location solution is integrated as a service inside SmartUJI, our larger platform for smart universities based on cartography. The SmartUJI APP, which provides map-based information about the campus's various facilities, and the SmartUJI AR, which lets users interact with the campus through an augmented reality interface, are two end-user mobile applications that the authors developed, deployed, and evaluated using our IPS and the SmartUJI services. The programs' utility in identifying university resources and overall enhancing spatial orientation was noted by visitors, faculty, and students who tried them. |
| [29]      | An assessment and test of the suggested methods are conducted in a case study of a Smart University campus.                                                                                                                                                                              | In the context of the Society 5.0 framework, this article suggests a customized service strategy for smart grids that uses social and contextual data, sophisticated algorithms, and cutting-edge sensing technology to provide users a tailored energy management solution. The article also suggests an architecture for the development and implementation of customized energy management services in various Smart Grid scenarios, highlighting the potential of personalized services in the context of the Smart Grid and its applicability within the Society 5.0 framework. With this method, end customers actively participate in the development and implementation of customized energy management services.                                                                                                                              |
| [30]      | The research created a unique evaluation framework known as the Smart Campus evaluation Framework, which consists of 48 indicators, using a narrative literature review technique. This framework is a great place to start when looking to advance evaluation in smart campus research. | By presenting the first complete evaluation methodology to evaluate university campuses for smartness, this study expands on previous conceptual work.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

"Digitalization" refers to the integration of digital technologies into all aspects of university operations, encompassing administrative and academic procedures. Coccoli et al. [31] state that digitalization allows universities to use technology-driven tools like learning management systems (LMS) and e-learning platforms to improve the quality of education and simplify operations. These real-time data collection and analysis systems for students enable instantaneous feedback and individualized learning pathways, thereby enhancing academic performance. The application of smart technologies like the IoT enables smart campuses, where networked devices effectively monitor and manage campus amenities, promote sustainability, and optimize resources [32]. Digitalization, however, entails more than simply integrating technology; it also entails changing instructional approaches. Smart institutions use smart pedagogy, which replaces conventional one-size-fits-all teaching methods with data-driven techniques. Uskov et al. [33] contend that this change makes education more student-centered and adaptable to meet individual learning demands by enabling more personalization of the learning process. As a result, digitalization is critical to the development of smart universities because it creates environments that are inclusive of all students while also utilizing cutting-edge technology. Industry 5.0 is a human-centric approach, highlighting the cooperation between people and intelligent technologies, in contrast to Industry 4.0, which concentrated on the automation of processes and data interchange across several areas [34]. This paradigm change is essential for smart institutions that use technology to enhance student learning, automate processes, and enhance human connections. Martynov et al. [35] assert that the integration of AI and machine learning (ML) into educational systems can provide students with individualized learning experiences tailored to their unique requirements and skills. Because of this human-machine partnership, intelligent institutions are able to use AI to track students' progress and provide them with immediate feedback via intelligent tutoring systems. With the use of these tools, teachers may step in when needed and provide specific assistance to problematic students. The humancentric approach of Industry 5.0, as highlighted by Petrusevich et al. [36], is in line with the objectives of smart universities, fostering settings where technology and human educators collaborate to provide more efficient and intriguing learning opportunities. Smart university models heavily rely on the idea of individualized learning. Universities can tailor the learning process to each student's specific needs by utilizing AI and adaptive learning technology. According to Wu et al.'s [17, 37], customized learning systems allow students to advance at their own speed by modifying exams and instructional material in real-time depending on their performance. Conventional educational institutions often expect students to adhere to a set curriculum, regardless of their unique learning requirements, in contrast to this method. Enhancing academic performance via personalized learning also increases student engagement. Students in individualized learning settings are more likely to

take charge of their education, establishing objectives and monitoring their progress, according to Ayeni et al. [38]. By focusing on areas where students may need extra help, teachers can better tailor their instruction to meet the requirements of each individual student by using adaptive learning technologies. Researchers from clever universities collaborate internationally to a significant extent, demonstrating the global character of their research. Carayannis & Morawska-Jancelewicz [39] demonstrate, using bibliometric analysis, that the United States, China, and Italy are at the forefront of the development of smart university models. International collaborations make it easier to exchange cutting-edge technology and best practices, assisting academic institutions all over the world in putting intelligent, specially designed solutions into effect. According to Polin et al. [30], institutional preparedness and resource availability are just as important to the success of smart universities as technology adoption. Based on the above analyses, this paper proposes the following hypotheses:

**Hypothesis 1:** As evidenced by keyword co-occurrence and collaboration patterns, smart universities' integration of AI, IoT, and big data improves academic outcomes and decision-making processes by facilitating more efficient campus operations and individualized learning pathways.

**Hypothesis 2:** The combination of adaptive learning systems and AI-driven technologies that meet the different requirements of students demonstrates how Industry 5.0's focus on human-machine cooperation in smart universities creates dynamic, customized, and inclusive learning environments.

**Hypothesis 3:** Co-authorship networks, a visual representation of international cooperation in smart university research, promote innovation and best practices while hastening the worldwide adoption of educational technologies, especially in critical domains like AI, IoT, and big data integration.

**Hypothesis 4:** Frequently appearing phrases connected to smart learning environments and technology breakthroughs show that higher education is moving toward data-driven, responsive, and student-centered pedagogical approaches as a result of the adoption of AI-driven learning analytics and smart classrooms.

## MATERIALS AND METHODS

Co-authorship networks, keyword co-occurrence, and index keywords were the metrics used for this study because they provide a strong grasp of the major trends, theme structures, and cooperation patterns in smart university research. The degree and kind of global cooperation in the area were assessed using this measure. This metric offers insights into the dynamics of knowledge creation and technology adoption throughout the world by determining which nations and academics make the most contributions to smart university research. Given the international character of technology improvements in higher education, this is especially crucial. To find recurrent topics and new trends in the literature, keyword analysis was used. This statistic reveals significant technical

and educational goals in smart university research and provides a detailed perspective of how certain themes (such as Industry 5.0, smart learning environments, and IoT) dominate the research landscape. The study focal areas were categorized via the use of index keywords. This makes it clearer which innovations in technology and teaching methods have been studied the most, guaranteeing a thorough grasp of the range of the study. The criteria used for this investigation were predicated on software capabilities and accepted bibliometric procedures. VOSviewer's unique capability to map bibliometric links led to the choice to utilize it for network visualization, enabling a more natural comprehension of intricate data sets. One of the main reasons for choosing VOSviewer was its ability to handle co-authorship and keyword co-occurrence data from Scopus database. The use of Scopus as the main database guarantees that the study is grounded on reputable, peer-reviewed literature, offering trustworthy insights into the evolution of the area. The content of 8061 research articles has been taken into consideration since 2016 and 2024 (Fig. 1).

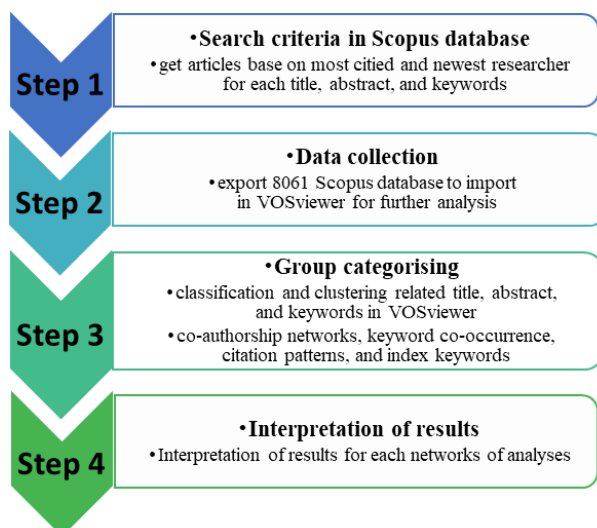


**Fig. 1 Steps in bibliometric analysis**

The time frame was chosen to reflect current advancements in digitalization and smart university technology. This guarantees that the study is relevant to both present and anticipated future developments in the field of higher education. A comprehensive bibliometric analysis is ensured by the entire and freely available data from this time period. The conference paper (4007), article (3490), book chapters (439), were taken into consideration. The search documents related to the “smart” and “University” issue are in title, abstract, and keywords. Through the inclusion of these particular document categories, the study guarantees a comprehensive representation of the scientific discourse on smart universities, including both practical and theoretical research. This manuscript poses the following research questions:

1. What patterns of collaboration can be identified in the network visualization of co-authorships between different countries in smart university research, and how

do these collaborations impact the adoption of key technologies like AI, IoT, and big data?

2. What are the most frequent terms found in the full scientific articles on smart universities, and what do these terms reveal about the key challenges and opportunities in the field?
3. Which keywords are most commonly used by authors in smart university research, and how do these keywords reflect the evolving technological trends and future directions of the field?
4. What are the most frequently used index keywords in smart university research, and what do they suggest about the focus, scope, and potential future growth areas in smart university studies?

The co-authorship network statistic was used to examine the trends in researcher and national cooperation. It indicates which nations and scholars have the most influence on clever university research. This measure, which visualizes the networks of co-authorship across nations, directly answers the research topic on international collaboration. It identifies the top countries in this field and illustrates the distribution of research contributions across geographical areas, demonstrating the level of international collaboration in promoting smart university models. It also aids in locating key writers and cooperative groups that are influencing the field. Analysis maps the thematic structure of the study area and highlights term linkages by measuring the frequency with which keywords occur together in academic manuscripts. In order to address research concerns about the most often used words and important keywords in clever university study, this statistic is essential. The study provides insights into the evolution of the smart university idea by mapping out the leading research subjects and developing trends within the area by finding the most often occurring phrases. It displays the main areas of interest for academics and highlights innovative fields like e-learning, AI, IoT, which are essential to the growth of smart universities. Analysis is concerned with determining the linkages between cited papers and how often research publications reference one another. Through the identification of foundational works that serve as the basis for later study, this statistic is essential for comprehending the development of the discipline. Finding the papers and scholars who are most often cited may be helpful in illuminating the core literature that influences the conversation about smart universities. This lends credence to the study question about the most important papers and writers in the area. The standard keywords that the database provides to classify research papers are the main focus of the Index Keywords study. These keywords aid in categorizing the articles according to their scope and subject matter. This measure is particularly important for a more comprehensive investigation's scope and focus, by elucidating upon the most frequently used index terms. This gives a general idea of how research on smart university has been classified and organized. It also aids our understanding of the broader themes guiding that study and characteristics of smart universities that are receiving the most focus now, be it

sustainability, educational change or technology integration. Term Density Mapping provides the glimpse of the frequency and intensity of term use across the whole body of literature. This statistic correlates with a better understanding of the subject areas and research focus of the field. It does so by mapping the major research clusters and key topics of inquiry, providing a clear sense of where intellectual action is concentrated. This overview of the smart universities discourse is obtained by answering all the three index and most common questions in the study. Bibliometric analysis offers a rich perspective of global research patterns by showing how countries engage in smart university research through co-authorship networks. The analysis of these networks directly speaks to the research topic of international co-authorship by revealing leader countries and how they promote smart university models. Examining term frequencies and keyword analyses as bibliometric methods identifies potential terms and phrases, based on rich academic formats drawn from various research work. This would be to plan where the most frequented body of research and emerging areas are, which is of direct relevance to the type of research questions used regarding the most cavalcade phrases and terminology. Bibliometric visualization tools like VOSviewer help render these results in an intelligible graphic form by plotting links between authors, keywords and countries.

## RESULTS

Fig. 2 presents the country co-authorship network of smart Universities related publications with five clusters (minimum number of documents of a country: 20). Figure 2 has a variety of colors, indicating the diversity of research topics. The large nodes represent the influential countries. The links between nodes represent the cooperative relationships among countries. The distance between the nodes and the thickness of the links represent the level of cooperation among countries.

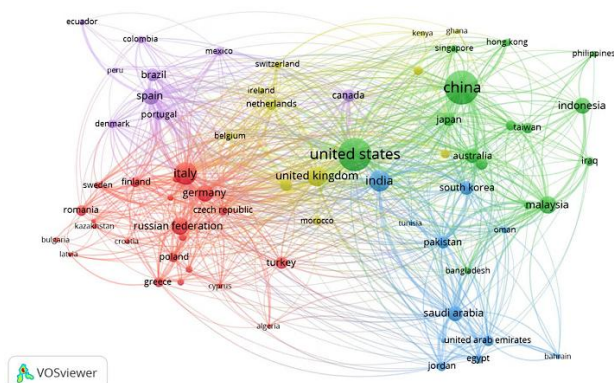


**Fig. 2 Co-authorship countries**

The co-authorship network found many clusters, with China, Germany, Italy, India, the United States, and the United Kingdom heading distinct groupings. These clusters demonstrate the global cooperation within the research community of smart universities. Every cluster exemplifies institutional and regional collaboration. Italy, spearheading the Red Cluster, boasts the most

participating nations, showcasing its leadership in organizing extensive cooperative initiatives related to smart universities. It's possible the EU legislation promoting digital education has led to an interest in smart technologies in higher education among some European nations. The United States and China lead the Green Cluster – a successful example of cooperation among the big science and technology powers. This indicates that studies from these countries are significant contributors to global policies regarding smart universities, particularly in relation to advances in artificial intelligence (AI), Internet of Things (IoT), and big data, which are vital technologies involved in the establishment of smart campuses. The other Clusters (India, Germany, France, Spain, etc.) are leading smaller, but still important research networks, all of which provide regional perspectives to the international dialogue on smart universities. India within the blue cluster, for example, highlights the country's growing investment in digital education solutions, particularly relevant given its large and growing student population. These clusters' worldwide reach indicates the need for improved international cooperation regulations. Smart university research leaders may operate as role models, with their approaches influencing international best practices. The expansion of collaborative financing methods, such as EU Horizon funding, is necessary to enable international research on educational technology. The international flow of ideas within these clusters may directly influence best practices for smart universities worldwide. To keep up with smart education advancements, universities should strengthen their overseas collaborations, particularly with establishments in highly developed nations such as China, the USA, and Italy. This global partnership is indicative of a shared goal to build technology solutions for postsecondary education. Policies to promote the international collaboration in the development of such technologies among countries like big data, artificial intelligence and the Internet of Things may speed up the accepted project of smart university in the world. Figure 3 shows co-occurrence and all key words with a number of occurrences of a keyword that is 100.

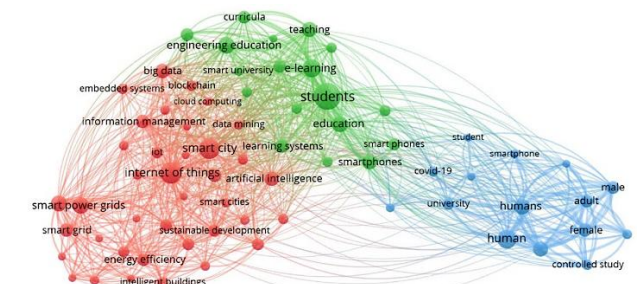


**Fig. 3 Co-occurrence – all key words (number of occurrence of a keyword 100)**

Key themes, including "Internet of Things," "smart city," "e-learning," and "higher education," were the focus of multiple clusters and dominating phrases identified by the keyword co-occurrence analysis. A broad nexus between



importance of "big data" and "artificial intelligence (AI)" in the development of smart institutions. The term "machine learning" emphasizes the expanding use of predictive analytics in education, while the existence of "smart grid" indicates the convergence of AI with campus energy management and operational efficiency.

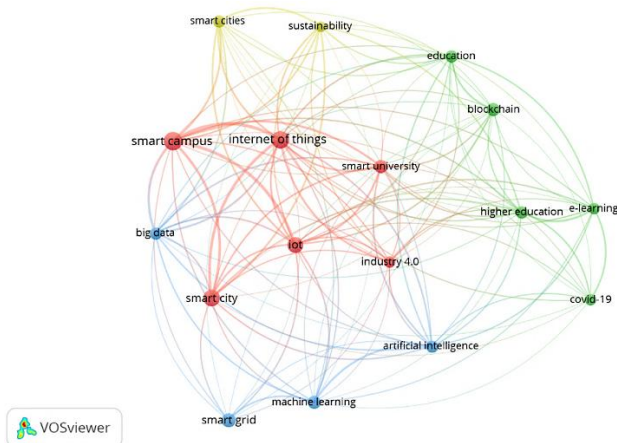


**Fig. 5 Co-occurrence – author key words (number of occurrence of a keyword 100)**

The terms "smart city," "sustainability," are associated with the Yellow Cluster. This cluster focuses on the integration of smart university projects with more comprehensive urban plans, including smart cities. Authors often describe the technical foundation supporting the development of smart campuses with sustainability as the primary objective. The emphasis on "sustainability" implies that intelligent universities are worried about lessening their environmental effect via green practices and technology, in addition to technical innovation. The Green Cluster with the keywords "e-learning," "blockchain," "COVID-19," and "higher education" is particularly indicative of current research tendencies. The words "E-learning" and "blockchain" are used, indicating that the emphasis is on how universities are using scalable, safe technology to facilitate remote and hybrid learning methods in response to the worldwide health crisis. The red and yellow clusters indicating the intersection between "smart city," "IoT," and "sustainability" highlight the need for integrated policy frameworks that link smart university programs with municipal sustainability plans. In order to foster sustainable growth and innovative teaching, policymakers should encourage cooperation between municipal and university administrations [40]. The epidemic has expedited the ongoing transition to digital learning paradigms, as seen by the inclusion of "e-learning" and "COVID-19" in the green cluster. In order to ensure that learning continues even in times of crisis, educational policies should place a high priority on the creation of scalable, digital platforms. The focus of the blue cluster on keywords "artificial intelligence," "big data", and "machine learning" implies that universities need to spend money on predictive technologies that improve both operational effectiveness and individualized instruction. Integrating AI-driven data into university administration systems may enhance decision-making, resource allocation, and student results. Figure 6

shows co-occurrence and index key words density visualization with number of occurrence of a keyword 80. These consist of "e-learning," "smart campus," "IoT," "smart city," and "students." The terms "students" and "e-learning" are used a lot, which highlights the significance of learners in astute university research. This suggests that a significant amount of research focuses on using smart technology to improve the educational experience for students and increase access to education via digital platforms. The rise in use of phrases like "smart city" and "IoT" highlights the connection between smart universities and urban development programs. This points to a rising interest in the ways that universities may both use and contribute to smart city technology.

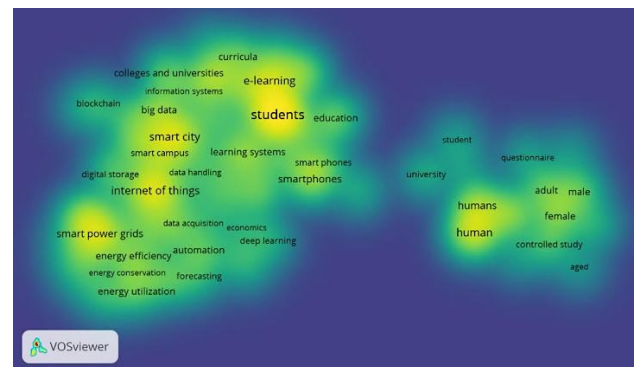


**Fig. 6 Co-occurrence – index key words density visualization (number of occurrence of a keyword 80)**

"Smart campuses" are becoming more common, which is in line with other clusters that concentrate on digital and physical environments. This emphasizes the need for campuses to be ecologically sustainable and technologically sophisticated. The focus on "students" and "smart city" implies that student-centered strategies that support urban development objectives should take precedence in educational programs. Governments should enact laws encouraging universities to work with urban planners to develop integrated smart campuses that support more innovative urban design. The emphasis placed heavily on "e-learning" highlights the significance of adaptable digital learning paradigms. It is essential that educational methods prioritize the ongoing advancement and enhancement of digital platforms, guaranteeing that students, irrespective of their geographical location, may get individualized, superior instruction. The terms "IoT" and "smart campus" are becoming more and more common, which indicates that universities must make IoT infrastructure investments. In order to build more responsive and adaptable campus settings, this might include smart classrooms outfitted with environmental sensors for energy efficiency, real-time data analytics, and cutting-edge connection options. The research's bibliometric trends uncover important patterns in the growth of smart universities and provide practical advice for directing their future, especially in the context of Industry 5.0. We can identify important areas for development and potential in the evolution of smart universities by examining co-authorship networks, keyword occurrences, and index keyword frequencies. The examination of co-authorship networks reveals

the robust international cooperation that propels the agenda for smart universities. Leading nations in these efforts include Germany, Italy, China, and the United States. These networks of cooperation are dense and allow for the sharing of advanced technologies like big data, IoT, and artificial intelligence. International collaboration like this quickens the implementation of Industry 5.0 concepts, especially intelligent systems and human-machine interaction. To embrace best practices and promote innovation internationally, universities should take advantage of these international collaborations. The formation of global research consortiums and cooperative initiatives may augment information exchange and expedite the advancement of intelligent university projects. Personalized learning pathways, student-centered learning, and the incorporation of adaptive technologies like AI-driven learning analytics are becoming more popular, according to a study of frequently used phrases in scientific papers. According to these developments, higher education will likely depend more and more on personalized learning experiences that are catered to each student's unique requirements in keeping with Industry 5.0's human-centric philosophy. In order to increase student engagement and results and create more responsive learning environments, universities should invest in adaptive learning systems and AI-driven analytics. The significance of combining smart technology with sustainable practices is shown by the bibliometric analysis's frequent appearance of keywords like IoT, smart campuses, e-learning, and sustainability. The objective of Industry 5.0, which is to integrate intelligent and human systems to build more sustainable and efficient campuses, is closely linked to the drive towards smart infrastructure. To improve operational efficiency and environmental responsibility, educational institutions should give priority to investing in IoT-based campus management, energy-efficient systems, and sustainable technology. Words like "e-learning," "digital transformation," and "smart pedagogy" are showing up more often, as the keyword co-occurrence analysis shows. This suggests that old pedagogical approaches are giving way to more flexible and technologically enhanced education. The focus of Industry 5.0 on fusing technology and human-centered education to enhance learning outcomes is in line with this. To provide more individualized, dynamic, and interesting learning experiences, universities should create blended learning models that include virtual learning environments, smart classrooms, and real-time data analytics. A rising dedication to Industry 5.0's environmental concerns is shown in the frequent occurrence of sustainability-related terms in the context of smart universities. Academic institutions must consider how smart technology adoption advances larger social and environmental sustainability as well as other societal objectives. In addition to implementing green technology, such as smart grids, energy-efficient structures, and renewable energy sources, universities should make sure that their instructional technologies are usable by students from a variety of backgrounds, including those who have impairments. The co-occurrence of phrases like

"IoT," "smart campus," and "sustainability" indicates a rising academic interest in the integration of smart university infrastructure with smart city infrastructure, as shown by the VOSviewer study of co-authorship networks. Though the bibliometric data shows encouraging patterns in research cooperation, the keyword frequency analysis does not fully convey the actual difficulties institutions have when trying to integrate with larger smart city networks. The technological compatibility of university IoT systems with citywide infrastructures is one of the main challenges. Universities often have difficulties integrating their internal systems with external municipal infrastructure, despite the academic literature's emphasis on the advantages of linked IoT networks for resource optimization and energy management, as shown in VOSviewer. Significant obstacles are presented by legislative and policy frameworks in addition to technological difficulties. A common dedication to developing smart campus technologies is shown by the VOSviewer study, which highlights international research cooperation, especially between countries like China, Italy, and the United States. Universities must, however, negotiate diverse regulatory environments when integrating with regional smart city regulations, especially when it comes to topics like energy management, cybersecurity, and data protection. For instance, regional variations in data privacy rules necessitate that universities make sure the massive volumes of data gathered from IoT devices, AI-powered learning platforms, and campus management systems adhere to both national and international regulations. The difficulty of following these rules, especially when working with other countries, may result in delays and higher expenses since institutions must have strict security measures in place to safeguard institutional and personal data. Furthermore, different towns and nations have different energy laws and sustainability requirements, which makes it more difficult to integrate university energy systems with smart networks that span the whole city. Universities must make sure that their systems abide by regional sustainability and environmental rules if they want to help a city achieve its sustainability objectives by using smart technology to reduce energy usage. In order to guarantee that the technology systems and rules are compatible, university officials and municipal planners must negotiate, which may be a time-consuming procedure. An aspect that is not apparent in bibliometric maps but is crucial to practical applications is ensuring compliance with local legislation while interfacing with municipal services, which sometimes slows or complicates the implementation of smart university programs. Although they are not immediately apparent in VOSviewer's keyword and co-authorship analysis, these legislative obstacles are essential to figuring out how well universities can integrate with larger smart city infrastructures. The VOSviewer study does identify collaborative groups that indicate possible future directions in spite of these obstacles. Shared financing possibilities and international collaborations, like those among European institutions, may be able to lessen some of the financial and legal obstacles. Even while these

partnerships are part of the academic network, they also offer a crucial practical approach to resolving the many problems associated with coordinating smart university and smart city projects.

## DISCUSSION

On a new technological basis, a digital culture is beginning to take shape, characterized by the digitalization of all social activities. The globe is changing into a digital environment of the information society [41]. The ideas of Industry 5.0, digitalization, and smart universities are interconnected and have the potential to significantly impact higher education in the future [48, 49, 50]. The term "digitalization" describes how digital technology are incorporated into routine tasks, radically changing the way businesses, especially educational institutions, run. Through data analytics and digital platforms, Universities may now provide individualized learning experiences, maximize resource management, and improve administrative efficiency. Industry 4.0, which focused on automation and data interchange in production, set the groundwork for Industry 5.0 [42, 43]. Industry 5.0 emphasizes human-intelligent system cooperation [44, 45]. It encourages a human-centric strategy in which cutting-edge technology like robots, AI, IoT collaborate with human intelligence to build more robust, adaptable, and effective systems. Smart universities are living examples of Industry 5.0 and digitalization [46, 47]. These establishments incorporate state-of-the-art technology to provide intelligent and networked learning environments. Smart universities improve the learning experience by using IoT, AI, and big data analytics, making it more personalized and engaging for each student. Additionally, by streamlining administrative duties, these technologies increase operational effectiveness and free up educators to concentrate more on teaching and research. There is a symbiotic link among these three ideas. The process of digitalization gives conventional universities the technical foundation they need to adopt Industry 5.0 concepts, which propels their transformation into smart universities. Smart classrooms with cutting-edge technology, data-driven decision-making procedures, and individualized learning programs that accommodate a variety of student groups are characteristics of this shift. Digital twins, cobots, hyper-personalization, mass customisation, and other enabling technologies together referred to as Industry 5.0 are driving the industrial revolution [48, 49]. Values are the engine of Industry 5.0 (IR5.0). Industry 5.0 – also referred to as the "Age of Augmentation" – is defined by the peaceful coexistence of people and technology [50]. Industry 5.0 is the outcome of humans and machines working together. An autonomous workforce will have a deep understanding of human motivation and purpose. In the workplace, humans and robots will cohabit not only courageously but also confidently because people will know that their robotic coworkers will be able to interact and collaborate with humans effectively. It will result in a manufacturing process that is highly productive and adds value, a flourishing autonomous system that can be trusted, and a reduction in

waste and associated costs. Industry 5.0 will change the definition of a "robot." Robots will not only be programmed devices that can do repetitive tasks, but they will also sometimes make ideal human companions. Cobots, or the next generation of robots, will emerge during the next industrial revolution and will be able to accomplish tasks quickly and intelligently, enabling the creation of robotic goods with a human touch. These cooperative robots will take care of safety and risk standards since they are aware of human presence. They have the capacity to see, understand, and feel not only the human being but also the goals and expectations of a human operator [51]. Building a better society where workers are happy with their lives and ready for higher productivity and automated processes is the primary objective of Industry 5.0. Industry 5.0 elements include penalization, user-based customisation, integration of the cognitive domain into human intelligence, and a shift to a natural environment. So, the motivation behind Industry 5.0 is the development of creative societies, and the central technology of this movement is human-robot interaction using repeating energy [9]. Universities all over the world must adjust and change the way they inspire today's students by giving them access to cutting-edge learning environments that will not only inspire students but also enhance the caliber and reputation of the institution, given how students are currently evolving and growing with the world of new technology. It is imperative that conventional universities change to become smart – that is, contemporary and intelligent – in the current world [52]. The following characteristics of a smart university might be listed:

- Smart Hardware & Software Systems: This clever device is a hardware and software system that helps to improve administrative and learning processes, setup.
- Smart Classrooms: These classrooms are equipped with cutting-edge technology and equipment to facilitate flexible and interactive learning, allowing teachers to design more interesting and successful classes.
- Personalized Learning Environments: Educators can create custom-tailored learning environments embracing the IoT and other technologies by recognizing the individualized needs of each student, thereby enhancing engagement.
- Smart pedagogy can be defined as innovative teaching strategies that are designed according to modern learning theories and practices, encouraging student engagement through introducing technology into learning environments.
- As such, a data-driven method of understanding and improving learning processes is Smart Learning Analytics (SLA). From tracking individual student progress and predicting results to creating personalized learning experiences.
- Specialization in Computer Science and Computer Engineering: A concentration on computer-related fields, representative of technology foundation of smart universities and their contribution to advancement of these fields through research and pedagogy.

- Sustainability Initiatives: Efforts to implement environmentally friendly processes and technology in university operations supporting sustainability as a core value and helping with environmental conservation.
- Knowledge Exchange and Community Engagement: Smart universities are marked by partnerships with other institutions, enterprises and communities, as well as linkages to the global educational and research community.

With perspective to Industry 5.0 and virtualization, the present study provides a detailed insight into the transformation of smart universities. Bibliometric analysis and visualization enabled us to determine key trends, collaborations, and technical developments and to access relevant new insights into the future of higher education. The results clearly indicate the significance of big data, IoT and AI technologies in improving campus operations and learning environments. This outcome supports Hypothesis 1, which assumed that the smart institutions' adoption of such technologies will enhance campus operations and personalized learning paths will yield positive academic outcomes and aid decision-making. On the co-occurrence analysis, it is being used frequently, with phrases AI and IoT, which even further supports this hypothesis by demonstrating a popular trend in the development of smart campus building blocks. Moreover, such technologies also empower students sensitive and flexible smart learning environments that meet students' needs. This reinforces the fact that technology alters the way students learn in a diverse range of ways and shows the important role played by nowadays AI and big data when it comes to customized education approaches. Secondly, the results are consistent with Hypothesis 2, which stated that the focus of Industry 5.0 on human and machine collaboration leads to dynamic and inclusive learning environments. The keyword analysis's frequent usage of phrases like "personalized learning systems" and "adaptive learning" demonstrates how these technologies meet the demands of a wide range of students, including those with impairments. Even though the data clearly point to the development of customized learning environments, further research into certain assistive technologies would strengthen the case for this theory. There are personalized learning environments powered by AI, improving academic outcomes and student Further research should explore in more detail the steps that AI can take to improve accessibility for children with specific learning needs. The results of co-authorship network analysis sequentially show that a world coalition is important for speeding up both the research and the technological use of smart universities. The emergence of nations leading the global network (such as the United States, China, and Italy in Hypothesis 3), validated the research findings. The results show that data-driven decision-making is increasingly becoming a fundamental component of smart universities, and that responsive pedagogical models are being significantly shaped by technologies such as AI-driven learning analytics. This confirms Hypothesis 4, which supposed the application of data-driven strategies and

student-centered methodologies in higher education are also growing due to the academic adoption of AI-based analytics and smart classrooms. The co-occurrence of learning analytics and smart classrooms as keywords in the analysis signifies a set of keywords being used to frame institutional proactivity in adapting to these new paradigms as learning analytics becomes more widely used. Such enhanced information can lead to better decisions, more effective monitoring of student outcomes, and the tailoring of learning opportunities to meet individual needs. Universities must accelerate and expand international collaboration in the fields of big data, IoT, and AI technologies. New technology diffuses faster due to international collaboration (co-authorship networks). International collaborations could be used to share resources, best practices, and strategies at institutions in order to break down barriers to technology adoption. In addition, their leadership position in technology might be maintained as universities work towards greater international cooperation and better deal with the challenges of smart university development. This makes the collaboration very important as smart technology needs to be weaved into different ecosystems of education. To improve student results, establishments need to invest in AI-powered studying analytics and personalised studying environments. There is a growing trend towards using these technologies for personalised learning routes. Universities must prioritize integration of AI and big data to enable more agile and student-centered approaches to teaching. Not only do personalized learning environments foster greater student engagement, but they also lead to higher accomplishments. By applying these technologies, universities will also be able to serve the differing requirements of their student bodies: students with impairments for example. For instance, although some countries may catch on faster to adopt certain technologies than others, educational group need to plan ahead with integrated approach on implementation of smart technologies to avoid such gap. The disparity in success rates between institutions suggests that constant investment in IoT and AI not only seem to take a heavy toll, they also carry with them a lot of obstacles as well. This gap may be partially bridged by developing models that scale well to implementation. Less disparate approaches to technology integration lead to a more evenhanded access to the benefits of smart universities, ensuring that no student is deprived of a benefit of state-of-the-art learning environments simply by virtue of their institution. Astute institutions have to include sustainability into their strategy for developing new technologies. The results demonstrate the increased emphasis on green practices, energy-efficient campus management, and smart grid technology. Investments in green technologies, such as IoT-enabled resource management and energy-efficient buildings, should be given top priority at universities. Data-driven decision-making need to be a proactive part of academic and administrative procedures at universities. Educational institutions are able to use AI, big data and learning analytics to keep track of students' accomplishments, resource utilization behaviour and how

effectively things are running operationally. By this means, we can make more targeted interventions—such as offering at risk kids the personalized academic support necessary for them to keep up or to drop in as infrequently as possible while not using too many scarce resources in doing so. With data and analytics, institutions will be able to make the changes to be effective and provide responsive services that lead to improved student outcomes and make the best use of resources. In this rapidly emerging landscape of higher education, it will also enable institutions to stay competitive and innovative by continually adapting to shifting educational needs. Analysis shows the multidisciplinary aspect of smart university research. Thus, computer science, educational technologies, sustainability studies and social sciences converge on its way to the promise of digitalization in higher education and reflects the need for a multidisciplinary approach to the subject. This multidisciplinary approach fosters an inclusive, dynamic, and future-ready learning environment while ensuring that smart technology implementation meets technical as well as human-centric needs. That significant level of worldwide cooperation, as observed in the figures showing coauthorship networks, suggests we share a vision and commitment to worldwide transformation of higher education. Our work with others is mutually beneficial; it allows us to share best practices, overcome technical and pedagogical hurdles, as well as create knowledge that transcends geographic and disciplinary boundaries. The range of research clusters showing that developing smart universities is an international undertaking, with various areas contributing unique knowledge and innovative ideas. The results highlight the critical roles that cloud computing, AI, and IoT have in the shift to smart campuses [53]. These technologies are not just helping hands; rather, they are starting to shape the entire concept of what makes a university smart. They enable innovative research methods, effective campus administration, and individualized learning experiences. But there are downsides to leveraging these technologies, including data privacy issues and ethical considerations, as well as the requirement that all parties are digitally literate. In this chapter, author highlight the potential for smart technologies to change the higher education landscape, but note challenges facing their implementation. That would produce a more balanced perspective – and constructive suggestions to universities as they face this transition. Thus, financial constraints are one of the primary challenges because using modern technologies such as AI, IoT, and big data analytics may require a large amount of fixed investment. The high upfront costs for the equipment, software and infrastructure, coupled with ongoing maintenance and operating costs can be especially problematic for schools with limited funding. This could exacerbate inequalities in access to intelligent learning environments. Innovative financing methods such as public-private partnerships and global funding platforms such as the EU Horizon initiative can mitigate these financial challenges. Another major challenge is faculty preparation and training since faculty and

administrative staff need to learn how to productively integrate smart technologies into teaching and administrative practices. Non-technical teachers might have skill gaps, while hesitant teachers might be the ones who have not heard of or are reluctant to use advanced techniques. These problems can only be addressed through comprehensive and ongoing training programs that provide teachers and staff with the skills and confidence they need to use smart technologies efficiently. The potential benefits of these technologies may be underused without such planning.” Ethical and privacy concerns also hinder the adoption of smart technologies. Handling sensitive data on faculty and students poses challenges for upholding strong security practices and complying with data protection statutes such as the General Data Protection Regulation. Clearly, inclusiveness needs to be considered, since some student groups, particularly imperiled or with limited access to digital sources, may face barriers to accessing the smart learning environment in its entirety. As such, it will be necessary to strengthen policy to ensure that these technologies are used ethically and inclusively.

## CONCLUSION

Smart universities refer to new-age learning environments which leverage medical technology to enhance the efficacy, flexibility and student-centric nature of the university. Besides the utilization of contemporary gadgets, the term reflects a change of the institutional setting into digital inclusion, customized education, and proof-based management. Critical reflection about the digitalisation of higher education has recently yielded the concept of the “smart university” – an institution embracing technologies such as big data analytics, IoT, AI to reform both teaching/learning and administration practices [54]. Smart university is establishing of digital technologies that enables productivity, creativity and flexibility across the entire university. Along with administrative processes, this includes the educational process, teacher–student relationships, and general campus operation. The idea of using smart technology ecosystems featuring seamless information transfer, automated functionality, and instant decision-making could shed light on smart universities [55]. The integration of big data, IoT and AI enhances institutional efficiency and brings about significant changes in how education is received and experienced [56, 57]. Fundamentally, the smart university seeks to bring a sense of flexibility, inclusivity, and personalization to the learning experience via technology, with the design of a learning environment that responds to students' diverse needs [58]. A smart university's deeper influence is found in how these technologies change teaching and learning, even while administrative enhancements like bettering campus security, automating student services, or managing resources more efficiently are fundamental components. Because AI makes adaptive learning systems possible, which customize course materials to each student's unique requirements, it directly affects pedagogy [59]. Such systems assess student performance in real-time, adjusting the difficulty of lessons, homework or tests to a

learner's progression and understanding. For instance, questions or problems that are more difficult and challenging can be given to students who have a knack for a particular subject giving them a chance to excel, while more resources and set of basics can be given to ones who have more trouble with the subject. In addition, AI-powered resources like as intelligent tutoring systems (ITS) provide students with individualized support outside of the conventional classroom [60]. These systems respond to student inquiries, provide immediate feedback, and help students understand difficult ideas using natural language processing. This will not only enhance the student experience but also provide assistance, allowing learning to be more flexible and accessible.' For example, as of how it is today, Arizona State University has leveraged AI-powered adaptive courseware to customize an entire student's educational path based on performance data [61]. This system contributes to individual education for students of the courses on a large scale that are taking the online or hybrid courses leading to increased involvement and performance. To enhance the learning environment, IoT connects systems, sensors, and devices throughout the institution to create a smart campus that constantly collects and analyzes data. This could also involve IoT in classrooms, where smart learning environments are created by adjusting seating, lighting, and temperature for student comfort and focus. As students interact with smartboards and connected devices, realtime data generation enables the educator to refine his or her strategy on the fly. By helping in the seamless interaction of students, teachers, as well as learning materials, IoT gadgets offer blended and distance discovering contexts beyond the standard class. These statistics ensure that, no matter where it is, information can be collected in an hour, learning opportunities can be made interactive, and timely feedback is possible. Integrated with smart devices and sensors, students may join virtual labs, do group projects, and access course material from anywhere. This ensures perpetual learning and is also specific to the individual needs of every student.

By enhancing the operational frameworks (such as controlling energy consumption) and by establishing connected learning environments (such as interactive classrooms), the University of Glasgow is developing a smart campus using IoT technology to offer its students the best possible experience [62]. Big data analytics help smart universities leverage plenty of data on student performance, participation, and preferences, which is needed to tailor their services and thereby smiting more of incoming students. Using predictive analytics, universities can assess the effectiveness of a course, pinpoint at-risk students and improve teaching methods through real-time data analysis. Big data not only enhances institutional decisions but also makes possible learning analytics that track individual student performance, such as attendance, participation, grades, and feedback. Analyzing and tracking students' learning outcomes can help instructors offer tailored interventions, which can in turn lead to potential improvements in students' learning outcomes. Big data

also contributes in analyzing course difficulty patterns and student feedback to generate curriculum patterns. This allows the school to constantly adjust its offerings to respond to changing demand. One good example of the contribution of big data analytics in higher education is the "Course Signals" [63] of Purdue University System. The system closely monitored students' advancement through various signs, including test ratings, participation, and tasks submitted. Upon pinpointing students at risk of falling behind, it employed anticipatory examination to furnish instructors and learners customized suggestions or cautioning notices. That allows for timely interventions to help keep students on track and improve their academic performance, be those interventions in the form of additional resources, more personalized support or other options.

The purpose of this study is to analyze the transformation of smart universities in accordance with digitalization and Industry 5.0 to detect major trends, challenges, and opportunities. It seeks to contribute to the conversation within academia on how higher education is evolving to suit societal needs and technology advancements. In this study, 8,061 research publications from the Scopus database from 2016 to 2024 are thoroughly evaluated using VOSviewer for network visualization and bibliometric analysis. The analysis is based on the publications that unite the sectors of "smart" and "university", focusing on the thematic areas of digitalization and Industry 5.0. The outcomes of this research help develop the concept of intelligent institutions through systematic examination of global cooperation macrotrends, technological innovations, and educational methodologies. Sustainability, digitization, Industry 5.0, advanced technologies such as blockchain, and AI, IoT are introduced in this article to present new ideas for preparing schools for Industry 5.0. In addition, in line with other studies on the digital transformation of higher education, the study highlights the importance of personalized, student-centered learning environments. Data shows how forward-thinking universities are raising their game and going way past merely digitizing their admin and teaching outputs. More advanced AI-based personalized learning environments that tailor the learning experience to the specific needs of every learner, boosting academic performance and student involvement. Learning management systems and intelligent tutoring allowing quick, customized assessment, personalization of learning as well as assessment of individual student performance. When integrated into learning management and intelligent tutoring systems, these technologies enable personalized feedback, adaptive learning and real-time monitoring of student performance. Such individualized method aligns with the core tenets of Industry 5.0, which aims for human-centric education that is more inclusive and productive, especially for learners. The paper also demonstrates that university research is increasingly also becoming – more global, with the US, China and Italy leading this trend. Through this collaboration, the global adoption of smart university processes and technologies will be accelerated, underscoring the

impact of higher education as an innovation engine in the digital age. In addition, smart universities have incorporated green technology and smart campus infrastructure that can save energy or even foster ecological consciousness as well. Thus for smart university students too, sustainability becomes the next big thing. There is a widespread adherence to the smart city frameworks, which predict that academic institutions seek to engage in, and benefit from, sustainable urban development. The results illustrate the complex landscape of smart university research and show how different technological innovations – such as IoT, AI, and smart grids – are adopted in the education sector. It indicates a focus on cross-national collaboration in research, that appears common globally for developing and utilizing smart university concepts. In addition, the emphasis on technology and education-related terms highlights the cross-disciplinary nature of smart university research, straddling the domains of Industry 5.0, digitalization and higher education. As higher education transitions to smart campuses, institutions must proactively strategize for the challenges ahead. That encompasses the fast pace of technological development as well as changing expectations from the community and students. Academic institutions are aiming to embrace these new technologies but will have to do so responsibly, ensuring academic integrity and the promotion of critical thought, and the robustness and agility of these institutions in the face of this disruption will be tested.

**Future directions:** Smart universities will increasingly focus their research on the intersection of technology innovation, educational improvement, and sustainable development. As they are adapting to the need of digitalization and Industry 5.0, Universities need to expand research topics to include essential issues such as AI personalization, blockchain security, multidisciplinary cooperation and sustainability. Tackling such hot-button issues may help inform future work to help guide the design of smart campuses that go beyond merely being technologically advanced to also being ethical, sustainable and resilient.

**Research limitations:** Although comprehensive, the coverage is limited to articles indexed in Scopus, which can represent a low hanging fruit and future work should generalised this work, exploring the effects across other databases and grey literature. The work highlights the importance of an interdisciplinary approach in educational research to ensure that various aspects of smart universities are maintained and to reflect the interrelated, contextual and movement of these dimensions.

**Practical implications:** The conclusions drawn offer guidance for university administrators, other policy makers and educators towards effective development and execution of smart university strategies responsive to the requirements of Industry 5.0 in order to prepare higher educational establishments to remain competitive and relevant.

**Potential biases of the results:** Reliance on the Scopus database may introduce biases into the findings by excluding pertinent studies from other databases and underrepresenting research conducted outside of English. The

emphasis on more recent publications (2016-2024) may obscure fundamental contributions from older periods or trends from less technologically sophisticated areas. In addition, the bidding political approach of bibliometric analysis might give more attention to measures that seem least quality, and therefore compatible with the final development of smart institutions, but that described some qualitative and contextual aspects regarding smart institutions development process.

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