IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 5 April 2023, accepted 20 April 2023, date of publication 25 April 2023, date of current version 1 May 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3270340

RESEARCH ARTICLE

Technological Spotlights of Digital Transformation in Tertiary Education

THANH-CONG TRUONG[1] AND QUOC BAO DIEP[2]
[1]Faculty of Information Technology, University of Finance-Marketing, Ho Chi Minh City, Vietnam
[2]Faculty of Mechanical-Electrical and Computer Engineering, School of Technology, Van Lang University, Ho Chi Minh City, Vietnam
Corresponding author: Quoc Bao Diep (bao.dq@vlu.edu.vn)

ABSTRACT In the current globalization trend, digital transformation is an indispensable requirement that affects all aspects of life. Within the education domain, it creates opportunities for tertiary education institutions to replace traditional teaching, learning, research, and operation methods with more innovative, creative, and cost-effective methods. This article aims to examine recent technological advancements to promote the transformation in tertiary education. Our research methodology consists of two main activities: 1) identifying relevant literature on the use of technology to promote transformation in tertiary education by adopting PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines; 2) conducting a thematic analysis based on the findings of the literature review; to explore the relationships between them in order to better understand the link between technological trends and digital transformation in tertiary education. The findings indicate that the current technology trends that are being concerned and deployed in the educational environment are Artificial intelligence, the Internet of Things, blockchain technology, and other relevant platforms and technologies such as Social networks, Mobile platforms, Big data analytics, Cloud computing, Robotic Process Automation, Virtual reality and Augmented reality and Additive manufacturing. The article also discusses the adjustment of tertiary education in the process of digital transformation with the support of technology and points out the shortcomings as well as research directions in the coming time.

INDEX TERMS Digital transformation, tertiary education, technology.

I. INTRODUCTION

In recent years, digital transformation is one of the trendiest terms that spread through media. The concept of digital transformation involves the usage of digital technologies to adjust or modify the existing processes and culture of an organization to create new values. Digital transformation in tertiary education represents a change in all aspects from teaching methods, classroom management techniques, and interaction with learners to program design, learning environment, and management and operation of the educational institution [1].

The utilization of digital technology in global tertiary education has shown many benefits and created favorable conditions for teachers and learners to overcome geographical and time barriers, personalized learning through adaptive education programs, and building digital equity for learners to access resources.

While there have been several surveys that have examined digital transformation in tertiary education and the education sector as a whole, they did not focus on the important aspect of understanding the technology trends that underpin this transformation [1], [2], [3], [4], [5]. As a result, there is a significant gap in knowledge in this area where technology trends and digital transformation in education are not yet closely linked. Our work aims to address this gap by focusing on the technology trends supporting digital transformation in education. By doing so, we aim to provide a more comprehensive understanding of the impact of emerging technologies on digital transformation in tertiary education. Our study will investigate the potential of technologies to enhance learning outcomes and improve access to education. Ultimately, we believe that our work will have important implications for

The associate editor coordinating the review of this manuscript and approving it for publication was Juan A. Lara.

TABLE 1. A comparison between our study and existing surveys in the literature.

Ref.	Year	Highlighted technology										
		AI	Social	Mobile	Analytics	Cloud	IoT	Blockchain	AR&VR	RPA	3D printing	Interactive tools
[1]	2020	x	x	x	x	x	x	x	x			
[2]	2021											
[3]	2022	x			x	x	x					
[4]	2023	x					x	x	x	x		
[5]	2023	x			x	x	x	x	x	x		
This study	2023	x	x	x	x	x	x	x	x	x	x	x

policy and practice in the education sector, and will provide valuable insights for researchers and practitioners working in this field. To affirm the originality and unique contribution of our study, we compared our work with relevant recent works in the literature, as presented in Table 1.

This paper aims to examine the trends of digital technology supporting the transformation in tertiary education in recent times. Besides, this paper also points out current problems in applying technology in practice and suggests future research directions. The research questions addressed in this paper are:

- What are the technology trends that are driving tertiary education in the digital era?
- How are digital technologies transforming tertiary education institutions?
- What are the current issues of the process of applying technology to transform tertiary education and further research directions?

The remainder of this manuscript is constructed as follows. The related theoretical background is briefly introduced in Section II. Follow by, Section III describes the research method employed in this research. The results and discussion are exhibited in Section IV. The conclusion of the paper and future research directions are pointed out in Section V.

II. THEORETICAL BACKGROUND

A. DIGITAL TRANSFORMATION

Digital transformation is a prominent trend affecting all aspects of life in recent times. There are different definitions for the terminology "digital transformation." For example, "the use of technology to radically improve performance or reach of enterprises" [6], "the use of new digital technologies, to enable major business improvements in operations and markets such as enhancing customer experience, streamlining operations or creating new business models." [7], or "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [8].

These definitions have the same points of utilizing technologies to improve service providing, adjust processes, affect the culture in the organization, and influence value innovation [9].

B. THE CORE TECHNOLOGIES THAT DRIVE DIGITAL TRANSFORMATION

Digital technologies have become the foundation for transformations in operations, and business models and deliver value, generate revenue, and improve efficiencies, such as artificial intelligence, platforms and technologies in SMAC group, Internet of Things, blockchain [8], additive manufacturing technologies, augmented reality, robotics, and automation. This subsection clarifies these core technologies.

Artificial intelligence (AI) is an area of computer science in which humans program to build intelligent machines. This intelligence can think, learn, decide, and work while solving a problem, just like human intelligence [10].

SMAC is a combination of four platforms and techniques underpinning digital transformation: (S) Social, (M) Mobile, (A) Analytics and (C) Cloud [11]. SMAC combines all components to create a complete, human-centered ecosystem that provides the platform for every organization.

The Internet of Things (IoT) is a terminology that implies a network of devices embedded with sensors, and others technologies aimed at connecting and transferring data in real-time over the internet [12]. IoT plays a crucial role in transforming daily products into intelligence: integrating remote control, real-time management, config the notifications, cloud services, and integration with users' phones and other smart devices.

Blockchain is a database that stores information in data structures called blocks, in which blocks are connected together, encrypted, and capable of expanding over time. Each block contains information about the creation time linked to the previous block, along with a timecode and transaction data [13]. The main goal of blockchain is to resist data manipulation. The usage of this technology promises to reduce fraud, errors, and costs, as well as promote transparency and trust in data and transactions.

Robotic Process Automation (RPA) is a software technology that allows the automation of manual processes and services by building software robots. RPA allows to capture and simulate automatically performing tasks on applications to manipulate data, trigger responses, and communicate with other digital systems without human intervention [14].

Additive manufacturing technologies also referred to as 3D printing, involve the creation of three-dimensional objects through the sequential layering of materials. These technologies vary in the types of materials utilized, including plastics, metals, or ceramics, and the specific process for object construction, such as fused deposition modeling, stereolithography, or selective laser sintering. The advent of additive manufacturing has had a significant impact on product design, development, and manufacturing, offering greater design flexibility and the ability to produce complex geometries and internal structures that would otherwise be challenging or unattainable using traditional manufacturing methods [15].

Virtual reality (VR) and augmented reality (AR) are technologies that have the potential to significantly enhance the digital transformation of various industries. VR, or Virtual Reality, refers to a simulated environment created for the user to experience and interact with. This is typically achieved through the use of a headset, which fully immerses the user into a digital world [16]. AR, or Augmented Reality, involves the overlay of virtual information onto the physical world to enhance the user's experience [17]. This technology is often utilized through devices such as smartphones, tablets, or AR glasses.

III. RESEARCH METHOD

This study utilized a systematic review and meta-analysis approach to identify and screen relevant papers in a specific research area. To ensure the accuracy and comprehensiveness of the review, the study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PRISMA guidelines are a recognized tool for conducting systematic reviews and meta-analyses, and their adoption in this study helped to ensure the reliability and validity of the review process. This type of research is appropriate for providing an overview of a research area by classifying and quantifying contributions according to the categories of classification [18].

After identifying a set of relevant papers, we used a qualitative research method to analyze the full content of each paper and identify contributions to find answers to research questions. Specifically, the reflexive thematic analysis method [19] was utilized to analyze the data. Reflexive thematic analysis is a method of analyzing and interpreting qualitative data that allows researchers to identify patterns or themes in a given data set. It is an approach that is easy to use and flexible, and it allows researchers to consider their own perspectives and biases when analyzing the data [19].

The research conducted in this study followed a four-step approach: (1) formulation of a search string and selection criteria to identify relevant papers, (2) assessment of paper eligibility, (3) development of codes or categories for data categorization, and (4) iteration over codes to identify emergent themes. In the first step, the search string was used to identify all relevant papers, followed by the assessment of each paper's eligibility in the second step. The third step involved the development of codes or categories for data categorization, and in the fourth step, the codes were iterated over to identify themes that emerged from the analysis.

A. STEP 1 - IDENTIFICATION

In order to determine the existing literature on the utilization of technology for digital transformation in tertiary education, a comprehensive search for relevant research was conducted. Given the nature of the thematic analysis of codes derived from the data, we elected to exclude keywords that denote specific methods or techniques in our search criteria, allowing such subjects to arise organically from the data.

In our study, the following search terms were utilized: "digital", "transformation", "technology", "higher education", and "tertiary education", and they were combined using the AND and OR logical operators. These terms were utilized to search against categories such as the keywords, title, and abstract of the articles, in order to generate preliminary insights into the field of focus. It is important to note that, in light of the limitations inherent in relying solely on a keyword approach, supplementary searches were conducted using both backward and forward literature searches, in order to enhance the search process.

Given that our methodology was thematic analysis, we implemented the search string across four digital libraries. Three primary electronic databases were selected for data collection and analysis: ScienceDirect, SpringerLink, and IEEE Xplore. In addition, we also scrutinized Google Scholar due to its extensive coverage of interdisciplinary fields, as noted in the work [20]. Our search was further enhanced by conducting a thorough examination of the bibliographies of the articles that were retrieved. The four databases utilized in this manuscript were given in Table 2.

TABLE 2. The electronic databases utilized in the manuscript.

No.	Database	URL
1	ScienceDirect - Elsevier	https://www.sciencedirect.com
2	SpringerLink	https://link.springer.com
3	IEEE Xplore	https://ieeexplore.ieee.org
4	Google Scholar	https://scholar.google.com

The criteria for inclusion of a paper in our study were established on the basis of three factors: (IC1) Relevance to digital transformation in tertiary education, (IC2) Presentation of contributions, including but not limited to discussions and evidence, related to technologies driving digital transformation, and (IC3) Publication in peer-reviewed journals. In accordance with the exclusion criteria applied, the papers exhibiting at least one of the following characteristics were removed from our sample:

- EC1: Antiquated (being more than 10 years old);
- EC2: Technical reports, short papers, or tutorials;
- EC3: Not written in English;
- EC4: Duplicate;
- EC5: Not address the digital technologies in the context of Tertiary education.

B. STEP 2 - VALIDATION

The author group conducted a systematic search of documents related to digital trends supporting digital

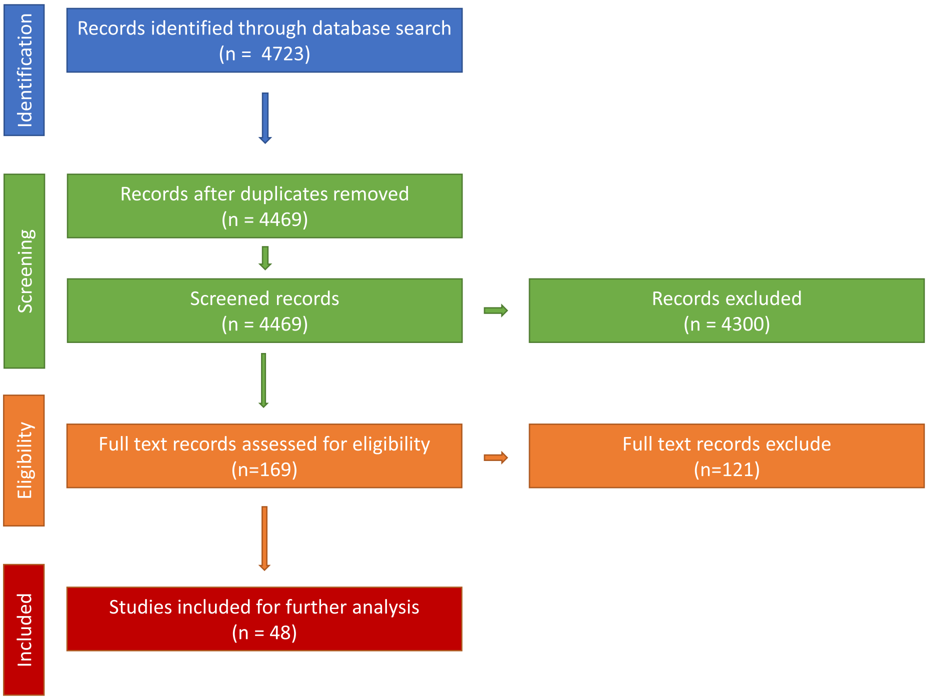


FIGURE 1. The PRISMA Flowchart of the selection process of relevant literature.

transformation in tertiary education in the databases mentioned above. Accordingly, the relevant literature published from 2012 to 2022 in the English language was chosen. In the initial search, 4723 articles were collected; then we applied all the basic exclusion criteria (from EC1 to EC4) before analyzing the adequacy of each paper. As a result, 169 documents remained to provide adequate analysis. The eligibility of each paper was evaluated by considering the EC5 exclusion criteria and the IC1, IC2, and IC3 inclusion criteria. Thus, we considered the papers which (i) addressed the digital technologies in the context of Tertiary education (EC5), (ii) relevance to digital transformation in tertiary education (IC1), (iii) presented contributions including but not limited to discussions and evidence, related to technologies driving digital transformation and (iv) published in peer-reviewed journals. The researchers evaluated each paper by conducting a preliminary review of its title, keywords, and abstract. If the paper did not meet the EC5 exclusion criteria, it was further assessed to determine if it satisfied the inclusion criteria (IC1, IC2, and IC3). If the paper was in alignment with the inclusion criteria, the researchers deemed it suitable for selection. Otherwise, we considered carefully the content of the papers to decide whether to select the paper or not. During the evaluation of eligibility, 48 papers were deemed suitable for further examination. Figure 1 displays the overview of the process of selecting papers.

C. STEP 3 - CODIFICATION

In this step, the authors repeatedly read through the documents related to the topic and take notes. Afterward, the initial codes were generated by searching the recurring patterns in the raw data. The Machine learning for language toolkit (Mallet) [21] was utilized to assist the author group to initiate the codes. The codes were assigned descriptive names to correspond to relevant sections of text. The codes were regularly reviewed and organized into distinct categories as new information patterns emerged. Upon completion of the initial coding stage, each researcher conducted a thorough review of their assigned codes to identify any redundant codes. Where redundancies were found, the codes were consolidated and the definitions of the codes were refined. As a result, 29 codes were identified from the data.

D. STEP 4 - GENERATE THEMES

The researchers engaged in a series of iterative readings and code refinement procedures to identify the underlying themes present in their study. Through this process, each broad code was critically evaluated to ascertain its transformability into a theme, and similar codes were consolidated under more abstract, high-level concepts. To guarantee the validity of the themes, the researchers convened a meeting to discuss and present their findings, analyze the similarities among themes, and reorganize the codes based on these similarities. Through this examination, the code names and definitions were refined, leading to a reduction in the number of codes that were then grouped into subthemes and eventually merged into a set of overarching themes. Throughout the entire process, the researchers continuously consulted the relevant literature and, in the end, formally defined and named the various themes. Consequently, the authors have identified five principal themes together with a total of 17 associated subthemes.

IV. RESULT AND DISCUSSION

A. RESULTS

1) ARTIFICIAL INTELLIGENCE APPLICATIONS: THE TREND THAT CHANGES THE EDUCATION INDUSTRY

The employment of AI in education (AIEd) has been a theme of interest to the research community for decades (with the milestone being the establishment of the International Artificial Intelligence in Education Society in 1997). Along with the digital transformation trend in education, AIEd has become a research domain drawn much attention from the community, especially in recent years. As a nascent domain of specialization, educational AI possesses the capability to revolutionize the methodologies and educational journeys of students. In the context of AI implemented in education, its application can manifest at various tiers. In relation to tertiary education, recommendations have been put forth with regard to at least two tiers: strategic or institutional utilization, as well as direct facilitation of teaching and learning [22].

With the large potential in data analytics, AI models were often utilized in forecasting, such as predicting the probability of students abandoning a course or using learning behavior to predict their academic achievement. For instance, AI models were used to build an early alert system for identifying students with a high probability of dropping out in the first year [23]. Meanwhile, machine learning (ML) models were employed to analyze student behavioral data when participating in online learning to predict student engagement. After that, the system automatically notified the teacher of low-engagement students so that the teacher could take appropriate intervention [24].

In another research direction, the development of intelligent tutors drew great attention from scientists as well as companies. For example, researchers developed AI tutors to teach Computer Science subjects, Mathematics, and practice reading and writing skills for students majoring in Psychology. Additionally, smart tutors also helped analyze mistakes and provided feedback to students to help them study better. Furthermore, teachers gained benefits from utilizing an AI-powered peer tutor recommender system and were able to save time for engaging in other activities [25].

AIEd also helped reduce the burden on teachers by automating basic activities in education such as automatic grading, interaction with the student, and assessment of teaching and learning activities. For instance, AI was utilized in the creation of automatic classifiers for exam questions through various means [26]. One method was the employment of natural language processing (NLP) techniques, which enabled the classifier to understand the exam questions' meaning and context, as well as recognize relevant features for classification. For example, an NLP model could be utilized to identify the main verbs or nouns in an exam question or to recognize the overall sentiment or tone of the question. Another way that AI could be utilized was through the implementation of machine learning algorithms, which could learn patterns and relationships in the data and make predictions based on these patterns. For example, a machine learning model could be trained on a dataset of labeled exam questions, and then use this training to predict the appropriate category or topic for new exam questions. Common machine learning algorithms that could be used for this included decision trees, random forests, and support vector machines. In summary, the use of AI in the development of automatic classifiers for exam questions facilitated the process of organizing and sorting exam questions and enhanced the accuracy and effectiveness of the classifier.

Apart from the above areas, AI also revolutionized tertiary education by developing adaptive systems and personalized learning experiences. Adaptive learning systems analyzed a student's progress and adjusted the coursework accordingly. It enabled students to learn at their own pace and provided feedback and support tailored to their needs. AI also facilitated personalized learning by assessing a student's learning style, interests, and performance history to create individualized experiences that matched their unique needs. These innovative AI-based systems provided more targeted interventions for struggling students and helped identify areas where students needed additional support. For example, the work by [27] proposed and showcased a framework that proposed collaborative activities catered to the unique requirements and inclinations of students. This was accomplished through the utilization of the Artificial Neural Network (ANN) and the Weighted Sum Model (WSM).

Table 3 presents a comprehensive overview of the salient features of the noteworthy studies discussed, encompassing the research direction pursued, the AI model or technique employed, as well as the key findings or benefits derived from each study.

2) INTEGRATING SMAC IN TERTIARY EDUCATION

SMAC (Social, Mobile, Analytics, Cloud) are four technical platforms and technologies that underpin an ecosystem that supports digital transformation for organizations and businesses. In tertiary education, the application of SMAC contributes to transforming operations and management, helping to create competitive advantages, and bringing new opportunities.

The emergence of social media platforms brought about a significant transformation in the manner in which individuals communicated and exchanged information with one another. In the realm of education, social media platforms introduced novel prospects for interaction and learning between teachers and students, which were previously unfeasible. Teachers leveraged social media platforms to disseminate vital information regarding assignments, class schedules, and other pertinent matters in real-time. Additionally, they utilized these platforms to respond to student inquiries, provide feedback

TABLE 3. Summary of Studies in Education Using Artificial Intelligence Techniques.

Ref.	Research direction	AI model or technique	Key findings/benefits
[23]	Behavioral analytics	AI models	Identify high-risk students for dropout in first year
[24]	Student engagement	Machine learning algorithms	Identify low-engagement students and notify teachers
[25]	Intelligent tutors	Machine learning algorithms	Enhances students' learning performance
[26]	Assessment and evaluation	WordNet with Cosine similarity algorithm	Automatic classify the exam question
[27]	Recommending collaborative activities	ANN and WSM	enhances students' academic performance

on academic assignments, and offer supplementary resources and materials to reinforce student learning [28].

These platforms also facilitated access to a wide range of educational content and resources, previously unavailable, through platforms such as YouTube, Pinterest, and LinkedIn. Furthermore, social media created new opportunities for collaboration and peer-to-peer learning, allowing students to connect with others, share ideas, and work collaboratively on projects, thereby developing essential social and teamwork skills while deepening their understanding of the subject matter.

Mobile technology has played a crucial role in our daily lives, and its impact on education, particularly in tertiary institutions, was significant. The use of mobile technology allowed students to access a wide range of learning materials, including videos, podcasts, and e-books. It also provided students with the opportunity to attend virtual classrooms, webinars, and online discussions, making distance learning and learning at their own pace feasible. The adoption of mobile technology also enabled students to communicate with their teachers and classmates, as well as complete coursework and assignments using their mobile devices, providing greater flexibility to balance academic commitments and personal lives, ultimately increasing access to tertiary education. Furthermore, mobile technology facilitated efficient collaboration among students, who could seamlessly work on group projects, share notes, and communicate using various mobile apps. An article by [29] explored the adoption and impact of mobile learning (m-learning) in higher education. The study assessed the critical factors for the adoption and application of m-learning in higher education using a sample of students. The factors associated with the adoption of mobile learning in higher education were classified into seven primary groups. The results showed that m-learning had the potential to be a promising educational technology for improving educational environments and fostering a culture of usage.

The utilization of data analytics brought about a paradigm shift in higher education by offering institutions the capability to attain insights into student performance, identify areas that required improvement, and optimize teaching and learning approaches. Data analytics played a pivotal role in promoting personalized learning by delineating individual student needs and preferences, allowing institutions to customize the learning experience to address each student's unique requirements. Moreover, predictive analytics could be implemented to detect students who were at risk of academic underperformance or attrition, providing targeted support and thereby enhancing retention rates and academic outcomes. The curriculum design was also benefited through data analytics by analyzing student performance data and refining the curriculum to better cater to student needs. The optimization of resources was realized through the identification of underutilized resources and their reallocation to maximize resource efficiency. Finally, data analytics was employed for institutional research to inform strategic planning and decision-making at the institutional level. In summary, data analytics transformed higher education by enabling evidence-based decision-making that improved student outcomes and fostered institutional effectiveness. The authors in [30] discussed how data analytics could be used in higher education to understand and model teaching processes. They introduced terms such as Learning Analytics, Academic Analytics, and Educational Data Mining, which were highly correlated and could build upon each other. The authors proposed a unified definition and framework for their use in higher education. This framework could help researchers explore new contexts and areas of inquiry in educational data analytics.

Cloud computing has revolutionized the approach to technology and data in the education sector, offering a solution to the challenges faced by educational institutions such as scaling up, infrastructure requirements, providing affordable education, and improving the quality of education. The adoption of cloud computing has enabled educators to focus on teaching and learning rather than managing IT infrastructure and has provided a wide range of educational resources and tools that enhance learning. Further, cloud computing has also facilitated personalized learning experiences by providing insights into student performance through data and analytics. In [31], the authors conducted research on the use of mobile cloud computing (MCC) services in higher education, developing a model to predict the effect of students' information management practices on their attitudes towards MCC services. The findings recommended the promotion of MCC services for personal information management, with the design of authentic learning environments and adequate support for students in using these services.

TABLE 4. Overview of reviewed sources on SMAC in education.

Ref.	Technology	Focus	Key findings/benefits
[28]	Social Platform	Use of Platforms for Student Engagement	enhances students' academic performance
[29]	Mobile	Adoption and Impact of Mobile Learning	learning anytime and anywhere
[30]	Analytics	Data Analytics in Higher Education	improving student success and retention, identifying at-risk students, and supporting personalized learning
[31]	Cloud computing	Students' attitudes towards Mobile Cloud Computing Services	improve the student's academic performance and efficiency of the learning tasks

Further, cloud computing offered more secure data storage and backup solutions, which ensured that educational institutions could protect sensitive data such as student records and research data from cyber threats and data loss. Nevertheless, the scalability of cloud computing meant that educational institutions could easily expand or downsize their computing resources according to their needs, making it easier to accommodate fluctuations in student enrollment or changes in the curriculum.

Table 4 provides a thorough summary of the sources that were reviewed on SMAC in education. The table covers various aspects such as research direction, technology, focus, and key findings or benefits of each study.

3) APPLICATION OF IoT IN THE TERTIARY EDUCATION

The Internet of Things network system helps increase connectivity between physical devices, from computers, and mobile phones to tablets, cameras, and wearable devices. The sensors make learning environments more intelligent and more interconnected than ever before. This improves the education system and brings a lot of added value to the physical teaching environment. IoT also changes the way schools operate, the teaching and learning process, and increases students' learning experience with a variety of features. The applications of IoT in tertiary education can be categorized into the following groups.

IoT has revolutionized the way that universities and colleges manage their campuses. With the use of sensors and connected devices, institutions can now monitor various aspects of their campus environment in real-time and make data-driven decisions to improve the overall experience for students, faculty, and staff. One of the most common IoT applications on campus is for temperature control systems. These systems use sensors to monitor the temperature in various buildings and adjust heating or cooling systems accordingly. This not only ensures that students and staff are comfortable but also helps to conserve energy and reduce costs.

Smart camera systems are another popular application of IoT on campus. These cameras can be used for security purposes, such as monitoring entrances and exits, but they can also be used to track foot traffic and identify areas of congestion or bottlenecks. This information can be used to optimize building layouts and improve the flow of foot traffic. Energy management is another area where IoT can be particularly useful. By using sensors to monitor energy consumption, universities can identify areas where energy is being wasted and take steps to reduce consumption. This not only helps to reduce costs but also contributes to a more eco-friendly and sustainable campus [32].

In addition to managing the campus environment, IoT can also be used to promote student health and wellness. For example, fitness trackers can be used to monitor the physical activity of students in real-time, and this information can be used to develop targeted fitness programs or to encourage healthy behaviors. Similarly, sensors can be used to measure students' stress levels and provide support and resources to those who may be struggling [33].

The integration of IoT technology in physical classrooms has led to the development of smart physical classrooms. These classrooms are equipped with a range of devices and sensors that can be used to enhance the learning experience for students and teachers alike. One of the key benefits of a smart physical classroom is the ability to tailor teaching to the emotional and cognitive states of individual students. By using sensors to monitor student behavior, such as facial expressions, posture, and even heart rate, teachers can gain valuable insights into how their students are feeling and adjust their teaching style accordingly. This can help to improve student engagement and retention. In addition, smart physical classrooms can also be used to monitor the learning process in real-time. For example, by using sensors to track student progress and engagement with learning materials, teachers can identify areas where students may be struggling and provide targeted support and feedback [34]. Another important feature of smart physical classrooms is the ability to combine IoT technology with AI to control student attendance. By using facial recognition technology, for example, smart physical classrooms can automatically track student attendance and ensure that all students are present and accounted for.

IoT technology integrated into the teaching and learning process has the potential to transform education by enabling personalized and adaptive learning experiences for students. With the help of IoT devices, students can learn anytime, anywhere, and at their own pace. By using sensors and connected devices to gather data on student learning behaviors and preferences, educators can design an adaptive curriculum that responds to the individual needs of each student [35]. For example, a student who is struggling with a particular concept may be presented with additional resources or personalized instruction, while a student who is excelling in a particular area may be given more challenging material to work on.

TABLE 5. Overview of reviewed sources on IoT in education.

Ref.	Research direction	Focus	Key findings/benefits
[32]	Smart Campus	IoT integration in building management systems	energy savings and environmental sustainability
[33]	Smart Campus	detecting perceived stress in students using IoT devices and machine learning	automatically detecting the stress level in students
[34]	Smart classroom	using sensors to monitor affective and cognitive state of the student	enhances students' motivation, attention and engagement
[35]	Teaching and learning	designing a teaching prototype using IoT devices	helps design an adaptive curriculum and personalized learning

Table 5 provides a thorough summary of the sources that were reviewed on IoT in education. The table covers various aspects such as research direction, focus, and key findings or benefits of each study.

4) BLOCKCHAIN APPLICATION IN TERTIARY EDUCATION

Blockchain technology has immense potential to support digital transformation in tertiary education due to its resistance to data change. Additionally, the utilization of a decentralized platform helps develop a platform in education that require clarity, data unalterable, security, and privacy. Furthermore, this technology empowers the development of decentralized applications dependent on peer-to-peer (P2P) transactions whose rules and the process can be automated using smart contracts capable of automatically executing the terms and agreements between the parties in the contract.

Apart from controlling the distribution and storage of important documents, such as degree certificates and transcripts, blockchain technology can also be utilized for other applications in the educational sector. For instance, blockchain can be used to store and share literacies, knowledge, as well as skills that learners have achieved during their studies [36]. This can create a decentralized system for sharing educational content that is accessible to learners from around the world, eliminating the need for intermediaries and ensuring the authenticity of the content.

Furthermore, blockchain technology can be used to create smart contracts that enforce the terms of training regulations automatically. This can help to improve accountability and transparency in the education sector by ensuring that all stakeholders follow the agreed-upon rules and regulations [37]. For instance, if a student violates a rule, the system will automatically record the student's file and issue the appropriate disciplinary action.

Another area where blockchain-based applications can be useful is in copyright management. By using a distributed ledger, blockchain can provide a secure and transparent system for managing copyright ownership and licensing. This can help to protect the intellectual property rights of creators and ensure that they receive fair compensation for their work [38].

Finally, blockchain technology can also be used to transfer student credits between universities. This can help to facilitate the process of transferring credits from one institution to another, making it easier for students to continue their education without the need to repeat courses or modules [39]. This can also help to reduce the administrative burden on educational institutions, making it easier for them to manage student records and credentials.

Table 6 presents a comprehensive overview of the sources that were examined regarding the use of blockchain in the field of education. The table encompasses a range of facets, including research direction, focus, and key findings or benefits of each study.

5) OHERS TECHNOLOGY

VR allows users to fully immerse themselves in a computer-generated environment and interact with it in real-time, and has a range of applications in fields such as entertainment, education, and training. For example, VR can be utilized to create immersive training simulations that support teaching and learning [40] or set up Massive Open Online Courses (MOOCs) with VR support [41]. AR, on the other hand, involves superimposing digital information onto the physical world, often through the use of a smartphone or similar device. It has numerous potential applications, including in retail, marketing, and education, and can be utilized to provide product demonstrations or to enhance the customer experience in a retail setting. Both VR and AR have the ability to transform the way organizations interact with their customers and employees, and are expected to play a significant role in the digital transformation process in the coming year.

The implementation of Robotic Process Automation in the context of tertiary education refers to the utilization of software robots for automating repetitive and routine tasks within the administrative and operational functions of the tertiary institution. These tasks may include data entry, scheduling, and record-keeping. The implementation of RPA has the potential to significantly streamline and optimize these processes, reduce the workload of staff, increase efficiency and accuracy, and allow for the allocation of valuable time and resources toward more strategic and creative initiatives. Furthermore, RPA has the potential to enhance the student experience by providing faster response times and reducing the possibility of errors in processes such as enrollment, financial aid, and grade reporting. For instance, in [42], the authors emphasized the importance of RPA robots, NLP, and ML in transforming education through the acceleration of the education system's evolution from information to

TABLE 6. Overview of reviewed sources on blockchain in education.

Ref.	Research direction	Focus	Key findings/benefits
[36]	Knowledge certification	use blockchain technology for verifying educational credentials	intermediary elimination and content authenticity
[37]	Smart contracts	Smart contracts in academic history and issue degree certificates	mitigate issues related to fraudulent degree certificates and lost academic records
[38]	Copyright management	blockchain-enabled solution to protect the intellectual property rights	effectively manage intellectual property
[39]	Trusted educational framework	blockchain-based decentralized framework for credit transfers	enhances transparency, efficiency, and security in credit transfers

TABLE 7. Overview of reviewed sources on other technology in education.

Ref.	Technology	Focus	Key findings/benefits
[40]	Virtual reality	create immersive training simulations	support teaching and learning process
[41]	Virtual reality	set up MOOCs with VR support	enhances students' academic performance
[42]	RPA robots	using NLP, ML to develop intelligent tutoring robot	support students' learning process
[43]	Interactive tools	using bioinformatics workflow tool to conduct experiments	enhance the teaching and learning process

intelligence. It highlighted the potential of these technologies to create innovative educational tools, including Intelligent Tutoring Robots.

The integration of additive manufacturing, also known as 3D printing, into tertiary education has become a subject of increasing interest. In this context, tertiary education refers to universities and other higher education institutions that offer courses and research programs. The purpose of incorporating 3D printing into tertiary education is to provide students with the necessary knowledge and skills to design, create, and produce objects using 3D printing technology. This can encompass subjects such as engineering, design, materials science, and digital fabrication. The inclusion of additive manufacturing in tertiary education offers students the opportunity to gain practical experience in a rapidly expanding and vital technology, preparing them for careers in industries that heavily rely on 3D printing. Additionally, incorporating additive manufacturing into research programs has the potential to lead to new innovations and advancements in the field.

Interactive tools can provide substantial support in the teaching process by offering an engaging and participatory learning experience for students. These tools encompass a wide range of applications, from virtual simulations and games to interactive presentations and quizzes. Interactive tools serve to clarify abstract ideas through visualization, provide practical exposure to real-world situations, and enhance student involvement in the classroom setting. The utilization of interactive tools in teaching, therefore, offers a dynamic and efficacious learning environment for students. As an example, the authors in reference [43] presented a new idea by using a workflow tool to enhance the teaching and learning of bioinformatics. The tool enables the performance of experiments, the execution of various algorithms, and the visualization of outputs to draw conclusions that are taught in lectures.

Table 7 presents a comprehensive overview of the sources that were examined regarding the use of other technology in the field of education. The table encompasses a range of facets, including technology, focus, and key findings or benefits of each study.

B. DISCUSSION

1) TECHNOLOGIES FOR TRANSFORMING THE TERTIARY EDUCATION INSTITUTIONS

The development and implementation of AIEd systems require a coordinated effort, which is best achieved through collaboration between the research community and educators. While researchers provide technical expertise, educators bring practical insights into the implementation and effectiveness of the systems. To ensure ethical AIEd development, transparency in data collection and decision-making algorithms are essential, and continuous evaluations and improvements should be made. Furthermore, these systems should be designed to be accessible and inclusive, while also integrating seamlessly with existing educational technologies. Adequate training should be provided to educators to interpret and utilize data effectively, as well as intervene when necessary to support struggling students

The potential of SMAC technologies, including Social, Mobile, Analytics, and Cloud, is emphasized in the text as vital for organizations' and businesses' digital transformation, including tertiary education. Institutions can explore these technologies' potential to enhance operations, management, and student learning outcomes. Social media platforms, as per the research cited, can foster communication among various stakeholders and support online learning communities. Institutions can use these platforms to create significant interactions, support self-directed learning, and improve student retention. Mobile technologies and platforms can allow flexible learning and create equity in digital learning, and institutions can adopt them to improve communication skills and academic achievement. Data analytics can provide insights into the factors affecting education, and big data analysis can personalize curricula, suggest appropriate learning methods, and aid in career orientation. Finally, cloud computing can reduce costs and improve the quality of education by providing necessary infrastructure, software, and hosting services, and institutions can utilize it to scale up, meet infrastructure requirements, provide affordable educational services, and improve quality education

Educational institutions can benefit from investing in IoT technology to create a smart campus and classrooms, ultimately enhancing energy efficiency, monitoring student well-being, and providing personalized learning experiences. Nevertheless, it is crucial for teachers to be trained on how to effectively use IoT devices to tailor their teaching to students' emotional and cognitive states, which can lead to increased student engagement and improved learning outcomes. In addition, educational institutions should explore the use of IoT devices to design an adaptive curriculum and personalized learning experiences that cater to individual needs and preferences. The integration of IoT devices into online learning platforms can also improve the quality of distance learning and facilitate remote learning. Nevertheless, privacy and security should remain a top priority when implementing IoT devices in educational institutions, ensuring compliance with relevant regulations and implementing appropriate security measures to protect students' data. Ultimately, educational institutions should continue to monitor IoT technology developments and explore new ways to integrate them into their teaching and learning processes to improve the quality of education and prepare students for the digital world.

Implementing blockchain-based systems for the secure storage and distribution of degree certificates and transcripts for students is essential to reduce fraud and ensure the safety of these documents. To achieve this, collaboration with blockchain developers and incorporating blockchain-based solutions into existing education systems is necessary. Additionally, utilizing blockchain for the storage and sharing of learners' knowledge, literacies, and skills acquired during their studies is beneficial. Creating a decentralized platform where learners can upload their achievements, which can be verified and shared with potential employers or other institutions, is recommended. Another way to enhance the efficiency of education systems is by creating smart contracts that enforce training regulations automatically, reducing the workload of administrators and ensuring that rules are followed consistently. In addition, utilizing blockchain to improve the safety and reliability of copyright management is another promising application. By creating a blockchain-based system that records the ownership and transfer of intellectual property rights, the integrity and ownership of digital assets can be secured. Lastly, exploring the use of blockchain for transferring student credits between universities can be achieved by creating a secure platform that allows universities to validate and transfer credits between institutions, ensuring that learners receive appropriate recognition for their achievements.

In order to enhance operations and transform educational institutions, it is worth considering the implementation of other technologies. Firstly, the exploration of the use of virtual reality VR and augmented reality AR can significantly enhance customer experiences, and training programs, and streamline operations. For instance, creating VR simulations to train employees in complex procedures or using AR to provide customers with virtual product demonstrations can revolutionize the way organizations interact with their customers and employees. Secondly, the adoption of RPA in administrative and operational tasks can free up valuable time and resources for staff to concentrate on more strategic initiatives. Automating repetitive tasks such as data entry, scheduling, and record-keeping can significantly optimize these processes, leading to increased efficiency and accuracy. Thirdly, the incorporation of 3D printing into tertiary education can provide students with practical experience in this rapidly expanding technology. This can prepare them for careers in industries that heavily rely on 3D printing. The inclusion of additive manufacturing into research programs can also lead to new innovations and advancements in the field. Finally, the use of interactive tools in teaching can create a dynamic and engaging learning environment for students. Such tools may include virtual simulations, games, presentations, and quizzes to clarify abstract ideas, offer practical exposure to real-world situations, and promote student involvement in the classroom setting.

The advent of technology has brought about a significant transformation in the way we acquire knowledge, communicate, and share information. The widespread usage of technology such as social media, virtual environments, and artificial intelligence has become ubiquitous in our daily lives, including education. Although the integration of technology in education has its advantages, it has also raised concerns about the potential impact on cognitive abilities and conventional learning methods. As a result, it is imperative to comprehend the effect of technology on education and cognitive abilities to devise effective measures that endorse responsible usage and preserve academic integrity. Therefore, measuring the impact of technology plays a pivotal role in the evaluation of its influence on education and cognitive abilities. The importance of measurement in assessing the impact of technology on education and cognitive abilities cannot be overstated. As technology is transforming traditional patterns of education, it is presenting both benefits and challenges to learning. Consequently, concerns are growing about the potential decline in cognitive abilities among individuals. To address these concerns, employing a comprehensive approach to measuring the impact of technology is necessary. This approach can provide us with a deeper understanding of its effects on learning outcomes and cognitive development. By doing so, we can develop effective strategies that promote the responsible use of technology, safeguard academic integrity, and preserve cognitive abilities. Hence, it is imperative to prioritize the need for measurement when evaluating the influence of technology on education and cognitive abilities.

2) STRATEGIES TO ENHANCE STUDENT LEARNING IN THE DIGITAL ERA

To effectively engage student learning in the digital era, especially Generation Z, sociologists suggest that teachers should modify their teaching methods, incorporate technology and resources, and increase interaction in the classroom. According to [44], educators should pay attention to the following strategies to meet the needs of this digital-born generation:

- Visual learning methods should be given attention: It has been demonstrated through research that the learning methods of today's young people differ from those of previous generations. As a result, long-form training programs with elaborate explanations are no longer effective. It has been found that this younger generation is more receptive to learning through familiar tools and that they are particularly adept at visual learning. In a recent study [45], it was shown that the incorporation of video into educational content can be highly effective.

- Emphasis should be placed on critical thinking and problem-solving skills: Critical thinking and problem-solving are important skills for people of all ages, but they are particularly relevant for Generation Z, who are growing up in an increasingly complex and rapidly changing world. In order to develop these skills, it is important for Generation Z to have opportunities to engage in activities that require critical thinking and problem-solving. These might include things like analyzing and evaluating news articles, debating issues and viewpoints, working on group projects, and solving puzzles and brainteasers. It is also important for Generation Z to be taught how to think critically and solve problems in a structured way, using tools and techniques like problem-based learning, design thinking, and the scientific method. By learning how to approach problems in a systematic and logical way, they will be better equipped to tackle the challenges they will face in their personal and professional lives.

- Adapt the lectures to meet the needs and time constraints of young people: As educators, it is crucial to consider the needs and time constraints of young people when adapting lectures. These students may have different learning styles, interests, and schedules than older students, and it is essential to take these factors into account when designing and delivering lectures. One way to do this is by utilizing a range of teaching methods, including interactive activities, group discussions, and multimedia presentations, to engage and stimulate young learners. It is also important to ensure that lectures are appropriately paced, with breaks and opportunities for questions and feedback. Additionally, it may be beneficial to consider the timing and duration of lectures, as young people may have shorter attention spans or other time constraints due to extracurricular activities, family responsibilities, or other commitments. By adapting lectures to meet the needs and time constraints of young people, educators can create a more inclusive and effective learning environment. Therefore, it is important to remain flexible and open to trying new approaches to meet the diverse needs of young learners.

3) CHALLENGES AND FUTURE RESEARCH DIRECTIONS

The integration of digital technologies into the realm of education has brought about a transformative change in the manner in which we learn and instruct. Despite the many benefits, the implementation of these technologies has also raised a number of challenges and open issues that demand our attention as follows:

a: CHALLENGES

- The application of technologies requires infrastructure such as network systems, equipment, services, and internet speed to develop to a certain extent. Nevertheless, in reality, many higher education institutions have not yet met the requirements for digital transformation. For instance, the absence of proper infrastructure, such as adequate internet connectivity, can render the utilization of technology a hindrance to the educational process rather than a benefit. It is important for institutions to overcome these challenges and embrace digital transformation in order to remain competitive and relevant in the rapidly changing education landscape
- The application of technology requires lecturers and students to have the ability to use them respectively. Otherwise, digital education could turn out to be a disaster. For instance, if instructors are not equipped with adequate training in utilizing technology for delivering instruction, they may encounter technical difficulties during lessons and struggle to effectively engage their students. In the same vein, learners who lack the necessary technology proficiency may find it challenging to keep pace with a digitally-enhanced class, leading to a decrease in motivation and compromised learning outcomes.
- The proliferation of digital technologies has resulted in growing concerns regarding the protection of personal information and privacy. The exponential growth of the internet and online services has resulted in the collection, storage, and sharing of personal data by various organizations, frequently without the explicit knowledge or consent of the individual. This has generated apprehensions about the potential abuse of personal information and the aftermath of data breaches, such as identity theft, financial fraud, and other violations of privacy. To alleviate these concerns, governments, and organizations are adopting privacy regulations and technologies aimed at safeguarding personal data. Despite these efforts, the preservation of privacy remains a formidable challenge in the digital era.

b: OPEN ISSUES

- What are the significant challenges that stakeholders such as faculty, businesses, and students must face due to the digital technology revolution?
- Which digital technology better supports the interaction between the school and employers, alumni?
- How to monitor the impact of digital technology on university operations?
- What are the methods to convince faculty and students to use new technology?

V. CONCLUSION

In conclusion, the present study sheds light on the prominent technological advancements driving digital transformation in tertiary education. Through a comprehensive examination of the literature, the authors identified five key themes including AI, SMAC, IoT, Blockchain, and other relevant technologies. These advancements have demonstrated their ability to narrow the divide between education and industry, thereby providing students with practical and applicable education that equips them for the demands of the contemporary workforce.

Given the rapidly evolving technological landscape, it is essential for educational institutions to adopt a proactive approach toward digital transformation. The effective integration of cutting-edge technologies has the potential to drive positive change and enhance learning outcomes and is therefore a vital component of modern tertiary education. Nevertheless, the authors recognize that there are limitations and obstacles associated with the implementation of these technologies that require further examination. As such, future research should focus on exploring efficient strategies for applying digital technologies in tertiary education. This study serves as a foundational step in this critical inquiry, emphasizing the importance of digital transformation and the potential benefits of utilizing the latest technological advancements in tertiary education.

REFERENCES

[1] L. Benavides, J. T. Arias, M. A. Serna, J. B. Bedoya, and D. Burgos, "Digital transformation in higher education institutions: A systematic literature review," *Sensors*, vol. 20, no. 11, p. 3291, Jun. 2020.

[2] M. Alenezi, "Deep dive into digital transformation in higher education institutions," *Educ. Sci.*, vol. 11, no. 12, p. 770, Nov. 2021.

[3] M. A. M. Hashim, I. Tlemsani, and R. Matthews, "Higher education strategy in digital transformation," *Educ. Inf. Technol.*, vol. 27, no. 3, pp. 3171–3195, Apr. 2022.

[4] L. V. Trevisan, J. H. P. P. Eustachio, B. G. Dias, W. L. Filho, and E. Á. Pedrozo, "Digital transformation towards sustainability in higher education: State-of-the-art and future research insights," *Environ., Develop. Sustainability*, pp. 1–22, Jan. 2023, doi: 10.1007/s10668-022-02874-7.

[5] A. Fernández, B. Gómez, K. Binjaku, and E. K. Meçe, "Digital transformation initiatives in higher education institutions: A multivocal literature review," *Educ. Inf. Technol.*, pp. 1–32, Mar. 2023.

[6] G. Westerman, D. Bonnet, and A. McAfee, "The nine elements of digital transformation," *MIT Sloan Manag. Rev.*, vol. 55, no. 3, pp. 1–6, 2014.

[7] M. Fitzgerald, N. Kruschwitz, D. Bonnet, and M. Welch, "Embracing digital technology: A new strategic imperative," *MIT Sloan Manag. Rev.*, vol. 55, no. 2, p. 1, 2014, doi: 10.5430/ijhe.v5n3p20.

[8] G. Vial, "Understanding digital transformation: A review and a research agenda," *J. Strategic Inf. Syst.*, vol. 28, no. 2, pp. 118–144, Jun. 2019, doi: 10.1016/j.jsis.2019.01.003.

[9] T. C. Truong, "The impact of digital transformation on environmental sustainability," *Adv. Multimedia*, vol. 2022, pp. 1–12, May 2022.

[10] J. McCarthy, "What is artificial intelligence?" Stanford Univ., Stanford, CA, USA, Tech. Rep., 2007.

[11] I. M. Sebastian, J. W. Ross, C. Beath, M. Mocker, K. G. Moloney, and N. O. Fonstad, "How big old companies navigate digital transformation," in *Strategic Information Management*. Evanston, IL, USA: Routledge, 2020, pp. 133–150.

[12] L. Atzori, I. A. Iera, and M. Giacomo, "The Internet of Things: A survey," *Comput. Netw.*, vol. 54, pp. 2787–2805, May 2010, doi: 10.1016/j.comnet.2010.05.010.

[13] M. Nofer, P. Gomber, O. Hinz, and D. Schiereck, "Blockchain," *Bus. Inf. Syst. Eng.*, vol. 59, no. 3, pp. 183–187, Mar. 2017, doi: 10.1007/s12599-017-0467-3.

[14] W. M. Van Der Aalst, M. Bichler, and A. Heinzl, "Robotic process automation," *Bus. Inf. Syst. Eng.*, vol. 60, pp. 269–272, Aug. 2018.

[15] I. Gibson, D. Rosen, B. Stucker, M. Khorasani, D. Rosen, B. Stucker, and M. Khorasani, *Additive Manufacturing Technologies*, vol. 17. Berlin, Germany: Springer, 2021.

[16] G. C. Burdea and P. Coiffet, *Virtual Reality Technology*. Hoboken, NJ, USA: Wiley, 2003.

[17] J. Carmigniani and B. Furht, "Augmented reality technologies, systems and applications," *Multimedia Tools Appl.*, vol. 51, no. 1, pp. 341–377, 2011.

[18] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," Keele Univ., Keele, U.K., Tech. Rep. EBSE-2007-01, 2007.

[19] V. Braun and V. Clarke, *Thematic Analysis: A Practical Guide*. London, U.K.: SAGE, 2021.

[20] A.-W. Harzing and S. Alakangas, "Google scholar, scopus and the web of science: A longitudinal and cross-disciplinary comparison," *Scientometrics*, vol. 106, no. 2, pp. 787–804, Feb. 2016, doi: 10.1007/s11192-015-1798-9.

[21] *Mallet: Machine Learning for Language Toolkit*. Accessed: Dec. 23, 2022. [Online]. Available: https://mimno.github.io/Mallet

[22] T. Bates, C. Cobo, O. Mariño, and S. Wheeler, "Can artificial intelligence transform higher education?" *Int. J. Educ. Technol. Higher Educ.*, vol. 17, no. 1, p. 42, Jun. 2020, doi: 10.1186/s41239-020-00218-x.

[23] E. Howard, M. Meehan, and A. Parnell, "Contrasting prediction methods for early warning systems at undergraduate level," *Internet Higher Educ.*, vol. 37, pp. 66–75, Apr. 2018, doi: 10.1016/j.iheduc.2018.02.001.

[24] M. Hussain, W. Zhu, W. Zhang, and S. M. R. Abidi, "Student engagement predictions in an e-learning system and their impact on student course assessment scores," *Comput. Intell. Neurosci.*, vol. 2018, pp. 1–21, Oct. 2018, doi: 10.1155/2018/6347186.

[25] Z.-H. Ma, W.-Y. Hwang, and T. K. Shih, "Effects of a peer tutor recommender system (PTRS) with machine learning and automated assessment on vocational high school students computer application operating skills," *J. Comput. Educ.*, vol. 7, no. 3, pp. 435–462, Sep. 2020.

[26] K. Jayakodi, M. Bandara, and D. Meedeniya, "An automatic classifier for exam questions with WordNet and cosine similarity," in *Proc. Moratuwa Eng. Res. Conf. (MERCon)*, Apr. 2016, pp. 12–17.

[27] C. Troussas, F. Giannakas, C. Sgouropoulou, and I. Voyiatzis, "Collaborative activities recommendation based on students collaborative learning styles using ANN and WSM," *Interact. Learn. Environ.*, vol. 31, no. 1, pp. 54–67, Jan. 2023.

[28] D. Cox and S. McLeod, "Social media strategies for school principals," *NASSP Bull.*, vol. 98, no. 1, pp. 5–25, Mar. 2014, doi: 10.1177/0192636513510596.

[29] H. Hamidi and A. Chavoshi, "Analysis of the essential factors for the adoption of mobile learning in higher education: A case study of students of the University of Technology," *Telematics Inform.*, vol. 35, no. 4, pp. 1053–1070, Jul. 2018.

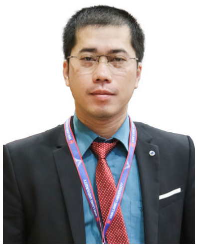
[30] A. Nguyen, L. Gardner, and D. Sheridan, "Data analytics in higher education: An integrated view," *J. Inf. Syst. Educ.*, vol. 31, no. 1, p. 61, 2020.

[31] I. Arpaci, "A hybrid modeling approach for predicting the educational use of mobile cloud computing services in higher education," *Comput. Hum. Behav.*, vol. 90, pp. 181–187, Jan. 2019.

[32] O. Bates and A. Friday, "Beyond data in the smart city: Repurposing existing campus IoT," *IEEE Pervasive Comput.*, vol. 16, no. 2, pp. 54–60, Apr./Jun. 2017, doi: 10.1109/MPRV.2017.30.

[33] M. Gjoreski, H. Gjoreski, M. Lutrek, and M. Gams, "Automatic detection of perceived stress in campus students using smartphones," in *Proc. Int. Conf. Intell. Environments*, Jul. 2015, pp. 132–135, doi: 10.1109/IE.2015.27.
[34] R. Popescu, D. Ponescu, H. Roibu, and L.-C. Popescu, "Smart classroom—Affective computing in present-day classroom," in *Proc. 28th Annu. Conf. (EAEEIE)*, Sep. 2018, pp. 1–9, doi: 10.1109/EAEEIE.2018.8534286.
[35] H. Maenpaa, S. Varjonen, A. Hellas, S. Tarkoma, and T. Mannisto, "Assessing IoT projects in university education—A framework for problem-based learning," in *Proc. IEEE/ACM 39th Int. Conf. Softw. Eng., Softw. Eng. Educ. Training Track (ICSE-SEET)*, May 2017, pp. 37–46, doi: 10.1109/ICSE-SEET.2017.6.
[36] D. Lizcano, J. A. Lara, B. White, and S. Aljawarneh, "Blockchain-based approach to create a model of trust in open and ubiquitous higher education," *J. Comput. Higher Educ.*, vol. 32, no. 1, pp. 109–134, Apr. 2020, doi: 10.1007/s12528-019-09209-y.
[37] L. M. Palma, M. A. G. Vigil, F. L. Pereira, and J. E. Martina, "Blockchain and smart contracts for higher education registry in Brazil," *Int. J. Netw. Manag.*, vol. 29, no. 3, p. e2061, May 2019, doi: 10.1002/nem.2061.
[38] J. Guo, C. Li, G. Zhang, Y. Sun, and R. Bie, "Blockchain-enabled digital rights management for multimedia resources of online education," *Multimedia Tools Appl.*, vol. 79, nos. 15–16, pp. 9735–9755, Apr. 2020, doi: 10.1007/s11042-019-08059-1.
[39] A. Srivastava, P. Bhattacharya, A. Singh, A. Mathur, O. Prakash, and R. Pradhan, "A distributed credit transfer educational framework based on blockchain," in *Proc. 2nd Int. Conf. Adv. Comput., Control Commun. Technol. (IACT)*, Sep. 2018, pp. 54–59, doi: 10.1109/IAC3T.2018.8674023.
[40] I. Perera, D. Meedeniya, C. Allison, and A. Miller, "User support for managed immersive education: An evaluation of in-world training for opensim," *J. Universal Comput. Sci.*, vol. 20, pp. 1690–1707, Nov. 2014.
[41] S. Hewawalpita, S. Herath, I. Perera, and D. Meedeniya, "Effective learning content offering in MOOCs with virtual reality—An exploratory study on learner experience," *J. Universal Comput. Sci.*, vol. 24, no. 2, pp. 129–148, 2018.
[42] Y.-H. Hu, J. S. Fu, and H.-C. Yeh, "Developing an early-warning system through robotic process automation: Are intelligent tutoring robots as effective as human teachers?" *Interact. Learn. Environ.*, pp. 1–14, Jan. 2023.
[43] A. Wickramarachchi, V. Mallawaarachchi, D. Meedeniya, I. Perera, and A. Welivita, "Enhanced student learning in proteomics—An interactive tool support for teaching workflows," in *Proc. IEEE Int. Conf. Teaching, Assessment, Learn. Eng. (TALE)*, Dec. 2018, pp. 228–235.
[44] V. Kuleto. (May 2012). *3 Metode Ucenja Za Nove Generacije*. [Online]. Available: https://www.valentinkuleto.com/2012/05/3-metode-ucenja-za-nove-generacije/
[45] M. Noetel, S. Griffith, O. Delaney, T. Sanders, P. Parker, B. D. P. Cruz, and C. Lonsdale, "Video improves learning in higher education: A systematic review," *Rev. Educ. Res.*, vol. 91, no. 2, pp. 204–236, Apr. 2021.

THANH-CONG TRUONG received the M.Sc. degree in computer science from the University of Information Technology, Vietnam National University, Ho Chi Minh City, and the Ph.D. degree from the Faculty of Electrical Engineering and Computer Science, VŠB–Technical University of Ostrava (VŠB–TUO). He is currently with the Faculty of Informatics Technology, University of Finance-Marketing (UFM), Ho Chi Minh City, Vietnam. He has published numerous research papers in peer-reviewed journals and international conferences. His research interests include artificial intelligence, swarm intelligence algorithms, and cybersecurity.



QUOC BAO DIEP received the B.Eng. degree in mechatronics from Can Tho University, the M.Eng. degree in mechatronics engineering from the Vietnam National University Ho Chi Minh City University of Technology, and the Ph.D. degree in computer science, communication technology, and applied mathematics from the VŠB–Technical University of Ostrava, Czech Republic. He is currently with the Department of Mechatronics, Van Lang University, Vietnam. He has published more than 20 research papers in peer-reviewed journals and international conferences. His research interests include robotics, machine learning, and swarm and evolutionary computation.