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Synergy of Internet of Things and Education: Cyber-physical Systems contributing towards Remote Laboratories, Improved Learning, and School Management

Rasikh Tariq[1*], Fidel Antonio Casillas-Muñoz[2], Syed Tauseef Hassan[3] & Maria Soledad Ramírez-Montoya[4]

Abstract

The modern Industrial Revolution has ushered in a wave of technological advancements, including the proliferation of over 20 billion digital identities associated with the Internet of Things (IoT) devices worldwide. Amid this complexity, IoT has emerged as a beacon of hope, offering multitudinous solutions from the perspectives of school management, instructors, and learners. The prime objective of this article is to review the current state-of-the-art in IoT and education specifically in areas like remote laboratories, improved learning, and school management. The implemented method is systematic literature review of IoT technology's practical applications and case studies to meet these key educational stakeholders' unique needs. The studies focus on remote labs, learning experiences, and campus administration. This comprehensive analysis gathered data from sources like Scopus and WoS and summarized insights from 122 articles. These cases encompass the foundational principles of IoT, its diverse applications in higher education, its challenges, and future avenues for research. Our findings indicate that (a) the implementation of IoT-based remote laboratories has transformed engineering education by enhancing the safety and operational efficiency of labs, improving students' comprehension of complex concepts, and facilitating a more interactive and engaging educational experience, (b) the integration of IoT systems within educational settings has profoundly enhanced both teaching and learning experiences by creating interactive, immersive environments and significantly improving student engagement and understanding through personalized and hands-on learning approaches, and (c) the integration of IoT technology within educational administration has significantly advanced the digitalization of traditional school management systems, enhancing administrative efficiency in areas such as schedule management, student records, and financial operations through automation, thereby streamlining processes and enhancing responsiveness in educational institutions. However, it must be noted that the current infrastructure, particularly in public universities, often falls short of fully harnessing IoT technologies to optimize the learning experience. Investments in infrastructure, teacher training, and curriculum design are imperative to fully leverage IoT's benefits for education.

Keywords: *Computational thinking, educational innovation, higher education, Internet of everything, smart education*

[1]*Tecnologico de Monterrey, Institute for the Future of Education, México, *Corresponding author. Email: rasikhtariq@tec.mx*
[2]*Tecnologico de Monterrey, Institute for the Future of Education, México, Email: fidel.casillas.gen@tec.mx*
[3]*School of Economics and Management, Anhui Polytechnic University, Wuhu, China. Email: sthassan_bit@yahoo.com*
[4] *Tecnologico de Monterrey, EGADE Business School & Institute for the Future of Education, México, Email: solramirez@tec.mx.*

Introduction

Thanks to the rise of the Internet of Things (IoT) in the Fourth Industrial Revolution, advanced cyber-physical systems have enabled objects to connect seamlessly anytime, anywhere, via any service, pathway, or data source. This technological paradigm shift has resulted in an astounding 20 billion digital identities worldwide. The omnipresence of this transformative technology has ignited the global integration of knowledge and intelligence at an unprecedented scale, which is demonstrated by the case studies reporting its impact (Sultana & Tamanna, 2022). Consequently, IoT has come out to be a new 4.0 powered technology to bring innovations in a wide spectrum of applications.

In this context, it is imperative to recognize that modern education and e-learning systems must not disregard the IoT's profound impact. Its integration intricately links with the pervasive automation reshaping various facets of our lives, including. IoT holds the potential to deliver inclusive, equitable, and high-quality education, transcending geographical boundaries and offering equal educational resources to individuals worldwide.

It is abundantly clear that education in the modern era faces formidable challenges to adapt to the continuously evolving standards of the cooperative and industrial sectors. Therefore, the effective utilization of cutting-edge technologies such as IoT potentially can elevate educational systems, facilitating the delivery of quality education that significantly contributes to the achievement of sustainable development goals (Zeeshan et al., 2022). Delving deep into the technical intricacies of IoT involves examining a vast network of interconnected devices and sensors. These devices collect and transmit data, which is processed and analyzed in real-time. The IoT ecosystem encompasses communication protocols, data storage methods, and security measures to ensure seamless connectivity and data protection. This intricate web of devices and data flows creates the foundation for the diverse applications of IoT in education.

The applications of IoT in academia extend far beyond a simple overview (as depicted in Figure 1). They encompass a broad spectrum of functionalities, including enabling remote laboratories, a critical component in distance education during the pandemic (Francisti et al., 2020). IoT also plays a pivotal role in managing schools and administrative systems efficiently. It enriches the teaching and learning experience by providing real-time data and insights. Moreover, IoT facilitates the development of smart campuses, monitors health and well-being, aids in foreign language acquisition, supports fine arts education such as music and dance, enhances physical education programs, and provides crucial support for special education initiatives (Xu & Li, 2021). These applications collectively showcase the transformative potential of IoT in modern education.

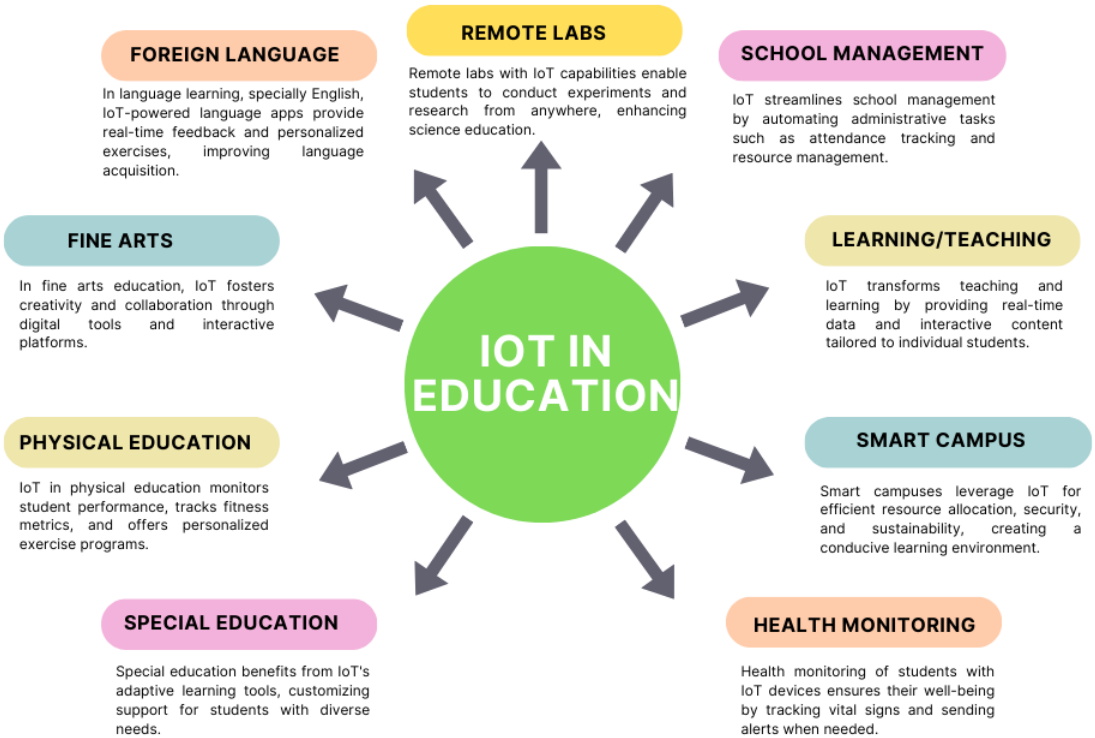

Figure 1. ***Different applications of the IoT in the educational sector. Source: author´s elaboration. The high-quality figure can be downloaded from: https://doi.org/10.6084/m9.figshare.24927696.***

Numerous studies and research findings provide valuable insights into the intersection of IoT and education. These investigations shed light on IoT's potential benefits, challenges, and practical applications in education, identify various technologies, including VR, 3D printing, and IoT, transform engineering education, and foster competencies essential for the future workforce. They focus on security concerns in educational settings and propose a Secure Internet of Schools Things (S-IoST) system for enhanced safety and communication. Kamal et al. (2018) provides a practical learning kit for IoT and blockchain, making these complex technologies accessible to students. These articles, along with other review articles (Soegoto et al., 2022), collectively underline the transformative potential of IoT in education, emphasizing the need for further research and practical implementations to maximize its benefits.

Most review articles in this field have primarily focused on systematic reviews, spanning 1999 (coinciding with the coining of the term "IoT") to 2017. However, these reviews often lacked in-depth analyses and explanations of critical domains such as remote laboratories, enhanced educational learning, and school management. Consequently, the research contribution of this work is to present an updated review of the literature (2017 to date), explicitly emphasizing these three domains. It is essential to note that this review article does not encompass other aspects of IoT in education, such as physical education, special education, fine arts, and foreign languages (as depicted in Figure 1), as they warrant separate dedicated investigations. The main objective of this research work is to understand the role of IoT in the development and implementation of remote laboratories, assess the impact of IoT technology on the learning experience, and identify emerging innovative trends in the usage of IoT in campus management.

Reviewing the articles systematically, this article is intended to trace synergies of IoT in three tenets of education: general trend of the use of IoT in education, kinds of education system used on the basis of IoT and implication of IoT for the future education. Thus, a set of research questions was formulated to address the existing literature gaps, which are:

1. What are the successful case studies of the development and implementation of IOT-based remote laboratories in educational settings?
2. How do different educational institutions and programs harness IoT for improved learning outcomes?
3. What are the emerging trends and innovative practices in using IoT for enhancing school management, resource allocation, and operational efficiency?

Theoretical Framework

The theoretical framework comprises two distinct components: the first delineates the realm of cyber-physical systems and the IoT, while the second expounds on their integration and interplay with the field of Education.

Cyber-physical systems and the IoT

The integration of Industry 4.0 technologies with cyber-physical systems (CPS) plays a pivotal role in shaping the landscape of manufacturing and sustainability. The IoT serves as the backbone, connecting embedded systems globally, leading to the evolution of CPS with connectivity. This extension of embedded systems enables applications at both macro and micro levels, emphasizing autonomy and adaptation, particularly fitting for Industry 4.0. In the context of Industry 4.0, Soori et al. (2023) focused on virtual manufacturing as a cornerstone, optimizing production processes through real-time data utilization. The synergy of radio frequency identification (RFID), big data analytics, and artificial intelligence (AI) further enhances the efficiency, consistency, and adaptability of manufacturing processes. Kim et al. (2023) employed text mining and machine learning to conduct a systematic exploration that identifies ten key research topics, contributing to a more cohesive conceptualization of servitization and product-service systems in the context of Industry 4.0. These studies collectively pave the way for advancing knowledge, fostering sustainability, and propelling transformative changes in both industry and society through the usage of Industry 4.0.

CPS play a pivotal role, extending beyond manufacturing. As the industrial scenario undergoes exponential changes, researchers such as Li et al. (2023) emphasizes the challenges faced by Modern Building Automation Systems (BASs) due to increased connectivity and accessibility, urging a comprehensive review of cyber-physical security to mitigate potential cyber-attacks and ensure the resilience of smart buildings. Additionally, Hasan et al. (2023) focused into the complexities of Smart Grid (SG) systems, emphasizing the need for robust cyber-physical and cyber-security measures to safeguard critical infrastructures from potential attacks. This comprehensive review encompasses SG models, communication standards, protocols, and cyber-security principles, providing insights and recommendations for future research. In conclusion, these studies underscore the critical role of cyber-physical systems and the imperative need for robust security measures in shaping the future of industries, smart buildings, and power systems. As technology advances, addressing challenges and embracing innovative solutions becomes paramount to ensure a secure and efficient digital transformation.

Likewise, the application of CPS and the IoT was also extended to educational technology. Shaqrah & Almars (2022) investigate the adoption of IoT applications for educational purposes, focusing on students' perspectives. Utilizing the UTAUT2 (Unified Theory of Acceptance and Use of Technology) theory and integrating innovativeness and social support constructs, they find that social support, facilitated conditions, innovativeness, and effort expectancy significantly influence the acceptance and usage of IoT applications in education. Collectively, these studies showcase the diverse applications and implications of IoT-related technologies in education, gaming, and robotics. As technology continues to evolve, these findings contribute valuable insights for further research and development in these dynamic domains.

Synergy of the IoT and Education: Virtual Laboratories, Improved Learning, and Campus Management

Cyber-physical theory-driven IoT has brought a significant revolution in all the applications, and its synergy with education has opened up new possibilities to improve the educational process. Liu et al. (2021) emphasize the importance of improving the intelligence of teaching environments in colleges and universities through the development of an IoT-based wisdom education platform, particularly highlighting the design of a smart classroom architecture. The common thread across these studies is the recognition of IoT's potential to revolutionize educational processes, from personalized learning experiences for the deaf to intelligent classroom management and hands-on STEM education. As educational institutions navigate the evolving technological landscape, the adoption of IoT technologies emerges as a promising avenue for fostering engagement, motivation, and innovative learning approaches. These studies contribute to the ongoing dialogue on leveraging IoT to transform and optimize educational practices across diverse learning environments.

This synergy of IoT and education can significantly improve the laboratory experiences in the Universities. Urbano et al. (2023) focus on enhancing the academic training of engineering professionals through remote laboratories, providing a flexible and scalable architecture that allows for hands-on experiments in mechanical physics without the need for physical presence. The studies collectively underscore the potential of IoT in fostering innovative and inclusive educational approaches, addressing various subjects and aspects of learning. As technology continues to advance, these endeavors contribute valuable insights for the ongoing evolution of educational practices, promoting accessibility, engagement, and real-world applicability.

IoT along with data analytics through artificial intelligence can also significantly change the performance of the administrative processes within the University campus. Umer et al. (2023) investigate into educational data mining, exploring the use of classifiers to predict students' academic performance based on features extracted from the Kalboard360 learning management system. Their findings underscore the importance of feature selection in improving prediction accuracy, with attributes such as 'Visited resources,' 'raised hands,' and 'student absent days' identified as crucial factors. This approach has implications for enhancing the student learning process and overall academic performance. Ahmed et al. (2022) focus on the pervasive issue of email spam in both general communication and the IoT. They conducted a comprehensive survey of machine learning techniques employed for spam filtering, categorizing them and providing a comparative analysis based on accuracy, precision, and recall. Their insights contribute to the ongoing efforts to combat spam and enhance the security of email and IoT platforms. In conclusion, these studies collectively highlight the complex role of technology in addressing challenges within the educational sector, ranging from attendance monitoring and academic prediction to spam filtering in communication and IoT services.

Material and Method

Design

This research is a systematic literature review the methodology of which was based on recommendations provided by Castillo-Martínez & Ramírez-Montoya (2021). The first step of review is begun through the analysis articles available on the websites thoroughly. Specifically, the articles are analyzed using thematic analysis. This collecting data has segments regarding the identification, screening, eligibility assessment, and final selection of research articles. The process starts with the identification phase, where the appropriate sources are picked. The screening stage entails sifting through these resources using established benchmarks and retaining those that seem pertinent. Another stage that comes after the first phase is the eligibility stage where each source undergoes a detailed examination, ensuring that it satisfies inclusion criteria. Then finally, in the inclusion stage, eligible sources are added leading to a complete and ordered analysis of IoT uses in education.

Data and sources of data

The main data of this study comes from Scopus and Wos websites totaling 161 articles on IoTs (Farias-Gaytan & Montoya (2023). Following this initial filtration process, a review of article titles retained 122 articles just after the evaluation of the title. The number of articles remained substantively high at this juncture, necessitating a refined focus to establish scientific justification. A substantial portion of the literature centered on IoT course content integration within existing degree programs, such as electrical engineering and computer science, diverging from the intended scope of this research. Additionally, many articles focused on pedagogical approaches to teaching and learning IoT, somewhat tangentially related to the core theme of "Internet of Things" and "education." Consequently, such articles were excluded. During the re-evaluation of article titles, those found not to align precisely with the research theme were eliminated. Notably, particular articles primarily concerned student perceptions within specific case studies, concentrating solely on gauging student perspectives on IoT technology. Topics to review from the articles are in Table 1.

Table 1.

Topics of IoT to review in this study related to labs.

Reference	Description of the lab
1. Basheer et al., (2021)	Smart automated computer lab
2. Prakash et al., (2021)	Automation laboratory, including programmable logic controllers (PLC), industrial PC (IPC), and hydraulic laboratories
3. Ga, Cha, & Kim, (2021)	School Science Learning Environments
4. Taj et al., (2021)	Analog electronics
5. Ramya et al., (2020)	Industrial automation
6. Al-Obaidi & Derbel, (2023)	Renewable energy
7. Pang et al., (2022)	Robotics
8. Ali et al., (2022)	Laboratory safety
9. Urbano et al., (2023)	Physics lab
10. Chacón et al., (2018)	Civil engineering

Data Collection

The research commenced with a systematic search of academic literature on the Web of Science (WOS) platform, employing the search query "Internet of Things" OR "IOT" in conjunction with "education." The temporal parameter required articles published between 2017 and 2024. Simultaneously, a Scopus search used the identical search query, "Internet of Things" OR "IOT" AND "Education," with the same temporal restrictions and a specific focus on research articles, excluding conference articles. Moreover, stringent criteria were applied to ensure the selection of only articles in the English language. Following this initial filtration process of the WOS list, a review of article titles retained 122 articles just after the evaluation of the title.

The number of articles remained substantively high at this juncture, necessitating a refined focus to establish scientific justification. A substantial portion of the literature centered on IoT course content integration within existing degree programs, such as electrical engineering and computer science, diverging from the intended scope of this research. Additionally, many articles focused on pedagogical approaches to teaching and learning IoT, somewhat tangentially related to the core theme of "Internet of Things" and "education." Consequently, such articles were excluded. During the re-evaluation of article titles, those found not to align precisely with the research theme were eliminated. Notably, particular articles primarily concerned student perceptions within specific case studies, concentrating solely on gauging student perspectives on IoT technology. These articles, although valuable, did not fit with the research questions proposed in this study and were, therefore, excluded. Several articles that did not directly pertain to IoT's educational aspects but focused on enhancing traditional engineering courses through IoT were included, possibly due to search engine anomalies in WOS and Scopus. Articles about IoT pedagogy were also excluded.

Data analysis

Thematic analysis is applied for data analysis purposes which was based upon one widely recognized method for thematic analysis in the context of a systematic literature review is described by Braun and Clarke (2006). Braun and Clarke's thematic analysis for systematic literature reviews is a structured yet adaptable method that starts with the researcher immersing themselves in the data, engaging in repeated readings, and jotting down initial coding ideas. This familiarity is crucial for the next step, where a systematic coding of noteworthy data features is conducted across the dataset, and relevant information is aggregated under each code. The researcher then begins the synthesis of these codes into potential themes, ensuring that all pertinent data for each theme is compiled. This collection is followed by a critical review, where the viability of the themes is assessed against both the coded data and the full dataset, leading to the creation of a thematic map. Subsequent to this, there is a phase of defining and naming themes, where each one is refined to convey a clear and distinct narrative within the dataset. Finally, the process culminates with the production of the report, where these narratives are interwoven with the data excerpts to form an analytic account, all the while contextualizing the findings within the broader research questions and existing literature. This methodological framework excels at systematically organizing and providing a detailed portrayal of the dataset, ideal for unearthing, analyzing, and communicating thematic patterns within the data. Applied to the specific case, it includes the definition of the research questions and the objectives which are defined previously. The data is extracted from WoS and Scopus through which codes are assigned to segment the extracted data. The themes are identified for the developed database related to remote laboratories, improved educational learning, school management practices, and well-being measurement. These themes are reviewed, and the data is synthesized to eventually report the results.

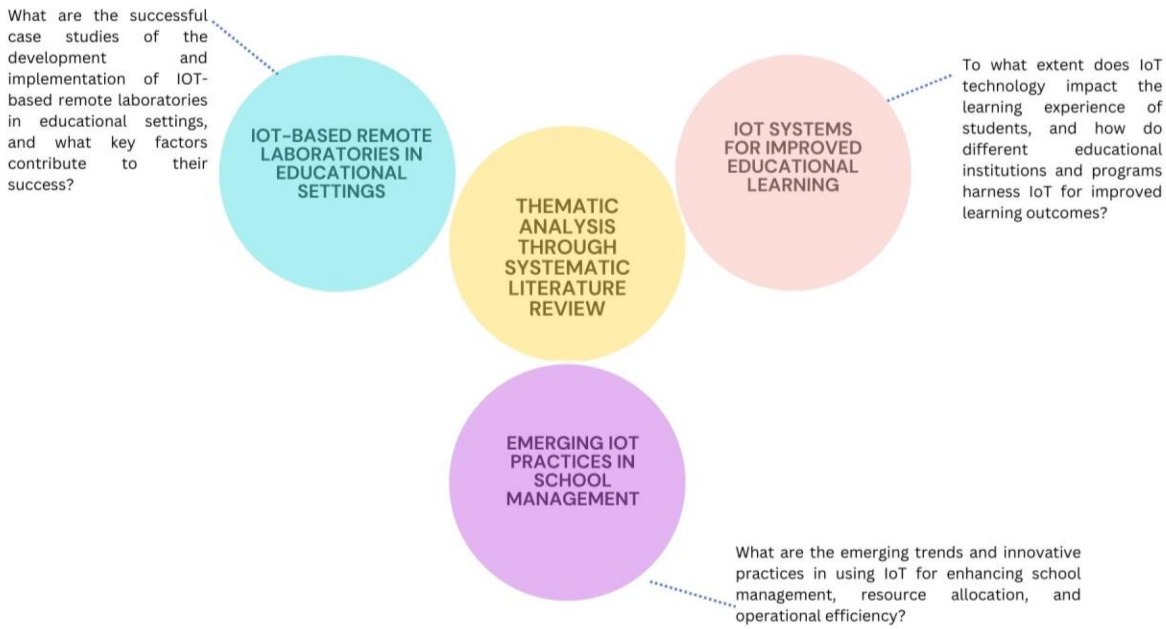

Figure 2. ***Thematic analysis through systematic literature review to respond to the research questions. Source: author´s elaboration.***

Findings/Results

The entire article is crafted to address three specific research questions focused on remote laboratories, enhanced educational learning, and school management. The results section precisely aligns with these research questions, providing in-depth exploration and analysis for each of them.

RQ1: IOT-based remote laboratories in educational settings

Our findings have revealed a transformative trend in the realm of engineering education, particularly through the digitalization of laboratories. Central to this transformation is the implementation of IoT technologies, which are redefining the capabilities of remote laboratories. The analysis points to a suite of IoT-enhanced environments that significantly bolster both the safety and operational efficiency of engineering labs. For instance, we observed the development of smart automated labs that are not only cost-effective but also integrate advanced security measures, such as real-time fire detection and automated alerts, thereby circumventing the limitations of conventional setups. In terms of educational efficacy, the results from the literature indicate that IoT-integrated remote laboratories markedly improve students' ability to grasp complex engineering concepts and enhance their hands-on learning experience. These laboratories are equipped with diverse systems ranging from programmable logic controllers and industrial PCs to sophisticated robotics setups that allow for high-quality remote interaction and manipulation. Such advancements have shown potential in elevating the practical skills of students in various engineering disciplines.

Answers to the first RQ reveal four themes: role of IoT, the use of virtual laboratory, function of distant learning, and essentials of IoT in education industry.

The role IoT has been identified as an education system as excerpt 1.

1. With IoT systems, teachers and administrators can more efficiently monitor and manage classroom resources, such as textbooks and materials. For example, an IoT school management solution can track the use and availability of books and other materials, alerting teachers when supplies need replenishment.

IoT transforms business landscape in education as well as it is an evitable distant learning system in this digital era. (Excerpt 2).

2. IoT plays a pivotal role in shaping the business landscape. With the integration of smart devices, edge computing, and big data analytics, IoT is not only transforming the way businesses operate but also how they engage with their customers.

The term "distance learning" describes any kind of instruction in which neither the instructor nor the students are physically present. Courses could be taken remotely through correspondence in the past, both at the university and high school levels. A designated area in a school or library where students and teachers can access computers with Internet connections for educational purposes. A remote lab is an experiment that is run and controlled remotely through the internet, as opposed to a virtual lab, which relies on software to mimic the lab setting. Teachers and students can conduct experiments and other lab work virtually using these labs' equipment and computers connected to the internet. Students have access to simulated versions of actual experiments in virtual labs. Regarding the seven most important aspects of the Internet of Things (IoT) education market:

1. Better Teamwork and Interactions
2. Tailored Education
3. Raising Student Participation in Class
4. Fourth, better management of resources

5. Strengthened Protections
6. Enhanced Productivity

Furthermore, the application of IoT in remote laboratories extends beyond traditional learning environments, incorporating cutting-edge technologies that facilitate an interactive and engaging educational experience. The integration of augmented reality applications and serious gaming installations supports in-class activities and remote learning, broadening the scope of pedagogical methods. The integration of the IoT into higher education has been demonstrated to notably enhance students' academic performance in engineering disciplines, providing enriched hands-on experiences through remote laboratories. This has been achieved through a variety of implementations, ranging from robotic systems and control systems equipped with Wi-Fi modules for seamless communication to human-machine interfaces that foster interactive learning. Furthermore, the adoption of IoT in education extends to the support of in-class activities with serious games and augmented reality applications, as well as facilitating the learning of computer programming, physics, and embedded systems through remote lab access. Innovations such as the incorporation of blockchain technology have also been identified as enhancing the management of information within IoT-enabled smart labs, suggesting a broad and impactful application of IoT technologies in enhancing educational outcomes and experiences. Additionally, the literature highlights the innovative use of blockchain technology to enhance the management of IoT systems within smart labs, indicating a forward momentum towards secure, scalable, and sophisticated educational frameworks.

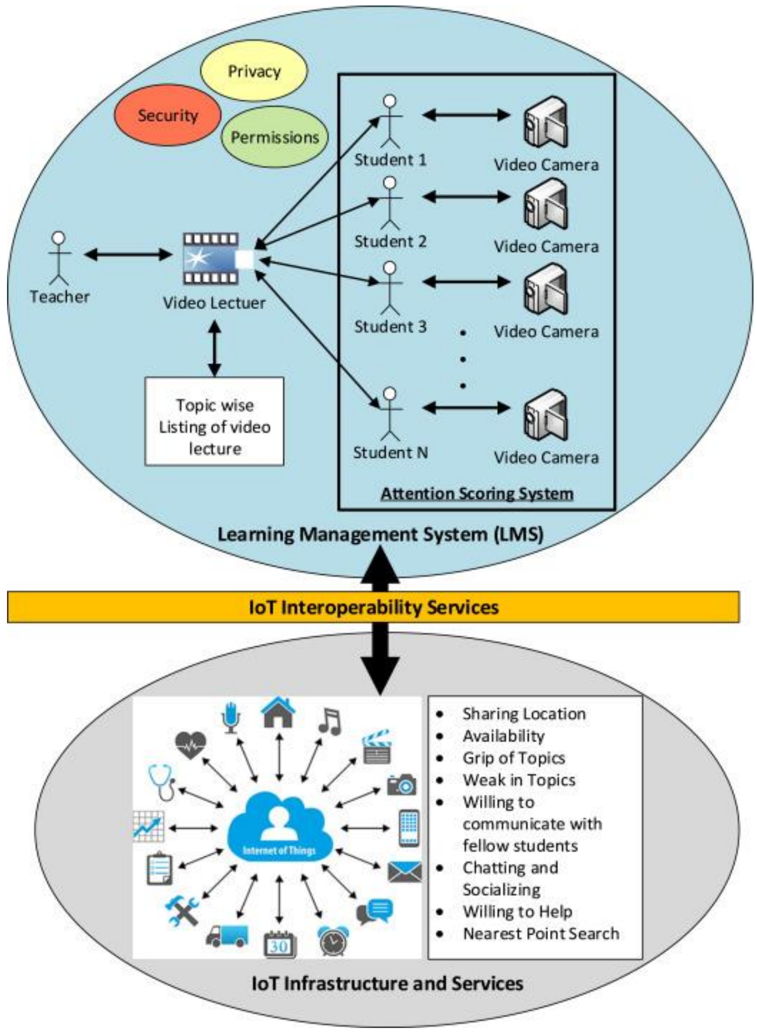

Figure 3. Enhancing eLearning Through IoT-Based Student Interaction Analysis.

As Figure 3 indicates an IoT-based framework for evaluating student attention, participation, and comprehension in remote lecture video settings is developed. Through machine learning it examines multimedia content to identify facial and eye features and subsequently develops the algorithm for the attention score calculation. The findings are instrumental in evaluating the success of electronic learning techniques and this tool can be integrated into a modern learning management system to promote e-learning (Farhan et al., 2018)

RQ2: IoT technology impact the learning experience of students and improved learning outcomes

In exploring the dynamic integration of IoT systems within educational paradigms, our review identified a diverse array of applications that significantly enhance both teaching and learning experiences. The introduction of game-based learning models in smart classrooms, for instance, leverages advanced IoT and augmented reality technologies to create interactive and immersive educational environments. These innovative approaches have demonstrated positive impacts on student learning outcomes, particularly in IoT-related courses, by fostering engagement and enhancing understanding of complex subjects. Moreover, the use of IoT to facilitate project-based learning in high school biology has shown substantial benefits in developing cognitive, interpersonal, and intrapersonal skills among students. Such IoT-integrated educational strategies underscore the potential of technology to transform traditional learning spaces into dynamic, interactive, and personalized learning experiences.

Further analysis reveals the application of IoT and big data in promoting innovation and entrepreneurship among college students, highlighting the technology's role in professional development and employability enhancement. Additionally, sustainability awareness and energy efficiency initiatives in European schools have been significantly bolstered through IoT-based methods, gamification, and competitive activities, showcasing the technology's capacity to engage students actively in educational pursuits. The flipped classroom model, enriched with IoT integration for teaching mathematical logic, illustrates how modern challenges associated with traditional teaching methods and digital distractions can be effectively addressed. Our findings also reveal that the integration of IoT technologies in education significantly enhances the teaching and learning experience by enabling the creation of smart classrooms. These classrooms utilize interconnected devices and sensors to gather real-time data on student engagement, behavior, and performance, facilitating a personalized learning environment. Educators can tailor their teaching methods and curricula to meet individual students' needs, thereby improving learning outcomes. Additionally, IoT-enabled tools offer immersive, hands-on experiences that enhance understanding of complex subjects and foster critical thinking skills. This approach not only makes learning more engaging and practical but also prepares students to effectively meet the challenges of the digital age, indicating a transformative shift in educational methodologies towards more adaptive and interactive models. This holistic examination of IoT's application across various educational settings—from enhancing eLearning through student interaction analysis to facilitating family education through interactive systems—demonstrates the technology's transformative impact on education, fostering a more engaging, practical, and relevant learning environment.

In a family level, IoT functions to Enhancing Family Education through IoT-Based Interactive Systems as defined by Sun, et. al., (2022) the flow of which is illustrated in Figure 4.

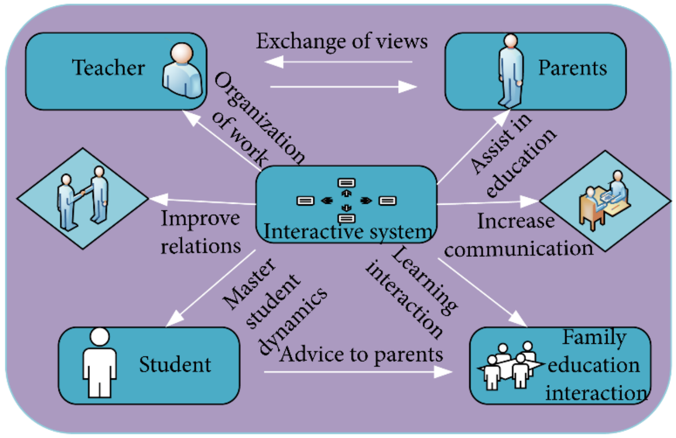

Figure 4. Enhancing family education through IoT-based interactive systems.

The problem of low frequency of parent-child interactions due to lack of time is discussed in this work. It proposes a Family Education Interactive System based on IoT to narrow the distance between parent and child. An embedded system, in this case, is beneficial in enhancing family education, enabling communication efficiency between teachers and parents (Sun, et. al., 2022).

In addition, IoT also impacts of management and conversation as indicated by Yasuoka et al., (2023a). In Figure 5, Yasuoka et al., (2023a) develop energy management and conservation using the IoT for energy management on a Brazilian university campus. The focus is on air-conditioning system efficiency, occupant comfort, lighting control, and energy waste reduction, contributing to sustainable campus operations and energy education. The project promotes responsible resource consumption, cost savings, and reduced carbon emissions while aligning with sustainable development goals.

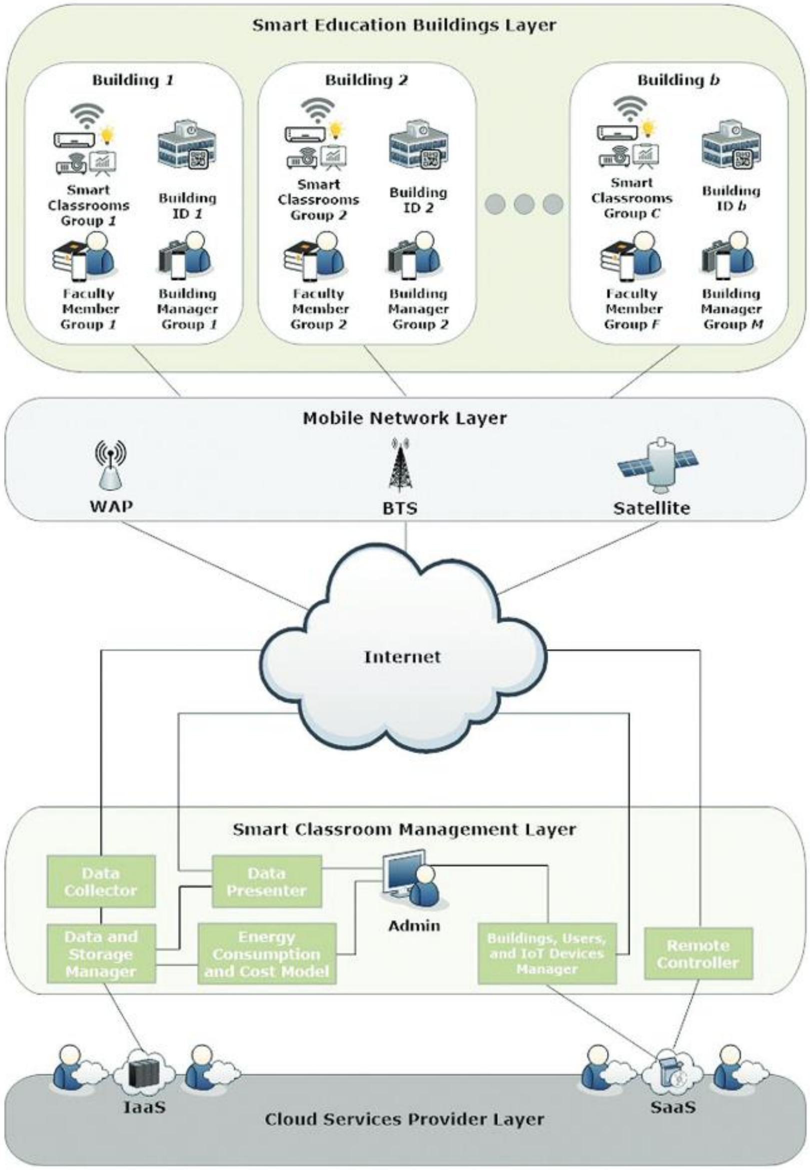

Figure 5. Energy management in a Brazilian University.

RQ3: IoT for enhancing school management, resource allocation, and operational efficiency

Our investigation into the current state-of-the-art applications of IoT technology within educational administration has brought significant advancements in the digitalization of traditional school management systems. By using IoT, educational institutions have experienced a marked enhancement in the efficiency of administrative operations, notably in areas such as schedule management, student records, attendance tracking, financial information, and more. This transformation is driven by the capacity of IoT to reduce manual workload through automation, leading to streamlined processes and agile administrative functions. The integration of IoT into educational management systems manifests in the development of smart and intelligent campuses, where automation and data-driven decisions foster a more effective and responsive administrative environment. Examples span a wide range of applications, from mobile education and administration to energy efficiency and digital activity portfolios, illustrating the broad potential of IoT to revolutionize school management.

Furthermore, the specific implementations of IoT technologies that have yielded notable improvements in various aspects of educational management. These include the use of RFID and face recognition for efficient attendance management, machine learning techniques for spam detection in email systems, and IoT-driven financial information systems that enhance data management and budgeting in colleges and universities. Additionally, IoT applications have been instrumental in improving process management, conserving energy through efficient management systems, and even predicting student dropouts with machine learning. Each of these instances underscores the transformative impact of IoT on making educational institutions more efficient, sustainable, and capable of providing enhanced support to students and staff alike as detailed in Figure 6 serving as a testament to the significant strides made in employing IoT technology to address the multifaceted challenges of educational management.

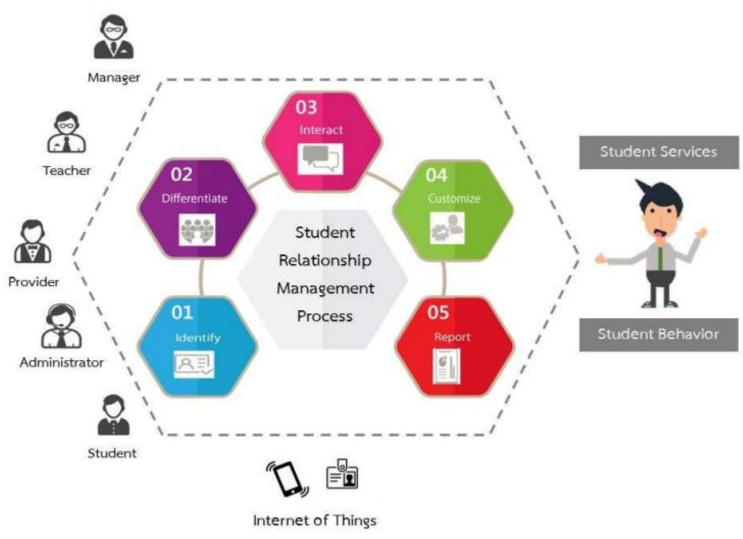

Figure 6. IoT to evaluate student relationship management.

This model of IoT develops and evaluates a student relationship management system. The IoT-driven system encompasses processes like identification, differentiation, interaction, customization, and reporting to enhance student relationships effectively, with experts rating it as highly suitable for practical implementation (Songsom, Nilsook, & Wannapiroon, 2019a).

Discussion

The discussion of this article involves the panorama from the three areas targeted in this article, spanning from the remote laboratories, improved educational learning, and practices in school management through the IoT. Our study reveals that synergy of IoT to the success of education in the future is obvious, stressing on the dynamic of IoT programs in education, development of creativity and innovation as well as students' managerial skills and management competency.

The first finding confirm that our results have substantiated that the integration of IoT technology significantly contributes to the development and success of virtual laboratories in higher education, highlighting a myriad of factors that underpin this achievement. Successful case studies from the literature, such as those involving smart automated computer labs, IoT-enabled remote laboratories for engineering disciplines, and safety monitoring systems, underscore the pivotal role of IoT in enhancing academic performance and offering practical, hands-on learning experiences. Notably, implementations ranging from robotic systems with electromechanical arms and control systems to Wi-Fi communication modules have demonstrated the technology's capability to provide immersive educational environments. This success is further evidenced by improvements in students' problem-solving skills, particularly in microprocessor technology, where a substantial increase in the number of students able to solve related problems was observed. The integration of augmented reality and serious gaming, alongside the application of blockchain technology for smart lab information management, represents additional layers of innovation, facilitating interactive learning and efficient data handling.

Various case studies on the implementation of IoT in the sucessful implementation of the virtual laboratories. Collectively, these examples—detailed in works by Basheer et al. (2021), Prakash et al. (2021), Ga, Cha, & Kim (2021), Taj et al. (2021), Ramya et al. (2020), Al-Obaidi & Derbel (2023), Pang et al. (2022), Ali et al. (2022), Urbano et al. (2023), and Chacón et al. (2018)—demonstrate the extensive application and effectiveness of IoT in remote laboratories across various engineering fields which also aligns with our finding.

By answering the research question, we affirm that IoT-based remote laboratories are instrumental in advancing educational outcomes, as corroborated by a broad spectrum of studies emphasizing the technology's role in facilitating innovative and effective learning and teaching methodologies. This evidence suggests that educational institutions should prioritize the integration of IoT technologies in their curricula and infrastructure to significantly enhance the quality of remote laboratories, thereby improving both the practical skills and theoretical understanding of students in the engineering and technology fields.

Second findings focus on the intentions that the use of IoT changes education perspectives in **IoT technology impact the learning experience of students, and improved learning outcomes.**

The results of our study on the impact of IoT technology on students' learning experiences validate a substantial improvement in educational processes and outcomes. The progress in this area is primarily credited to the implementation of IoT technology in the development of intelligent classrooms and remote laboratories. These advancements have played a crucial role in tailoring and enhancing learning environments to meet individual needs and foster active participation. Our research indicates that the effective incorporation of IoT in educational environments has resulted in enhanced student involvement, conduct, and achievement, enabled by the collection and analysis of data in real-time. This has allowed educators to customize teaching methods to meet the specific needs of each student, thus maximizing learning results. There are six significant findings that demonstrate the substantial impact of the IoT: (1) Individuals will consume content in varying ways, (2) those who are adaptable will not only survive but also flourish, (3) the nature of testing will undergo transformation, (4) expectations will undergo a shift, (5) new areas of study will emerge, and (6) job competition will become global in scale.

By 2020, it is estimated that there will be more than 6 billion smartphones and 50 billion Internet of Things (IoT)-enabled devices worldwide. Considering the global population is currently 7.6 billion and increasing, it is necessary to alter the approach to developing and writing content. In recent years, there has been a significant increase in the visual nature of the world. As an illustration, video has surpassed written content as the favored method of consuming information, and video itself has undergone transformation. A study discovered that incorporating an interactive element into a video result in a 40% increase in engagement compared to videos that lack this feature. Similarly, this applies to educators, learners, and business owners in the field of online education. It is essential to remain informed about the latest IoT information and trends. Analyze data that reveals the specific times, locations, and online activities of your target audience, and take advantage of this knowledge. Attaining these objectives may necessitate adopting more agile strategies over a period of time, but this adaptability can enhance your chances of success in the constantly changing digital environment. By having internet connectivity on mobile devices, such as phones, and the potential for other tools like pens, it is possible that the format of exams could shift from traditional question-and-answer assessments to more research-oriented projects. Instead of responding to multiple choice questions, students will be required to utilize the internet to locate answers and elaborate on their discoveries. Given the widespread availability of the internet, it is logical to harness the vast amount of information it offers for productive purposes.

The IoT not only revolutionizes individuals' internet connectivity but also transforms their lifestyles, expectations, and habits. Artificial Intelligence (AI) and the IoT bring about advancements in various areas such as home security, expedited coffee brewing, optimized energy consumption, and accelerated streaming services. Home automation, currently one of the most significant trends in the field of IoT, offers unparalleled convenience and a sense of security to individuals. Once individuals become accustomed to this convenience in their daily lives, it will become the standard expectation for how they anticipate accessing other forms of information as well.

As IoT-related advancements and data collection increase, new employment opportunities will emerge. Teachers must create innovative curricula and majors to adapt to this change, while students should focus on future career prospects in emerging fields, particularly in technology-driven professions. eLearning is the process of globalizing education, allowing individuals from any location to engage in virtual classrooms and obtain academic qualifications. Given that the IoT is connecting people worldwide, it is reasonable to expect that jobs will become more competitive. Consequently, an increasing number of students will likely turn to eLearning as a means of obtaining affordable and accessible education.

There will be a strong demand for specific skills, advanced accreditation, and guidance. eLearning instructors should contemplate the diversification of their classes and coursework, while providing superior learning resources in comparison to their competitors. By doing so, it may assist their students in gaining a competitive advantage in future career fields that will have a global scope.

Our research aligns with the contributions from, for instance, Petrović et al. (2022) showcase IoT-infused game-based learning as a significant enhancement to higher education, while Tsybulsky & Sinai (2022) demonstrate the technology's role in enriching high school biology education through project-based learning. Ma & Pan (2023) explore IoT's capability to foster innovation and entrepreneurship among college students, highlighting big data's complementary role. Contributions such as those by Mylonas et al. (2021) emphasize the importance of IoT in promoting sustainability awareness and energy efficiency in European schools, engaging students through gamified learning environments. Similarly, Mohamed & Lamia (2018) and Farhan et al. (2018) reveal how flipped classroom models and IoT-based student interaction analysis can significantly boost engagement and comprehension in mathematical logic and eLearning contexts, respectively. Further underscoring IoT's educational benefits, Sun, et al., (2022) focus on IoT's utility in analyzing waste-sorting behaviors and enhancing family education through interactive systems, respectively. Studies by Lin et al. (2021) and Magrabi et al. (2018) focused into the augmentation of computational and critical thinking skills within engineering education, facilitated by IoT and collaborative IoT device projects. Notably, Ali et al. (2017) and Suwastika et al. (2022) examine the transformative effects of IoT-enhanced flipped case-based learning in medical education and the development of IoT-based educational tools for Industry 4.0, respectively. These examples, alongside insights from Sun et al. (2022), Villegas-Ch et al. (2020b), and Yasuoka et al. (2023b) who have documented various aspects of IoT's positive impact on educational learning and teaching processes. Through this comprehensive analysis, we have addressed the research question by highlighting how different educational institutions and programs harness IoT technology for improved learning outcomes, marking a transformative shift towards more adaptive, interactive, and effective educational methodologies. The corresponding implication suggests that educational institutions should continue to explore and expand the use of IoT technologies to further enrich the learning experience, ensuring students are well-prepared for the challenges and opportunities of the digital age.

RQ3: Trends and innovative practices in using IoT for enhancing school management

Our findings affirm that the Internet of Things isn't just used in everyday life; it's also used in many other areas, such as education. IoT can be used to improve learning by creating smart classrooms, tracking and analyzing student performance in real time, and making it easier for people to learn from afar. Our analysis demonstrates that the integration of IoT technology has markedly improved school management by streamlining processes traditionally characterized by extensive and repetitive tasks.

This study explores the untapped potential of IoT and big data in fostering innovative and entrepreneurial skills among college students. By utilizing IoT to collect data and employing a C4.5 decision tree algorithm for analysis, the study demonstrates that this approach significantly enhances students' professional development and employability, addressing a crucial gap in the education sector (Ma & Pan, 2023).

Figure 7 has reported various case studies which have demonstrated that the efficiency in the school management can be improved through the integration of IoT. Additionally, the literature reflects on IoT's versatility in school management across various domains such as mobile education, administration, and student management (Songsom, Nilsook, & Wannapiroon, 2019), showcasing its broad applicability and impact. Our findings also align with another research article by Zaballos et al., 2020 who have also documented various aspects to highlight the application of IoT for campus management. By addressing the research question, we ascertain that IoT's deployment in educational settings paves the way for enhanced management practices, resource allocation, and operational efficiency, as corroborated by comprehensive evidence across the spectrum of school management functions. The corresponding implication underscores the critical need for educational institutions to adopt IoT solutions actively, leveraging the technology not just for educational delivery but also for comprehensive management and operational optimization.

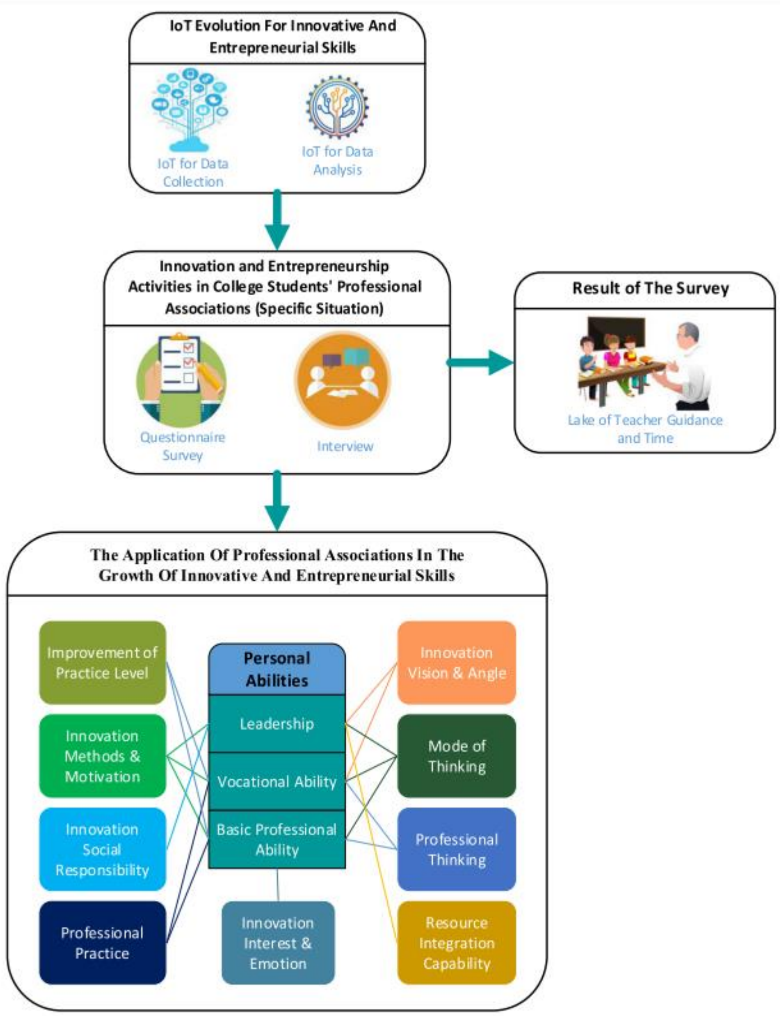

Figure 7. Leveraging IoT and Big Data for College Student Innovation and Entrepreneurship.

The implications of this research article show how big a change the IoT can bring to different parts of education. In the area of online labs, adding IoT technology has made schoolwork better in engineering fields. This is because it gives students real-life practice with robots and quick data capture. This not only helps solve problems better but also connects with the wider studies on how effective the IoT is for learning far away. This affects our learning in school too. IoT helps to make smart classrooms and fun learning tools, giving each person a personalized way of learning that keeps their interest. Educators can teach students better by using real-time data about how they are learning. This helps improve understanding and problem-solving skills. In the field of school management, IoT technology makes office tasks easier and helps with resources and decision-making using data. This results in better and faster schools. The findings also stress the importance of more study and spending on buildings to use IoT's big potential, especially in untouched areas like physical education, language learning, and special needs teaching. In general, when IoT is added to learning it can make it more personal and interesting for students.

Conclusion

In conclusion, the ongoing technological revolution has brought about some incredible changes, especially with the rise of over 20 billion digital identities linked to IoT devices worldwide. This fusion of the physical and virtual worlds has deeply affected education, especially with the increased demands during the global COVID-19 pandemic. The challenge of delivering quality education, especially through e-learning, has been real, and virtual meetings have sometimes made it harder for instructors to connect with students. However, during these challenges, there's a silver lining in IoT. It is like a beacon of hope, offering a bunch of benefits for everyone involved in education – from school management and instructors to learners. This article provides a detailed review of how IoT is being used in real-life situations, like in remote labs, learning experiences, and managing campuses. The findings highlight how IoT can be a game-changer in higher education, making education better, making the learning experience richer, and helping teachers do their jobs more efficiently. The article also underlines the need for investing in infrastructure, training teachers, and designing curricula to take advantage of what IoT has to offer in education. And it goes beyond just academics – exploring how IoT impacts academic performance, making learning more interactive, and even contributing to the well-being of students. Ultimately, integrating IoT into education has the potential to make learning more personal, engaging, and practical, preparing students for the challenges of the digital age.

In academia, the widespread acceptance in education of the IoT as a transformative technology is evident at various levels. However, a significant research gap remains in IoT's applications in physical and sports education. While some isolated studies exist, the absence of integrative research that compiles and reviews these endeavors leaves a void in our understanding of how IoT can revolutionize physical education and sports training. Similarly, in the context of language learning, especially English as a second language, numerous research articles explore the potential of IoT, but there is a scarcity of comprehensive studies that provide a holistic perspective. A comprehensive framework, detailed methods, illustrative case studies, and a thorough examination of the associated challenges are still missing, hindering our ability to harness IoT's full potential in language education.

One recommendation for the specialists and researchers working towards educational technology is that a critical area that demands immediate attention is the integration of IoT into special needs education. The literature in this domain is exceptionally sparse, with only a handful of articles addressing this crucial aspect. Pursuing inclusive education requires urgency for more extensive and dedicated research efforts to explore how IoT technologies can accommodate the unique needs of individuals with disabilities.

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Appendix

Table A.1

Current state-of-the-art available in the digitalization of the engineering laboratories.

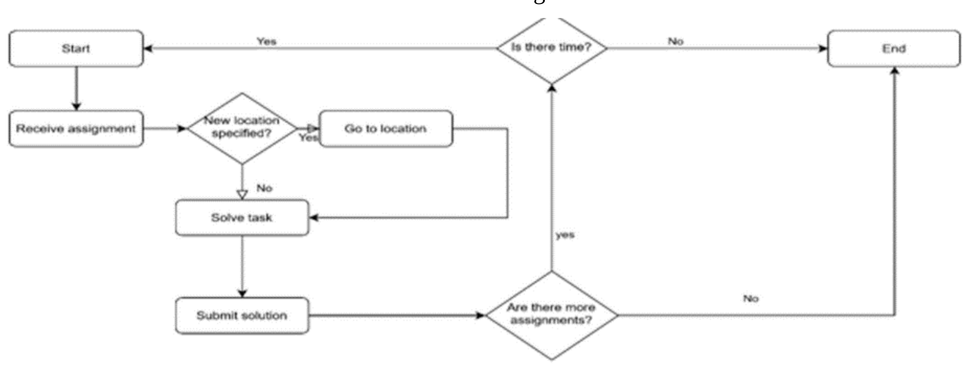
Reference	Description of the lab	Outcome of research
(Basheer et al., 2021)	Smart automated computer lab	This paper introduces an IoT-based system for creating a secure and automated computer lab. It detects security threats like fires and sends email alerts to users. The system is cost-effective, energy-efficient, and reliable, addressing limitations in existing solutions and enhancing lab security and efficiency.
(Prakash et al., 2021)	Automation laboratory, including programmable logic controllers (PLC), industrial PC (IPC), and hydraulic laboratories	This paper highlights the transformation of a traditional automation lab into an IoT-enabled remote laboratory, emphasizing the role of technology in modern engineering education, specifically in India. It discusses the implementation of IIoT for remote operation of PLC, IPC, and hydraulic labs, offering web-based control from remote locations.
(Ga, Cha, & Kim, 2021)	School Science Learning Environments	This study identifies three student challenges in scientific inquiry: limited access to diverse measuring tools, difficulties adapting tools to complex inquiries, and unequal data analysis opportunities. It proposes an Arduino-based IoT solution, enabling affordable, customized tools and equal data access. It offers an example using a temperature/humidity sensor connected to a development board to transmit and visualize data on an IoT Platform, enhancing student-led scientific exploration.
(Taj et al., 2021)	Analog electronics	This work focuses on designing an IoT system using the Red Pitaya STEMLab board for remote experiments in analog electronics. It offers a cost-effective solution for conducting both integrated and external practical work with minimal latency and portability. The study compares this remote system's performance to traditional hands-on labs, particularly in the "RC charging and discharging circuit" experiment. The goal is to enhance electronics' resource utilization and self-learning capabilities through efficient remote experimentation.
(Ramya et al., 2020)	Industrial automation	The article presents a remote laboratory for sensor-based experiments using IoT and embedded systems to enhance sensor learning in engineering and industrial automation applications.
(Al-Obaidi & Derbel, 2023)	Renewable energy	The paper focuses on using IoT for a renewable energy lab, offering remote access and skill development through virtual experiments.
(Pang et al., 2022)	Robotics	This study created an online remote robotics experiment system using digital twin (DT) and IoT technology, enhancing students' skills training efficiency and quality in industrial robotics courses during the COVID-19 pandemic.

(Ali et al., 2022)	Laboratory safety	This research proposes a real-time, smart, vision-based lab safety monitoring system to ensure students' compliance with personal protective equipment (PPE) in educational labs. Various YOLOv5 and YOLOv7 models were trained using a novel dataset, achieving promising results for PPE detection. The system can enhance lab safety and promote a health and safety culture among students.
(Urbano et al., 2023)	Physics lab	Professional education, especially in engineering, should empower students to interpret their environment effectively. Remote laboratories, presented in this paper, offer flexible options for hands-on learning, enabling experiments like free fall, Hooke's law, and parabolic motion via scalable IoT technology. These labs enhance engineering education without requiring physical presence.
(Chacón et al., 2018)	Civil engineering	This paper showcases how civil engineering education harnesses IoT technology. It emphasizes the integration of sensors, microcontrollers, and IoT concepts to address civil engineering challenges, enhance automation, enable monitoring, and control civil engineering processes. The cost-effective approach can be applied in educational settings, paving the way for open-source teaching labs in civil engineering schools.

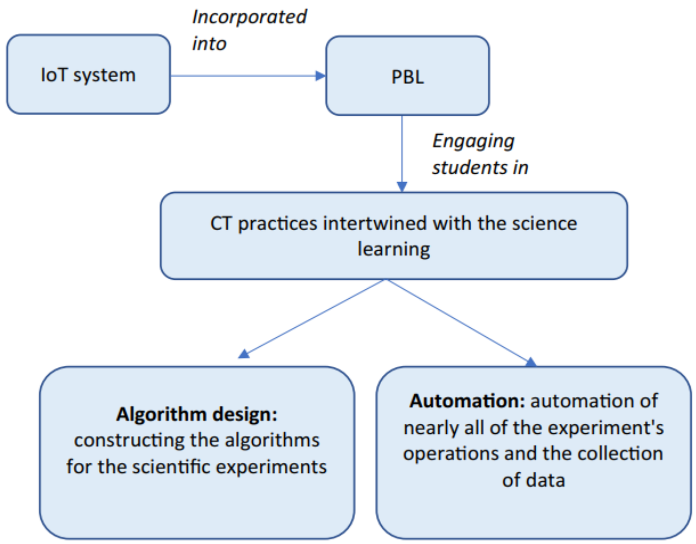
Table A.2

Summary of the articles in the literature related to using the IoT in the learning and teaching process.

Reference	Theme	Description
(Petrović et al., 2022)	IoT-Infused Game-Based Learning Elevates Higher Education	This article discusses a game-based learning model in a smart classroom using advanced technologies like IoT and augmented reality. It evaluates the model's impact on students' learning in IoT-related courses at the University of Belgrade, finding positive results. Integrating educational games into learning management systems is recommended to enhance formal higher education learning.

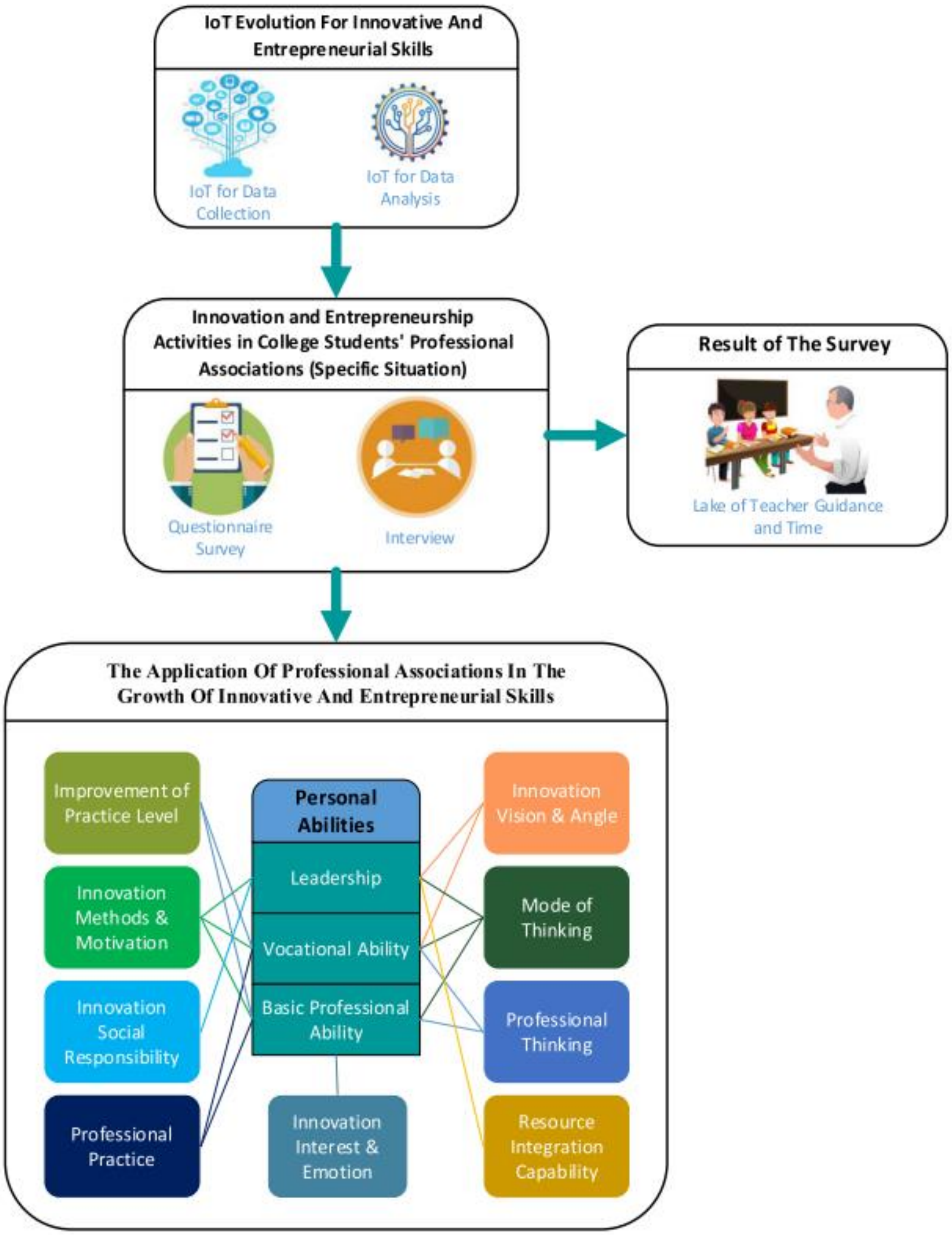


(Tsybulsky & Sinai, 2022)	Enhancing High School Biology Education Through IoT-Based Project Learning	This article explores the integration of the IoT into high-school biology project-based learning. Through qualitative analysis of students' experiences and skills development, the study uncovers significant learning experiences and their impact on cognitive, interpersonal, and intrapersonal skills. The research contributes valuable insights to high school project-based learning theory and practice.



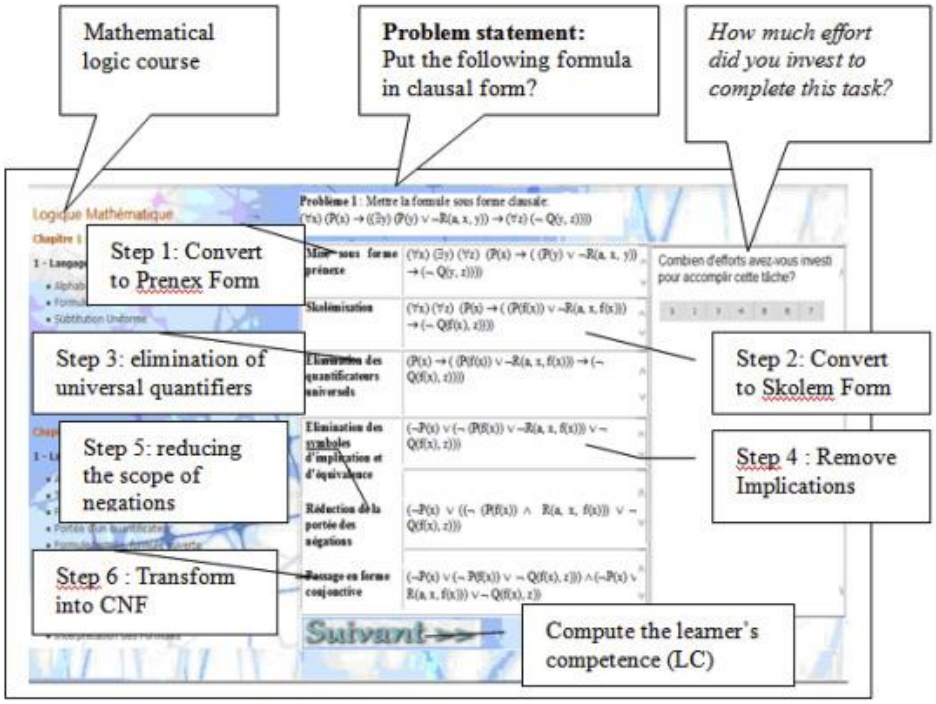
(Suwastika et al., 2022)	IoT-Based Mathematical Balance Tool for Education 4.0	The advent of Industry 4.0 has given rise to Education 4.0, revolutionizing the education sector. This study focuses on developing an IoT based mathematical balance tool to support modern education trends, including remote access, personalization, and practice with feedback. The system, developed through a structured IoT development method, exhibits optimal performance with 100% accuracy in reading student activities and rapid data processing, offering innovative support for math education in Indonesia.
(Mylonas et al., 2021)	Enhancing Sustainability Awareness and Energy Efficiency Through IoT and Gamification in European Schools	The GAIA H2020 research project employed IoT-based methods, gamification, and competitions to raise sustainability awareness and promote energy efficiency in European schools. The project successfully increased digital skills and encouraged active participation by engaging students and teachers. Findings demonstrated that competition, gamification, and IoT-based activities significantly boosted student engagement and overall performance, offering promising avenues for sustainable education.

(Ma & Pan, 2023)	Leveraging IoT and Big Data for College Student Innovation and Entrepreneurship	This research explores the untapped potential of IoT and big data in fostering innovative and entrepreneurial skills among college students. By utilizing IoT to collect data and employing a C4.5 decision tree algorithm for analysis, the study demonstrates that this approach significantly enhances students' professional development and employability, addressing a crucial gap in the education sector.

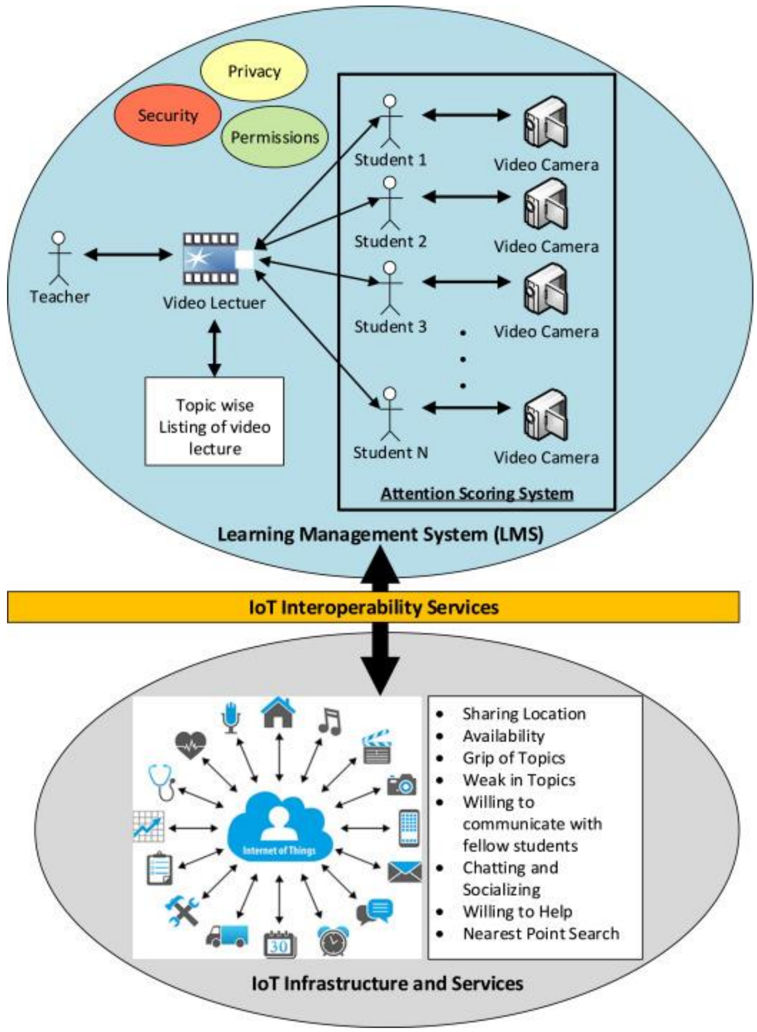


(Mohamed & Lamia, 2018)	Enhancing Student Engagement with Flipped Classroom and IoT in Mathematical Logic Education	In response to modern students' challenges with traditional teaching methods and digital distractions, this paper explores integrating the flipped classroom and the IoT in teaching mathematical logic. The study employs an Intelligent Tutoring System (ITS) to support students' problem-solving skills outside the classroom. Results indicated that factors like perceived

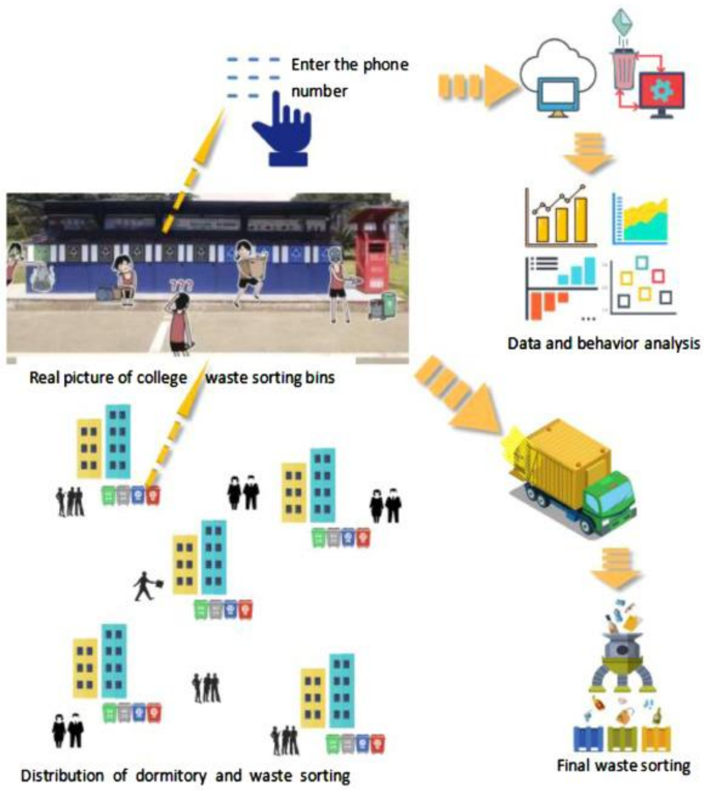
usefulness, self-efficacy, compatibility, and perceived support influence students' intention to continue using the flipped classroom method.



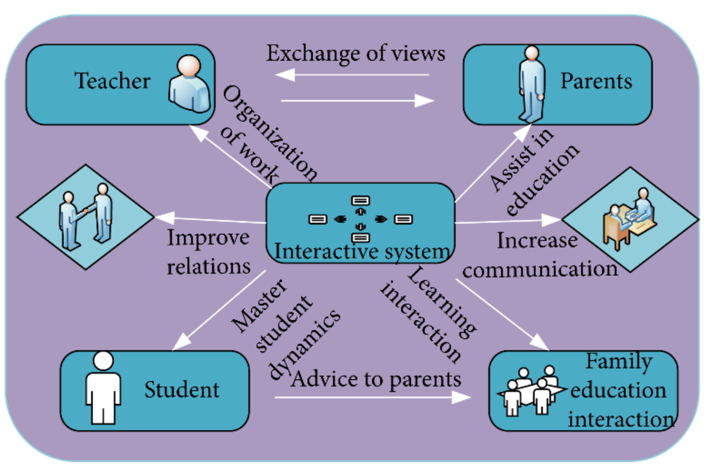
(Magrabi et al., 2018)	Enhancing Critical Thinking in Engineering Education through IoT	This article underscores the importance of teaching critical thinking skills in engineering education. It advocates for instructional strategies that engage students actively, prioritizing the learning process over content memorization and employing assessment methods emphasizing intellectual challenges. The article acknowledges barriers like limited resources and time constraints but suggests project-based and collaborative activities as effective means to foster critical thinking. It presents examples of students and faculty collaborating on IoT device projects, highlighting successful outcomes in critical thinking development.
(Farhan et al., 2018)	Enhancing eLearning Through IoT-Based Student Interaction Analysis	An IoT-based framework for evaluating student attention, participation, and comprehension in remote lecture video settings is developed. Through machine learning it examines multimedia content to identify facial and eye features and subsequently develops the algorithm for the attention score calculation. The findings are instrumental in evaluating the success of electronic learning techniques and this tool can be integrated into a modern learning management system to promote e-learning.



(Xia et al., 2021)	Analyzing Waste-Sorting Behavior of College Students Using IoT and Behavioral Models	Using IoT bins and the questionnaire, this article reviews waste sorting behaviors among college students. The study combines TAM (Technology Acceptance Model), TPB (Theory of Planned Behavior), and NAM (Norm Activation Model) to examine intentions and behavior for waste sorting. The study showed that there is more recycling during pre-class and meals. The study also revealed that students' perceptions or subjective norms have a greater effect on behavior and that the current incentives do not impact their behavior. The study provides useful suggestions on how to improve public waste sorting.



(Sun, Guo, & Zhao, 2022)	Enhancing Family Education through IoT-Based Interactive Systems	The problem of low frequency of parent-child interactions due to lack of time is discussed in this work. It proposes a Family Education Interactive System based on IoT to narrow the distance between parent and child. An embedded system, in this case, is beneficial in enhancing family education, enabling communication efficiency between teachers and parents. The study indicated an increase of 19 percent in customer satisfaction and an eight percent improvement in communication. Structural family therapy to improve family dynamics and interactions for IoT application in family education.



(Lin et al., 2021)	Enhancing Computational Thinking through AIoT Learning with Augmented Reality	This study delves into the importance of cultivating students' computational thinking (CT) competencies in today's educational systems. It highlights the role of Artificial Intelligence of Things (AIoT), which combines AI and IoT, as a valuable tool for CT training. The research introduces a novel approach using Augmented Reality (AR) technology, demonstrating its positive impact on students' problem-solving abilities, comprehension, and application planning and design skills, ultimately enhancing their CT skills.
(Ali et al., 2017)	IoT-Enhanced Flipped Case-Based Learning in Medical Education	This article discusses integrating Case-Based Learning (CBL), flipped learning, and the IoT in medical education. It proposes the IoTFLiP platform to facilitate flipped case-based learning by providing real evolutionary medical cases, fostering decision-making skills, and enhancing teamwork. It emphasizes security and privacy for personalized medical data and supports various application delivery approaches. The platform extends the Interactive Case-Based Flipped Learning Tool (ICBFLT) and utilizes IoT devices to create real-world medical scenarios, enriching medical students' academic and practical experiences.

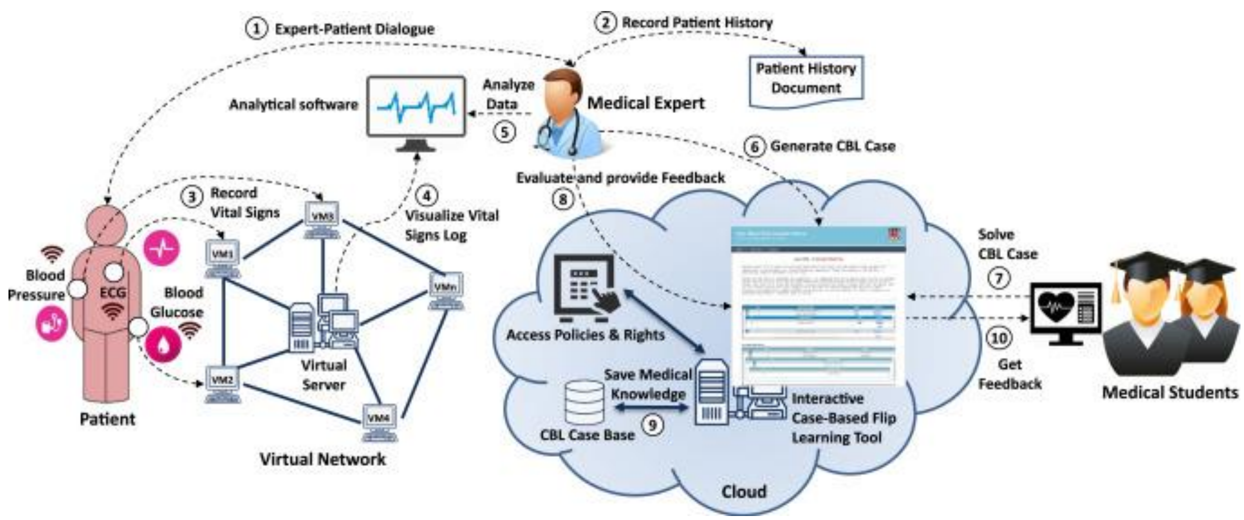
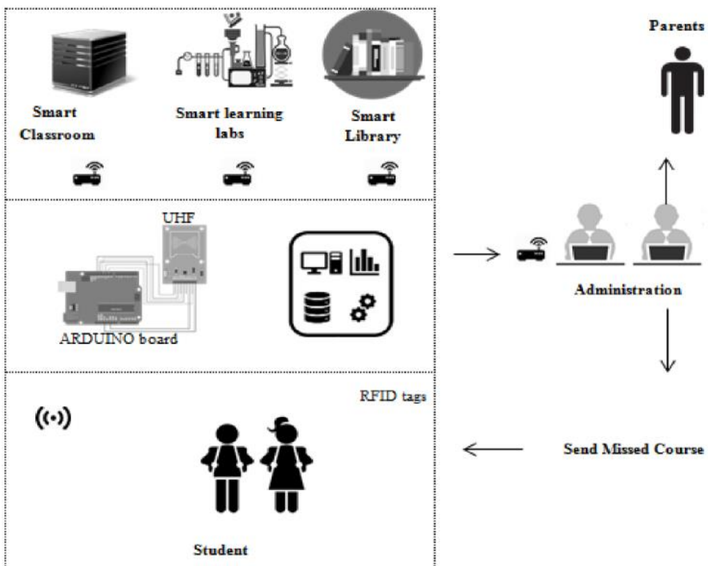
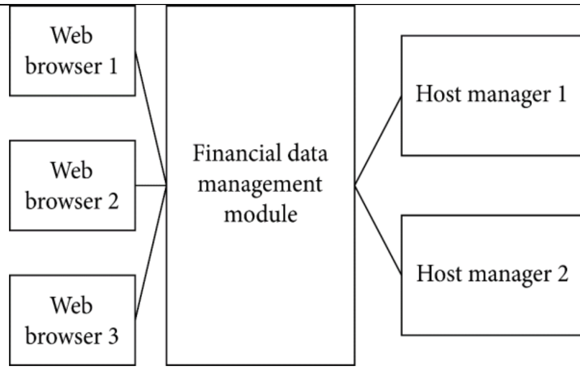


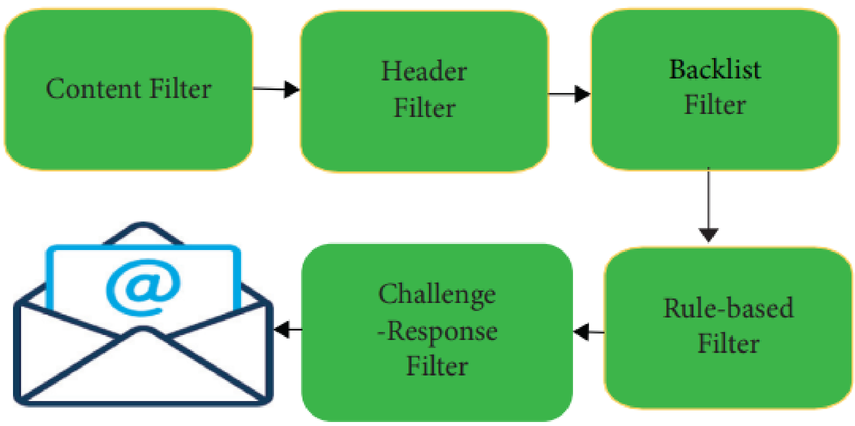
Table A.3

Current state-of-the-art available in the usage of IoT for school management.

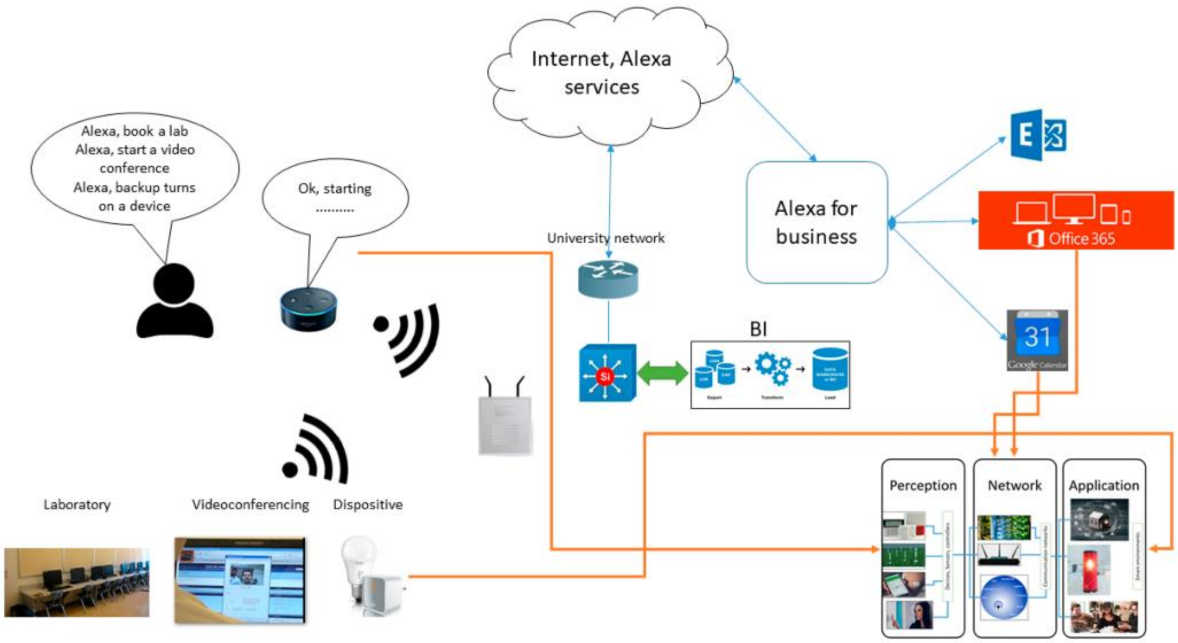
Reference	Application of IoT	Description
(Zhao, Zhao, & Qu, 2022)	Attendance management	In this article, IoT technology supports attendance management in college classrooms. The system combines RFID and face recognition technologies to efficiently monitor and record students' attendance, including late arrivals, early departures, absenteeism, and substitutions. While RFID offers accuracy and cost-effectiveness, face recognition provides detailed attendance data, although it can be affected by environmental factors. Together, these IoT-based solutions improve classroom attendance management in higher education institutions. 
(Guo, 2022)	Financial information system	This financial information system for colleges and universities incorporates IoT to enhance data management, budgeting, and analysis, improving financial efficiency and adaptability.



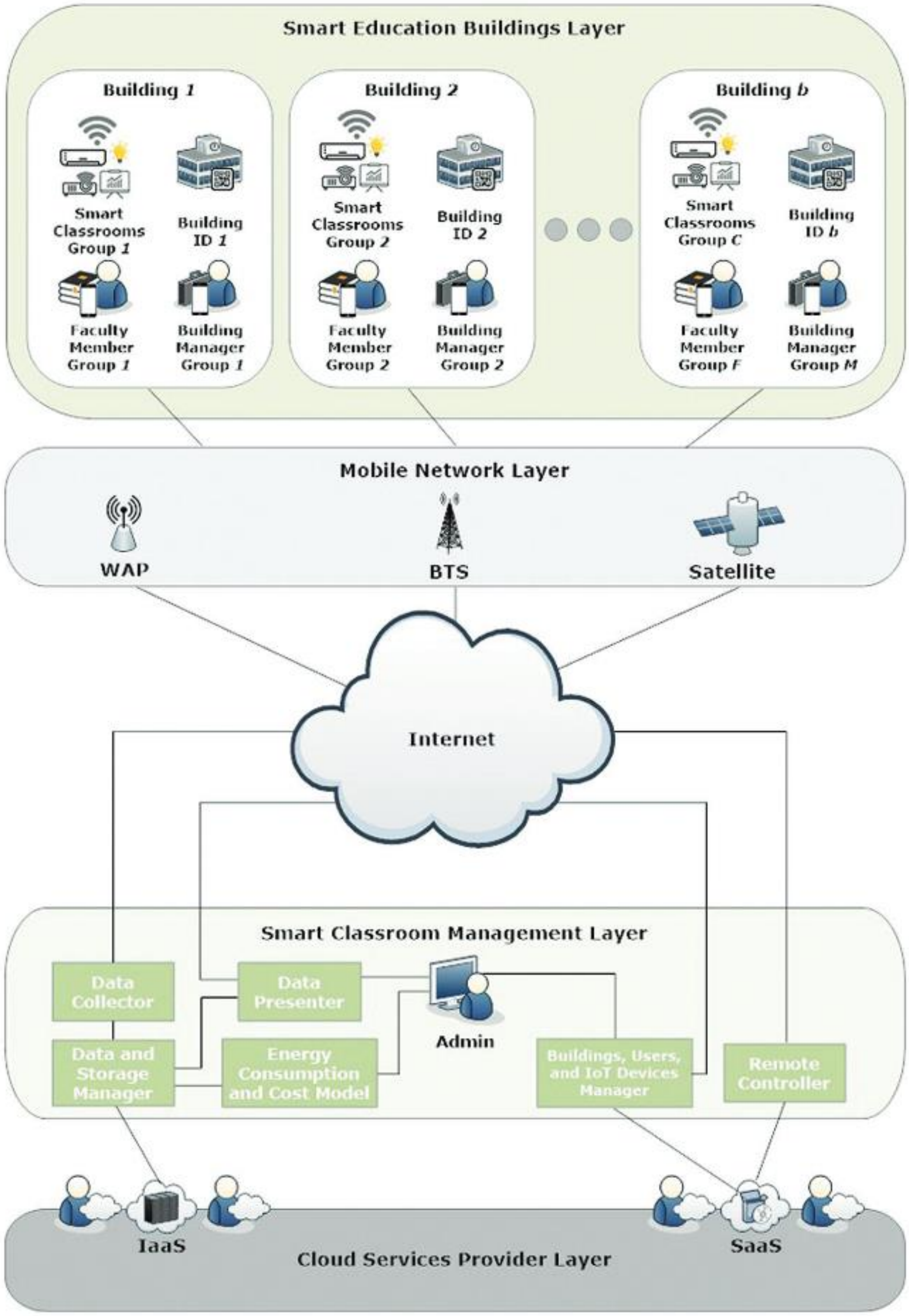
(Ahmed et al., 2022)	Spam detection in email	This paper surveys machine learning techniques, including Naïve Bayes, decision trees, neural networks, and random forests, used for spam filtering in email and IoT platforms. It categorizes and compares these methods based on accuracy, precision, and recall, providing insights and future research directions.



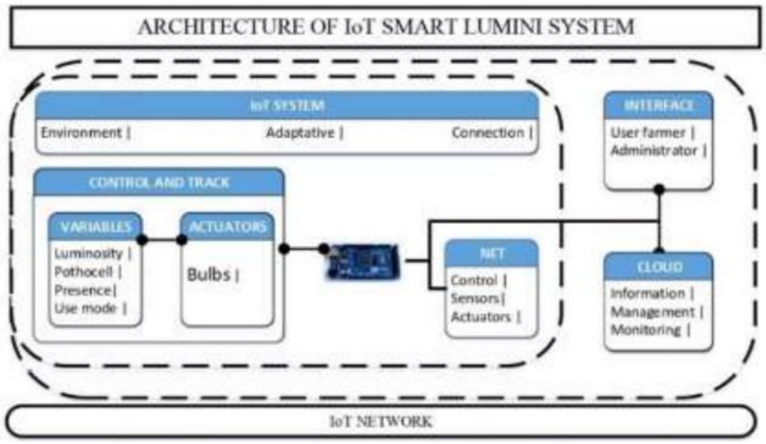
(Villegas-Ch et al., 2020a)	Improved process management	The article discusses the use of IoT to enhance administrative management processes in a university setting. IoT technology is employed to automate and optimize routine tasks, reducing the need for manual effort and improving process efficiency within the university campus.



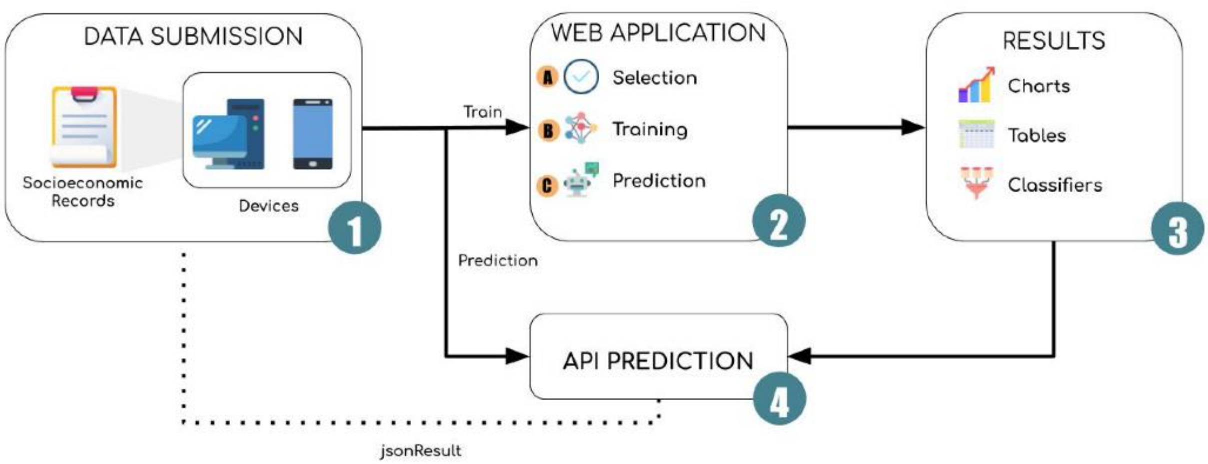
(Yasuoka et al., 2023a)	Energy management and conservation	This article discusses the GENIIOT project, which utilizes the IoT for energy management on a Brazilian university campus. The focus is on air-conditioning system efficiency, occupant comfort, lighting control, and energy waste reduction, contributing to sustainable campus operations and energy education. The project promotes responsible resource consumption, cost savings, and reduced carbon emissions while aligning with sustainable development goals.



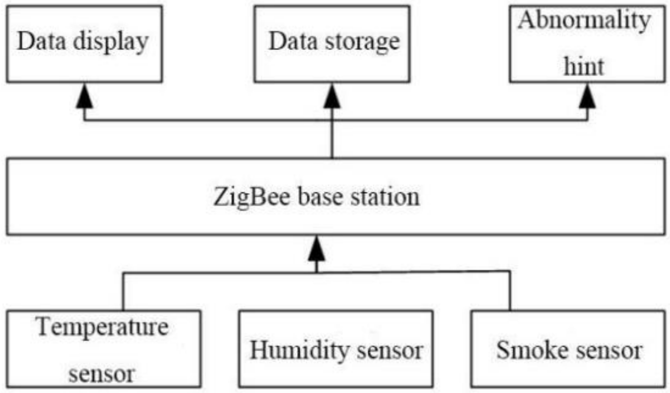
(González-Amarillo et al., 2020)	Smart lightening	IoT is employed in smart lighting systems to create adaptable, intelligent lighting solutions that optimize energy consumption in buildings for sustainability.



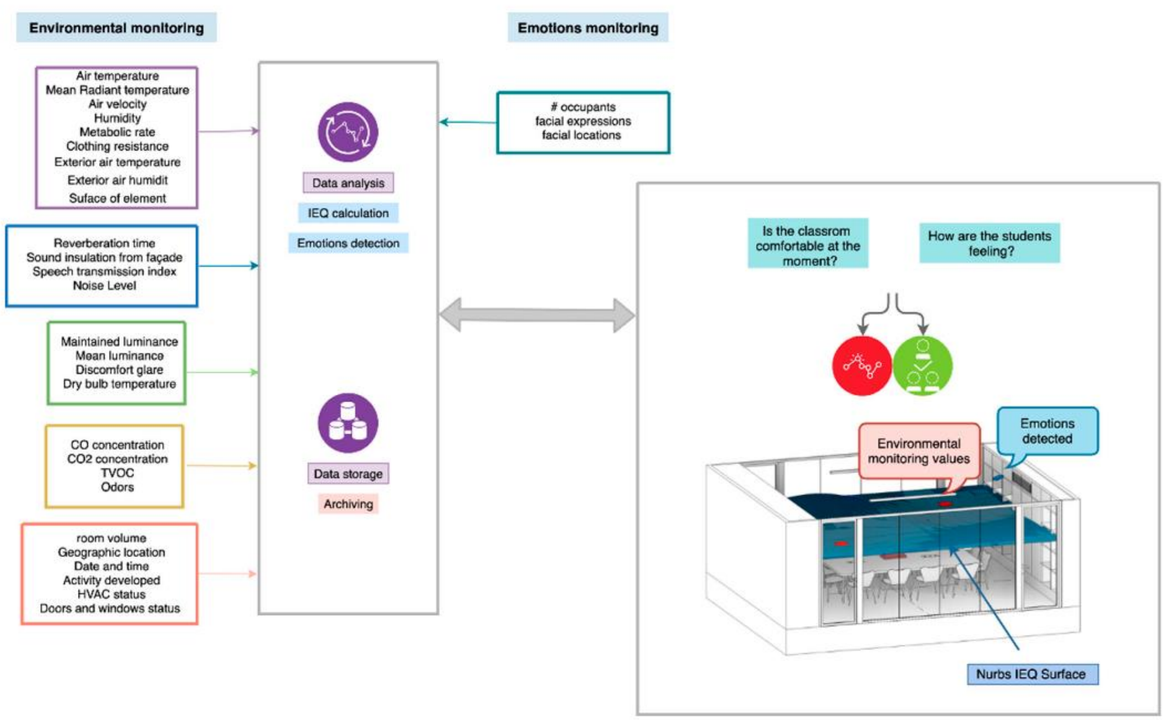
(Freitas et al., 2020)	Student dropout prediction	IoT is utilized in a predictive framework for student dropout using machine learning, leveraging socioeconomic data to identify potential dropouts during pre-registration and automating the prediction process to improve management and personalized follow-up.



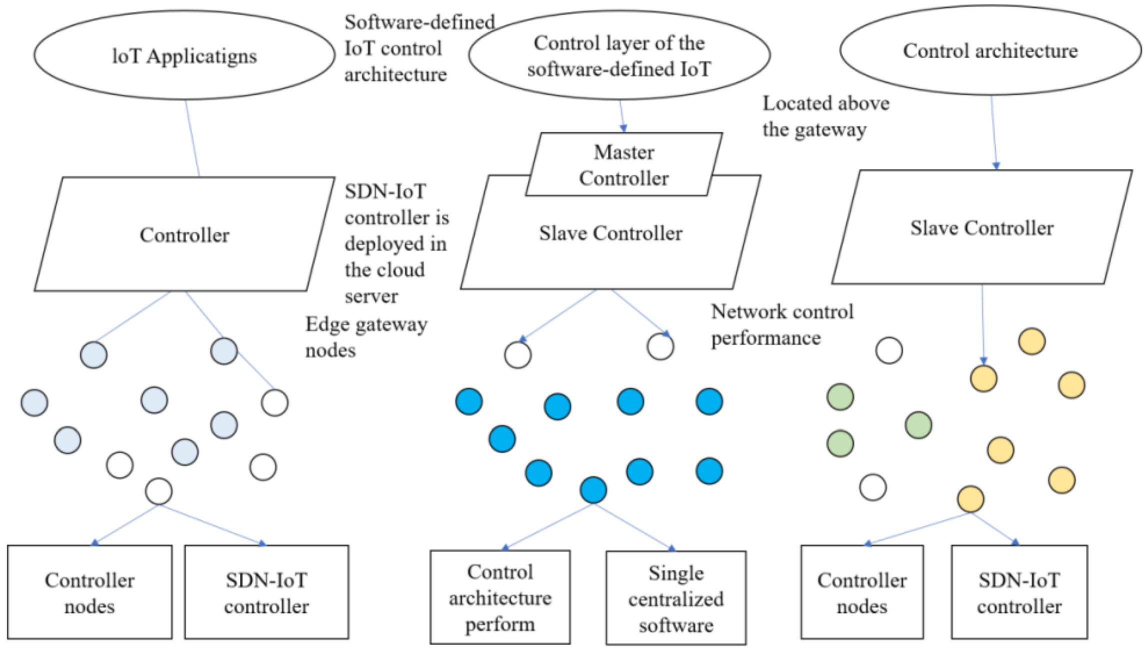
(Liu, 2021)	Campus Network Equipment Environment Monitoring	IoT is employed in monitoring campus network equipment environments. It involves designing a monitoring system with sensors for temperature and humidity, which demonstrated high accuracy and efficient data transmission, validating its effectiveness for campus network applications.



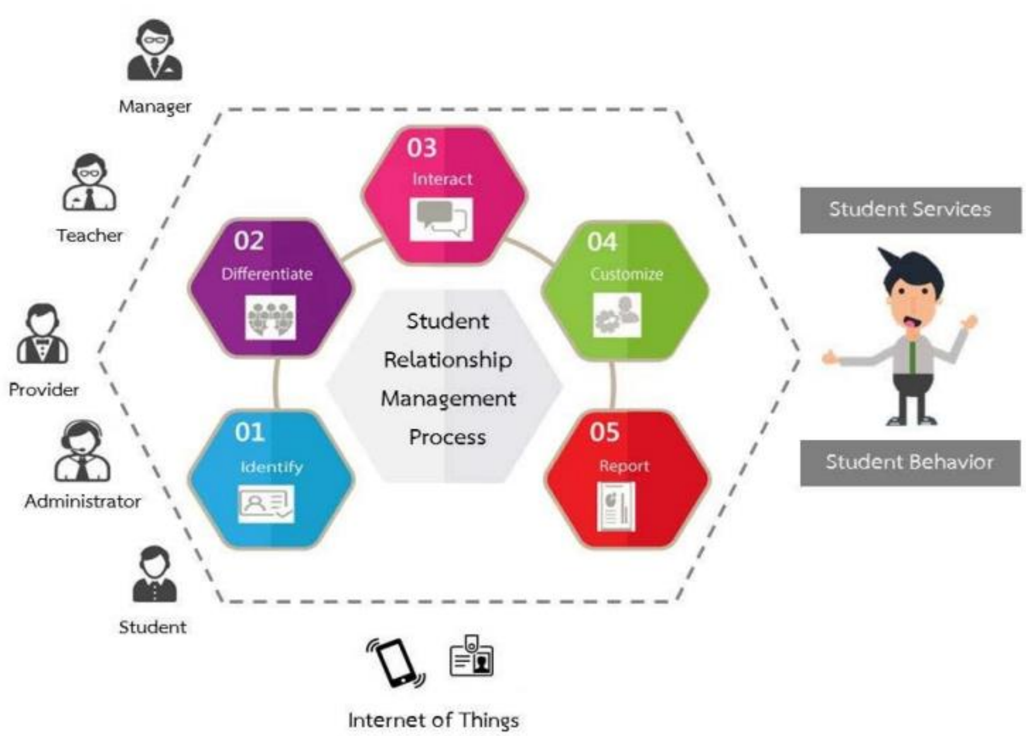
(Zaballos et al., 2020)	Thermal comfort monitoring	IoT is used in smart campuses (SCs) to integrate building information modeling tools with wireless sensor networks for environmental monitoring and emotion detection, providing insights into thermal comfort levels and promoting energy efficiency on educational premises.



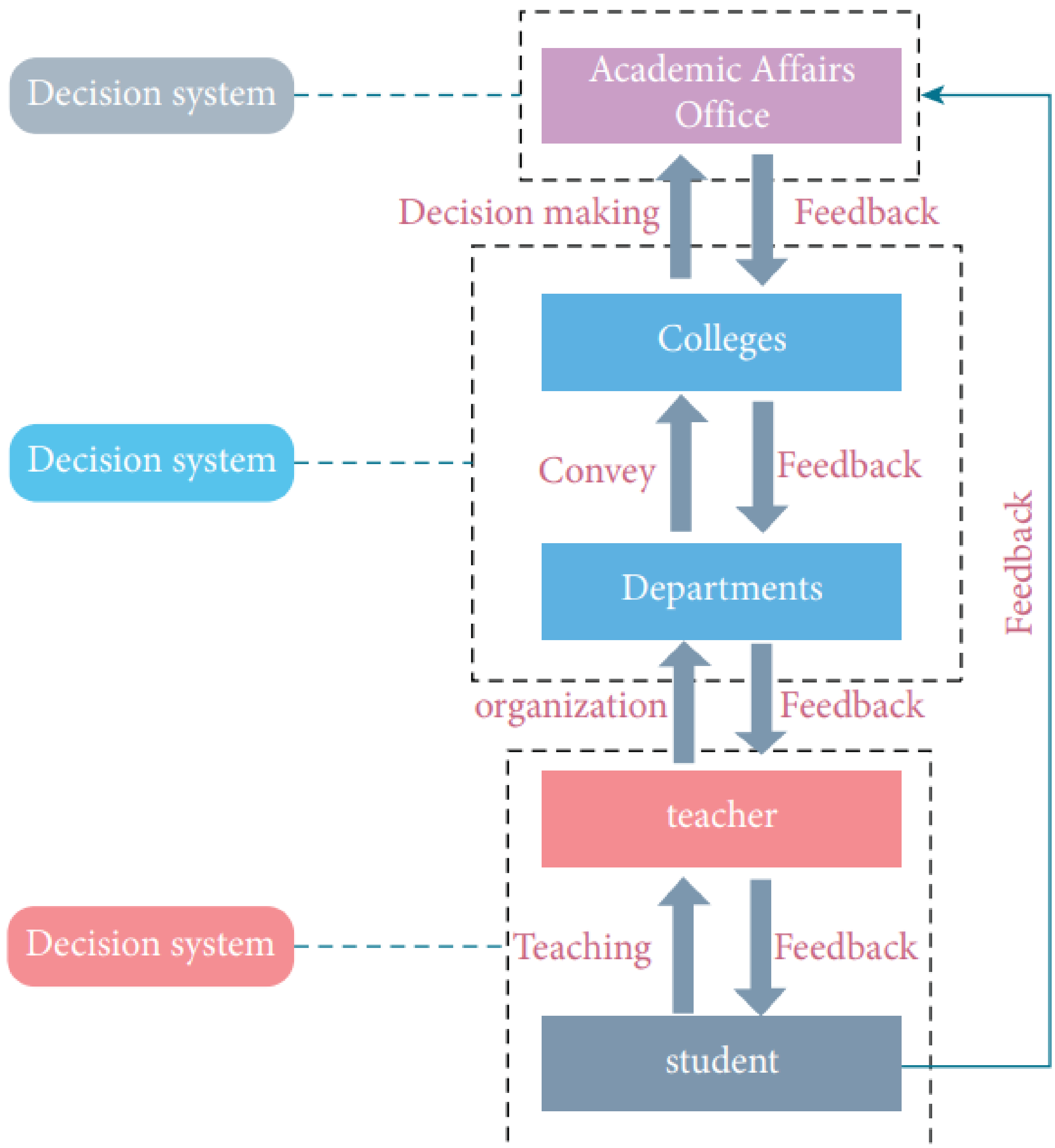
(Liu & Liu, 2023)	Educational management automation system	This article reports on IoT to design a control mechanism for an educational management automation system focused on physical education. IoT facilitates data integration and optimization in resource management, equipment, and course quality, ensuring efficient utilization of sports resources, enhancing sports management efficiency by over 20%, and improving overall college management.



(Songsom, Nilsook, & Wannapiroon, 2019a)	Student relationship management	This article utilizes IoT to develop and evaluate a student relationship management system. The IoT-driven system encompasses processes like identification, differentiation, interaction, customization, and reporting to enhance student relationships effectively, with experts rating it as highly suitable for practical implementation.



(Guo, 2021)	Teaching evaluation process	This research employs IoT technology to enhance the teaching evaluation process in applied undergraduate colleges by creating an IoT architecture to collect impact indicator information, establishing a teaching evaluation index system, and utilizing fuzzy comprehensive evaluation for quantification and analysis, ultimately aiming to improve teaching quality and guide the development of teachers and students.



(AnnRoseela & Godhavari, 2020)	Exam paper leakage detection	In this article, IoT is utilized to create an "Exam Paper Leak Protection Framework" that employs RFID readers, fingerprint sensors, a buzzer, an LCD, and a Wi-Fi module to securely store and monitor exam papers, alerting authorities in the event of unauthorized access and potential paper leakage.