# Preliminary Study of Internet of Educational Things and Big Data Analytics Adoption in Higher Education Institutions

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**Abstract**

The proliferation of digital devices in higher education institutions, coupled with Internet of Everything (IoE) technologies, drives the adoption of big data analytics for informed decision-making within smart universities. To examine the Internet of Educational Things (IoET) and Big Data Analytics (BDA) in higher education, a systematic literature review explores various BDA methods and their benefits, including targeted course offerings, personalized learning, and employment opportunities post-education. Additionally, innovative business processes and BDA techniques enhance organizational cultures within emerging economies. However, challenges exist regarding data tracking, collection, storage, analysis, interpretation, the tenuous connection between data sciences and network sciences, alongside security, privacy, and ethical concerns. The report underscores the need to advance the analytical skills of all stakeholders- including decision-makers, administrators at different levels, course developers, and students- not just faculty, within smart universities to effectively apply various advanced BDA techniques that leverage large educational datasets for informed, data-driven decision-making in a competitive global market.

## Introduction

The transformation through digitalization in emerging economies has led to increased data collection across various sectors such as education, health, marketing, retail, and technology. Higher education institutions are leveraging the Internet of Things (IoT) and big data analytics (BDA) to promote BDA adoption for strategic planning and sustainable competitive advantages. Due to large data sets including student, research, administrative, curriculum, teaching, and learning data generated from various online instructions, intelligent classroom architecture-related activities support academic business operations (Lambert, 2020; Daniel et al., 2015). The Internet of Things, also referred to as the Internet of Everything (IoE) or Web of Things, is projected to be the most influential technology, which encompasses various digital platform learning types, including Electronic Learning (E-Learning), Mobile Learning (M-Learning), Ubiquitous Learning (U-Learning), and Federated Learning (F-Learning). Therefore, electronic and mobile devices, machines, and sensors integrated into global networks, including the Internet/Intranet/Extranet, generate vast amounts of educational data within the academic community. M-Learning utilizes portable and handheld devices. U-Learning represents a straightforward approach to mobile learning, enabling learners to access supplementary content and collaborative learning environments with the interactive capabilities that enhance stakeholders' value in higher education (Al-Emran, Malik & Al-Kabi, 2019; Gómez, Huete, Hoyos, Perez & Grigori, 2013).

The recent COVID-19 pandemic has accelerated and enhanced data gathering in higher education institutions through web-based educational systems and Internet of Things applications. Wi-Fi-enabled smart learning environments incorporating IoET applications, intercommunication, and synchronization are set to revolutionize the education sector by improving internet accessibility and facilitating technology use in rural areas. Consequently, providing evidence-based mechanisms enhances learning processes to generate substantial educational data in virtual spaces. The rapid advancement of technology-savvy generations empowers students to access educational materials and monitor academic progress. The Internet of Educational Things (IoET) involves using IoT tools in smart universities, providing opportunities for campus infrastructure development and improving resource management through big data generation to foster the adoption of big data analytics. Thus, it facilitates the transformation of education systems through flexible interactions and federated learning, enhancing IoT device scalability and security (Chandra & Karani, 2020), while creating opportunities for infrastructure improvement related to big data analysis and data generation in education. Furthermore, it cultivates competencies for staff and students in academic business operations, offers an innovative approach to tracking student progress in various programs concerning IoET and BDA adoption to create value and efficiency, optimizing productivity and profitability by leveraging substantial educational data. The Internet of Educational Things (IoET) establishes a smart energy chain from education to assessment, transforming objects into smart entities to fulfill strategic business priorities. Innovations in online program management platforms focus on digitalization, learner support, program size, and partnerships to optimize productivity and profitability through the effective implementation of BDA in a smart university environment, which necessitates a unique blend of resource configuration and reconfiguration to ensure effective learning platforms in the industrialized world (Sudirtha et al., 2021).

The Internet of Everything (IoE) transforms various aspects of life, including education, waste management, and smart cities. It incorporates automation, essential for seamless services within user-associated algorithms, and presents challenges in global model updates in diverse environments. However, BDA and IoT technologies are reshaping decision-making in higher education institutions to meet evolving needs and enhance performance. Adopting IoE and big data analytics is crucial for real-time predictive decision support systems utilizing advanced BDA techniques to extract insights on market valuation, accountability, transparency, corporate partnerships, regulatory bodies, and customer value, while ensuring the relevance and quality of learning programs. Nonetheless, concerns over economic, technological, social, and educational changes necessitate effective decision-making to unlock the value of the exponential growth of data. This includes intensive data mobilization for national and global development in contemporary higher education. Smart universities, equipped with video lectures and smart boards, improve performance and student engagement, necessitating digital strategic plans for BDA adoption in the global economy. Despite widespread agreement among scholars and practitioners, IoE, BD, and BDA remain far from achieving their full potential within higher education in developing economies (Uggla & Soneryd, 2023; Mircea, Stoica & Ghilic-Micu, 2021; Khalid et al., 2018). A significant gap exists between the actual need for BDA and current investments, particularly in higher education institutions in the early data-driven stages in emerging economies (Amin et al., 2022).

**Formulating the Problem**

Aspects of IoE, BD, and BDA technologies, such as their techniques, capabilities, processes, benefits, and challenges, require further clarification of these key components in emerging economies. Thus, navigating the literature on IoE, digital university business processes, the big educational data environment, BDA methods, and organizational capabilities to identify requirements and implications for perceived benefits and challenges in smart universities is a daunting task (Uggla & Soneryd, 2023; Mircea, Stoica & Ghilic-Micu, 2021; Liu, Wang & Xiao, 2021). The central question to address this problem is: What is the current state of IoT and big data analytics adoption, alongside digital transformation in higher education institutions (HEIs) in an emerging developing economy, to create business value?

The following sub-questions help address the main query:

1. What issues arise from digital university business processes in a big educational data environment involving the Internet of Things (IoT) and big data analytics in an emerging economy?
2. What methods and analyses are used in conducting big data analytics in higher education institutions?
3. What are the benefits and challenges of using the Internet of Things and big data analytics in higher education institutions?

According to Webber & Zheng (2020), technology, people, processes, and culture in the higher education environment enable data-informed decision-making. However, in the transformation era of digitization with IoE within an emerging economy context, this study seeks to address BDA adoption related to data-informed and data-driven decision-making, utilizing big data and big data analytics capabilities to leverage continuously changing dynamic business processes in HEIs to conclude with some main findings and recommendations for further studies.

## Internet of Educational Things in Digital University Business Processes

The Internet of Things (IoT) facilitates smart education through cloud computing, promoting the adoption of big data analytics, creating career opportunities with personal growth, and enhancing financial success in a global market. This aligns with developing 21st-century skills aimed at revising IoT-related STEM courses. Consequently, it paves the way for advancements in digital transformation, revolutionizing interactivity through virtual and physical objects in hybrid classes that blend online and face-to-face learning. This empowers digital citizens and transforms global higher education, enhancing economic development, research, and innovative learning opportunities in higher education institutions (Kassab & Darabkh, 2020). However, the increasing presence of ubiquitous computing, integrating IoET and big data analytics applications, exposes complex budgeting models that are still unclear when aligning universities' strategic plans within higher education institutions. Within academic environments, challenges in the digital transformation era—marked by the Fourth Industrial Revolution (4IR)—evolve with dynamics, complexity, interfaces, robustness, and interaction required for effective collaboration among stakeholders in higher education within emerging economies (Amin et al., 2022).

Stakeholders in higher education institutions encounter challenges during the digital transformation era, as they seek to embrace the Fourth Industrial Revolution (4IR) and adapt to evolving dynamics, complexity, interfaces, robustness, and interaction to foster effective collaboration in academic settings. Previous studies have underscored the significance of the Internet of Everything (IoE) in activity-based learning, facilitating social communication networks between the real and digital realms, interactivity with smart objects, data, and processes, creating billions of interconnected networks of emerging technologies (Selinger, Sepulveda & Buchan, 2013).

Moreover, the Internet of Learning Things (IoT) influences teaching strategies by providing interactive environments, global content access, and adaptive learning experiences. This encourages educators to grasp IoT, big data, and analytics for successful implementation. Specifically, integrating IoT devices into smart academic environments fosters collaborative and innovative navigation of networks and scalability, ultimately leading to the success of the Social Internet of Things. IoT smart campus models in education encompass smart machines, classrooms, teaching methods, learning strategies, energy management, secure access control, and student health monitoring systems with feedback mechanisms. As IoE capabilities expand, these innovations enhance institutional performance, accelerate learning, and improve teaching efficiency while presenting opportunities for addressing threats in evolving Internet-connected higher education systems.

Innovative technologies include database systems that generate data from various sources, such as traditional classrooms, adaptive educational hypermedia systems (AEHS), intelligent tutoring systems (ITS), tests, quizzes, social networks, e-learning, and virtual environments. Big educational data represents a global trend that involves capturing, storing, distributing, managing, and extracting large, complex data points—both structured and unstructured—found in extensive knowledge repositories (Daniel, 2019). Thus, promoting the adoption of big data analytics (BDA) techniques fosters informed decision-making and enhances the academic community by improving curriculum development, administrative services, teaching, learning, research, and assessment activities, while also achieving institutional goals through various systems and repositories. Higher education institutions (HEIs) in emerging economies often lack the educational experience required to adopt the Internet of Educational Things (IoET) and advanced BDA techniques, which could enhance business value and competitive advantage by ensuring data-driven decision-making while improving student engagement and performance (Webber & Zheng, 2020; Williamson, Bayne & Shay, 2020). Consequently, guidelines for data storage, access controls, compliance regulations, and data governance policies influence various business processes, reflecting the diverse characteristics of the data's V's dimensions (structural dimensions) and providing a holistic approach to data management challenges necessary to remain competitive in a data-driven landscape. Furthermore, the transformative potential of massive data combined with advanced big data analytics techniques can effectively address challenges related to administration, consulting, research, and augmenting teaching and learning within an academic business ecosystem. (Dede, Ho, & Mitros, 2016; Stojanov & Daniel, 2024).

**Key Characteristics**

10 Vs: Volume, velocity, variability, variety, value, veracity, validity, volatility, virtualization, and vulnerability

(Kumar, Marchena, Awlla, Li, & Abdalla, 2024).

7V's. Volume, Velocity, Variety, Viscosity, Variability, Veracity, and Volatility (Desouza & Smith, 2014).

The structural dimension of Big Data covers elements of volume, velocity, veracity, variety, volatility, and value (Poulovassilis, 2016).

6Vs: Volume, Velocity, Veracity, Variety, Verification, and Value (Daniel, 2015).

5Vs: Volume, Velocity, Variety, Value, Veracity (Sivarajah et al., 2017).

4Vs: Volume, Velocity, Variety, Value (Abbasi et al. 2016).

**Big Data Analytics Defined**

Big data analytics is essential for digital transformation and innovation in the big data revolution. It enables stakeholders such as administrators, faculty, and students to analyze vast data and make informed decisions. The transformation of data into information occurs through layers of big data analytics architecture, data sources, content formats, and aggregation using databases and storage systems (DBMS, NoSQL databases, HDFS, and Hadoop cloud) for efficient real-time analysis of large academic data sets, thereby enhancing decision-making in business operations (Wang et al., 2018). Consequently, institutional, descriptive, diagnostic, predictive, and prescriptive analytics stimulate education and promote data stewardship while ensuring security, privacy, and compliance with regulatory guidelines. Education data mining (EDM) automates data collection, analysis, and visualization for adaptive learning, enhancing knowledge discovery and modeling techniques (e.g., regression models, cognitive models, and Bayesian networks). This promotes big educational data analytical applications to advance knowledge discovery, streamline administrative tasks, and predict academic progress, teaching methods, research outcomes, performance prediction, and institutional growth in emerging economies (Nguyen, Gardner, & Sheridan, 2020). However, intelligent decision-making, which supports optimization in an academic context, has not fully realized its potential in emerging economies due to insufficient resources and capabilities in BDA adoption. Table 1 indicates previous studies in the literature review with stakeholders in various institutions related to research methods in digital transformation with the Internet of Things, big data, and analytics business processes in countries.

Table 1. Studies on Digital Transformation with the Internet of Things

| Study | Stakeholders | Research Methods | Institution | Country | Journal |
|---|---|---|---|---|---|
| Rubel & Jones, (2017). | Students Faculty | Focus group | Oral Roberts University (ORU) | US | Journal of Law and Public Policy. |
| Al-Emran, Malik, & Al-Kabi,. (2019). | Higher education Institutions /Universities | education sector- review study of IoT in education, medical in education | Ton Duc Thang University & Al Buraimi University College | Vietnam & Oman | SpringerNature |

| Study | Stakeholders | Research Methods | Institution | Country | Journal |
|---|---|---|---|---|---|
| Dede, Ho& Mitros, (2016) | Student Faculty | Focus group | Havard | USA | EDUCAUSE Review, Digital Access to Scholarship at Harvard (DASH) |
| Murumba & Micheni, (2017). | Institution staff | a desk search and reviewed sources of literature | Technical University of Kenya | Kenya | The International Journal of Engineering and Science, |
| Attaran, Stark & Stotler, 2018). | students, instructors, administrators, and the public | Systematic literature review | California State University, USA | US | Industry and Higher Education |
| Chaurasia & Frieda Rosin, (2017). | 23 experts in the higher education sector | semi-structured interviews | Indian higher education institutions | India | Emerald |
| Khalid et al., 2018 | Higher education institution | Systematic literature review | Universiti Sains | Malaysia | Int. J. Management in Education, V |
| Alshuaibi et al., 2018 | business students | Questionnaire | Malaysian public university | Malaysia | Emerald |
| Seres, Pavlicevic & Tumbas, (2018) | Institution staff | Systematic literature review | University of Novi Sad | SERBIA | IATED Digital Library |
| Selwyn & Gašević (2020) | Faculty | Focus group | Monash University | Malaysia | Taylor & Francis |
| Baig, Shuib & Yadegaridehkordi, (2021). | Managerial side of virtual university (VU) campuses in Pakistan | online survey questionnaire | University of Malaya, virtual university (VU) campuses in Pakistan, and Universiti Kebangsaan Malaysia (UKM) | Pakistan | MDPI |
| Vassakis, Petrakis & Kopanakis, (2018). | organisations | Systematic literature review | University of Crete, Technological Educational Institute of | Greece | Springer |

| Study | Stakeholders | Research Methods | Institution | Country | Journal |
|---|---|---|---|---|---|
| | | | Crete | | |
| Khaw & Teoh (2023) | Private higher education institutions | online survey questionnaire | Universiti Sains Malaysia, Minden, | Malaysia | Emerald |
| Atyeh, Jaradat, & Arabeyyat,. (2017) | National - three managers for three departments are formed as decision-makers | semi-structured interviews | Al al-Bayt University, Mafraq, Al-Balqa Applied University, As-Salt | Jordan | International Journal of Computer Science and Network Security |
| Stojanov & Daniel,(2024) | students, instructors, administrators | Systematic literature review | University of Otago | New Zealand | Springer |
| Grant, 2012). | Provost, instructional designers, and academic deans | Case study, survey | The University of Missouri. Lou | USA | Education Resource Information Center (ERIC) |
| Webber & Zheng, (2020) | institutional leaders, decision-makers, and external stakeholders | Systematic literature review | University of Georgia and Ohio State University | USA | IHE Research Projects Series |
| Capurro, Fiorentino, Garzella & Giudici, (2022) | a comprehensive group of 25 experts, i.e., Experts at firms within digitally related sectors | semi-structured interview data together with a prior literature review of big data analytics. | Organisations | Across countries | Emerald |
| Muhammad, , Tasmin & Aziati, (2020, April) | Administrators, big data experts, Academic Solution Providers, IT specialists in Big data, and IT administrators in higher education | Semi-structured interview | High education sector | Malaysia | Journal of Physics: Conference Series, Open Access |

| Study | Stakeholders | Research Methods | Institution | Country | Journal |
|---|---|---|---|---|---|
| | institutions | | | | |
| Ajigini, 2023). | Tertiary institutions - research universities, technical and vocational education, and training (TVET) colleges, technological universities, private institutions, and other universities | Quantitative method | The Independent Institute of Education, Sandton, South Africa | South Africa | International Journal of Emerging Technologies in Learning (iJET), |
| Ghashim, & Arshad,(2023) | Universities and colleges around the world | Bibliometric analysis with VOSviewer | University, Alburj Campus, Jazan 82812, Gizan, Saudi Arabia; School of Informatics and Cybersecurity, Technological University Dublin, | Saudi Arabia & Ireland | MDPI Journal/ Sustainability |
| Ramlowat & Pattanayak (2019) | In the education sector, IoT resources are in computer science, distance education, medical science education, and consumer | Systematic literature review | University of Mauritius, | Mauritius, | Springer, Information Systems Design and Intelligent Applications, Advances in Intelligent Systems and Computing |

| Study | Stakeholders | Research Methods | Institution | Country | Journal |
|---|---|---|---|---|---|
| | green education. | | | | |
| Mircea, Stoica, & Ghilic-Micu, (2021) | IoT in a higher education environment | Quantitative method – Survey and structural equation modeling | Romanian higher education system | Romania | IEEE/ACCESS |
| Madni, Ali, Husnain, Masum, Mustafa, Shuja, & Hosseini, (2022) | Higher Education institutes in developing countries | A comprehensive review of existing studies from 2016 to 2021 | Higher education sector | Saudi Arabia, Malaysia, Pakistan, Bangladesh, etc. | Frontiers in Psychology, www.frontiersin.org. |

## Methodology

Cooper's (1988) suggestions effectively guided a systematic literature review to address the research problem. This procedural approach assisted in (a) formulating the problem, (b) collecting data, (c) evaluating the appropriateness of the data, (d) analyzing and interpreting relevant data, and (e) organizing and presenting the results. The results were compared with current issues in selected higher education institutions.

**Describe the search strategy process**: To achieve the review objectives, search strings were applied to five major academic databases: IEEE Xplore, ScienceDirect, Emerald Insight, Springer Link, and Taylor and Francis. Subsequently, keywords were combined with the Boolean "OR" operator to include synonyms, interchangeable words, and meanings. Similarly, the Boolean 'AND' operator linked the search keywords. The title was also explored through alternative searches when the required title results were insufficient. It was found that the searched databases contained articles that could answer the defined research questions of this study. The keywords used for searching included: "digitalized transformation," "Internet of things in higher education," "Internet of Educational things," "Internet of everything," "adoption of big data analytics," "big data analytics techniques," "big data business processes and benefits," and "big data analytics capabilities and challenges." The literature search also included keywords such as data mining, big educational data, analytics, higher education, big data analytics, and emerging economy.

**Data evaluation and analysis:** The selection of articles depended on their relevance. To achieve the research objectives and answer the research questions, quantitative, qualitative, mixed methods, and literature reviews published in peer-reviewed journals since 2011 were utilized to identify techniques, processes, challenges, and benefits of IoE and BDA adoption in higher education. The selection of studies involved applying inclusion and exclusion criteria. Key search descriptors and strings were employed across five databases: IEEE Xplore, ScienceDirect, ERIC, Emerald, MDPI, Springer, education technology journals, and Taylor and Francis. A total of 98 studies were identified based on the described procedure. Of these, 36 focused on issues related to digitalized HEI business processes with IoE, big data, big data analytics (BDA), and BDA capabilities; 23 examined BDA methods and analyses of benefits; and 28 concentrated on IoE and BDA benefits and challenges. The remaining articles were excluded from this review because they could not be used to address the three main questions of the study. Only articles directly related to IoE, digital university business processes, big data, BDA methods and capabilities, and the associated benefits and challenges that contributed to answering the three research questions were included in this review. Therefore, this literature review adhered to the outlined procedure, limited to the specified keywords and search criteria across the listed databases. Table 2 provides citations for the sources included in the results section.

Table 2. Sources Found Corresponding to the Research Questions

| Focus | Sources |
|---|---|
| Digitalised HEIs' business processes with IoT, IoET, BD, BDA, and BDAC | Khalid, Ram, Soliman, Ali, Khaleel, & Islam (2018)<br>Vassakis, Petrakis & Kopanakis, (2018), Baig, Shuib, & Yadegaridehkordi, (2022); Lee & Lee, (2015)<br>Matkovic, Tumbas, Maric & Rakvic, (2018), Kompella, (2024), Wang, Kung, Wang & Cegielski, (2018), El-Haddadeh, Fadlalla & Hindi, (2024), Seres, Pavlicevic, & Tumbas, (2018); Komljenovic, Birch, Sellar, Bergviken Rensfeldt, Deville, Eaton, & Williamson, (2024)<br>Capurro, Fiorentino, Garzella & Giudici, (2022), Petkovics, Tumbas, Matkovic, & Baracskai, (2014), Shabana & Sharma, (2019), Vaitsis, Hervatis & Zary, (2016), Adrian, Abdullah, Atan & Jusoh, (2016). Rosdi, (2017), Xu & Pero, (2023), Udeh, Orieno, Daraojimba, Ndubuisi & Oriekhoe, (2024), Murumba & Micheni, (2017), Pratsri & Nilsook, (2020); Munshi & Alhindi, (2021), Ang, Ge & Seng, (2020), Rieckmann, (2012), Williamson, (2019), Cao, Duan & Li, (2015), Job, (2018), Matto, (2022), Nilashi, Keng Boon, Tan, Lin, & Abumalloh, (2023), Sivarajah, Kumar, Kumar, Chatterjee & Li (2024); Khaw & Teoh, (2023); Chaurasia, Kodwani, Lachhwani & Ketkar, (2018).<br>Fernández-Batanero,Montenegro-Rueda,Fernández-Cerero, & López Menéses, (2024), Madni, Ali, Husnain, Masum, Mustafa, Shuja, ... & Hosseini, (2022), Al-Emran, Malik, & Al-Kabi, (2019), Mkrttchian, Gamidullaeva, Finogeev, Chernyshenko, Chernyshenko, Amirov & Potapova, (2021), Lee, (2019) |
| BDA methods, capabilities and analysis | Romero & Ventura, (2010); Cao, Duan & Li, (2015); Ray & Saeed, (2018); Shabanab & Sharma, (2019); Job, (2018)<br>Grosan, Abraham, Grosan & Abraham, (2011); Matto, (2022),<br>Baig, Shuib, & Yadegaridehkordi, (2020), Nilashi, Keng Boon, Tan, Lin, & Abumalloh, (2023), Sivarajah, Kumar, Kumar, Chatterjee & Li (2024), Ashaari, Singh, Abbasi, Amran, & Liebana-Cabanillas, (2021); Lepenioti, Bousdekis, Apostolou, & Mentzas, (2020); Balaji, Annavarapu & Bablani, (2021); |

| Focus | Sources |
|---|---|
| | Koukaras, & Tjortjis, (2019); Kui, Liu, Liu, Liu, Zeng, & Zhang, (2022); Sharma, Sharma, Purohit, Rout, & Sharma (2022); Wolniak & Grebski (2023). Nguyen, Gardner & Sheridan, (2020); Leitner, Khalil & Ebner, 2017); Ang, Ge & Seng, (2020); Sivarajah, Kamal, Irani & Weerakkody, (2017); Lee & Lee, (2015); Khaw & Teoh, (2023) |
| IoET and BDA benefits and challenges | Choi, Hung, Peng, & Chen (2022); Ray & Saeed, (2018); Balaji, Annavarapu & Bablani, (2021), Sharma, Sharma, Purohit, Rout, & Sharma (2022), Sivarajah, Kamal, Irani & Weerakkody, (2017); Stojanov, & Daniel, (2024); Lee & Lee,(2015); Madni, Ali, Husnain, Masum, Mustafa, Shuja, ... & Hosseini, (2022); Chaurasia & Frieda Rosin, (2017), Daniel, (2015), Al-Emran, Malik, & Al-Kabi, (2019), Mkrttchian, Gamidullaeva, Finogeev, Chernyshenko, Chernyshenko, Amirov & Potapova, (2021); Shabanab & Sharma, (2019), Ashaari, Singh, Abbasi, Amran, & Liebana-Cabanillas, (2021); Lepenioti, Bousdekis, Apostolou, & Mentzas, (2020); Chaurasia, Kodwani, Lachhwani & Ketkar, (2018); Lee, (2019), Khaw & Teoh, (2023), Fernández-Batanero, Montenegro-Rueda,Fernández-Cerero, & López Menéses, (2024); Webber & Zheng, (2020); Wang et al., (2018), Chaurasia & Frieda Rosin, (2017), Williamson, Bayne & Shay, (2020); Yousef, (2024); Attaran, Stark & Stotler, (2018); Ang, Ge & Seng, (2020). Nilashi, Keng Boon, Tan, Lin, & Abumalloh, (2023); Sivarajah, Kumar, Kumar, Chatterjee & Li (2024) |

Note: Twenty papers are classified into two or three categories in the table.

## Results and Discussion

Digital transformation strategies in higher education aim to enhance service delivery and the student experience through IoT infrastructure, cloud computing, and innovative business models utilizing large-scale data sets across various platforms for business transformation and market-making with big data analytics to promote smart education (Williamson 2018; Komljenovic & Robertson 2016). Technological innovations, organizational changes, marketization, and political-economic dynamics are essential and necessitate key competencies for global service delivery to maintain a competitive edge in the education sector (Uggla & Soneryd, 2023; Rieckmann, 2012). Therefore, opportunities and challenges in IoE interconnectivity foster student engagement, competitiveness, and cost-effective solutions, along with addressing the social, cultural, economic, and political dimensions of datafication in education to capitalize on profit-making opportunities driven by regulatory demands for a market-driven economy (Williamson, 2019; Williamson, 2019).

However, higher education institutions in emerging economies face limited adoption and insufficient expertise in IoE and BDA, with the analytical capabilities needed for advanced analytics techniques to enhance digital transformation in cloud-based environments for big data-oriented business value in smart universities. Sixty-five males and sixteen females from nine public universities, twenty-one males and four females from six private universities, as a sample survey in Ghana, comprising faculty members, information systems directorate staff, administrators, and coordinators, indicated exposure to the following various analytics. Business, descriptive, diagnostic, predictive, prescriptive, social media, web, streaming, visual, machine learning, educational data mining, rule-based systems, academic, and learning analytics, with the level of BDA analytics types assessed at the departmental level. Notably, meso-level analytics types at the departmental and faculty levels received more attention, while micro, nano, and macro levels related to students, institutional, and governance levels in higher education within the emerging economy context have received less focus.

Throughout the data life cycle, big data analytics in higher education enhances resources and sustainable development in learning and educational data mining, necessitating BDA capabilities to address challenges related to data, processing, and management (Vassakis et al., 2018). Therefore, a strategic big data assessment model and policy development are needed to improve data access, security models, enrollment, and retention for timely academic success, maintaining the business value of large implementations in a technological ecosystem to optimize decision-making in socio-economic activities involving processes and institutional culture (Adrian, Abdullah, Atan & Jusoh, 2016; Campbell, DeBlois, & Oblinger, 2007). Consequently, the future relies on informed decisions and navigating global changes, which require knowledgeable champions among decision-makers within smart universities (Yousef, 2024; Chaurasia, Kodwani, Lachhwani & Ketkar, 2018). Therefore, enhancing competitiveness in internet computing and analytical skills is crucial for decision-making by interpreting new knowledge and addressing the growth of unstructured data.

Table 3. Stakeholders' Perspectives for Higher Education Institutions' Digital Business Process Model, Big Data, and Analytics Processes in BDA Adoption

| Educational stakeholders' level | Educational stakeholder | Processes associated with business transformation at educational stakeholder levels | Level types of analytics Macro, mega, meso, micro, and Nano | Various applications of big data analytics (main analytics) | The key technique (s) used to perform the analysis of the collected educational data |
|---|---|---|---|---|---|
| Students level | learners | Mega process- Learning & teaching process Student and teacher mobility realization | Micro and Nano | Learning analytics, learner analytics, personalized learning analytics, | Association-rule mining, Clustering, classification Sequential pattern mining, neural networks, and decision trees, logistic regression, Social network analysis Context-aware LA solutions tools, LA |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | dashboards<br>Visualization tools. .<br>Adaptive learning courseware |
| Departmental (Courses) | Lecturers, Researchers, curriculum developers, Administrators | Mega process-enabling process, Learning and teaching process, research process | Meso | Learning analytics, learner analytics, Descriptive, Predictive, Social media, Rule-based system, Diagnostic, Prescriptive analytics, Web analytics, Small-scale BDA | Statistical correlation analysis, fuzzy clustering analysis, grey relational analysis, K-means clustering, fuzzy-association-rule mining and visualization information, graphic techniques, Association-rule, clustering, classification, sequential pattern analysis, dependency modeling, and prediction |
| Faculty level | Instructors/ lecturers/ Tutors/mentors, educational researchers, and administrators | Mega process-Learning and teaching process, research process | Meso | Learning analytics, learner analytics, business analytics, small-scale BDA Descriptive, Predictive, Social media, Rule-based system, Diagnostic, Prescriptive analytics, Web analytics | Automatic text analysis, content analysis, text mining, and Social network analysis<br>Statistic correlation analysis, fuzzy clustering analysis, grey relational analysis, K-means clustering, and fuzzy association rule mining<br>Clustering, classification, and association rules mining,<br>Fuzzy techniques. |

| | | | | | |
|---|---|---|---|---|---|
| Institutional level(Faculty department, courses, and other educational activities and services) | Administrators, developers of curriculum and learning design, systems designers, funders, marketing | Mega and major processes include Learning and teaching process, research process enabling the planning and governance process, sub-processes and tasks | Macro | Business analytics, Big data analytics, educational data mining, Academic analytics, Learning analytics, learner analytics, Institutional-wide scale BDA | Association-rule mining, learning decomposition, and logistic regression, Decision trees, Bayesian models, and other prediction techniques visualization, machine learning, learning sciences, psychology, social network analysis, semantics, artificial intelligence, e-learning, and social aspects |
| Governance level(Regional, National, International | Policymakers, institutional boards of directors, executive management teams, national governments, education authorities, funders, and sponsors | Mega and major processes-redefining educational, research, and administrative services of higher education institutions | Macro and mega | Cross-institutional analytics with cross-institutional data. (e.g., cross-institutional policy-making, demographic analysis of educational stakeholders | Association-rule mining, learning decomposition, logistic regression, social network analysis |

Source: Author

**Big Data Analytics Benefits –Innovation, Opportunities, and Competitive Edge**

Higher Education Institutions (HEIs) are redesigning processes to optimize resources, meet customer needs, and enhance business models. Therefore, promoting the integration of internal capabilities and global partnerships is essential for data-driven innovation and maintaining a competitive edge (Lee, 2019; Rosdi, 2017). Big data analytics capabilities improve business model innovations, reduce costs, optimize operations, and enhance students' learning activities, knowledge discovery, and analytical skills, fostering resource optimization and institutional efficiency in managing large volumes of data (Attaran, Stark & Stotler, 2018). Advanced techniques for analyzing extensive educational data at five levels—course, department, institution, region, and national/international—enable higher education institutions to transform their business operations (Udeh-Orieno, Daraojimba, Ndubuisi & Oriekhoe, 2024; Siemens & Long, 2011), enhance academic performance, and cultivate a data-driven culture that adapts to market and technological changes for sustainability, particularly in emerging economies (Daniel, 2015). However, challenges arise in analyzing and interpreting big data management, influenced by technology, organizational structure, and inadequately skilled personnel (Nilashi, Keng Boon, Tan, Lin, & Abumalloh, 2023; Rosdi, 2017). In the effort to leverage innovative Big Data Analytics (BDA) models across various management levels—nano, micro, meso, macro, and mega—within higher education institutions, it becomes feasible to address political and economic pressures, maintain competitive advantages, and improve retention, institutional reputation, and graduation rates through actionable intelligence for decision-making (Siemens & Long, 2011). Therefore, policymakers must create an enabling design environment to enhance pedagogical practices and invest in BDA infrastructure to achieve a competitive advantage. (Choi, Hung, Peng & Chen, 2022).

**Big Data Analytics Adoption Challenges: Data, Process, and Management**

Big Data is becoming increasingly complex, necessitating new data analysis and modeling methods to enhance organizational outcomes and investment returns through quality and accessible data. Consequently, collaboration with experts and employee proficiency in managing data warehouses is crucial to ensuring robust security while adapting to traditional systems, complying with privacy laws, and balancing legal data use with government privacy monitoring alongside BDA infrastructure to prevent security breaches (Ang, Ge, & Seng, 2020). While data sharing is essential for business efficiency, security challenges arise from the distributed, complex, and vulnerable data sets across higher education institutions, particularly with modern data infrastructure designed for scalability and competitive advantage. Therefore, effective big data governance in higher education institutions requires transparency and accountability. Regarding policy challenges related to cloud applications with IoET, data storage access, and applications necessary to maximize value from big data initiatives, BDA is recognized as a significant tool in addressing sustainability challenges in emerging economies. (Vassakis et al., 2018; Wang et al., 2018).

## Conclusions

Academic digital business processes have transformative potential with the Internet of Educational Things (IoET) and big data analytics (BDA) to manage the overwhelming proliferation of digital technologies and diverse information systems to streamline research priorities, forecast future trends, and enhance educational outcomes in emerging economies. However, technological, social, economic, and political shifts related to security, ethical, legal, and risk concerns, along with the need for advanced analytical skills, require attention to ensure continuous growth in the widespread engagement of learners, faculty, and administrators in smart education environments (Wang, Li, & Zuo, 2025; Amin et al., 2022).

In the era of digital transformation, navigating the Internet of Everything (IoET) and Big Data Analytics (BDA) paves the way for innovative business models in academia, enabling data-informed decisions that enhance activities for decision-makers. However, this approach addresses the ongoing challenges regarding data, processes, and management faced by smart universities in emerging economies like Ghana. Therefore, increasing the adoption of BDA methods—and understanding the benefits and challenges of IoET and BDA—can leverage large data sets, serving as a game-changer for modern business operations. Consequently, it provides insightful decision-making for stakeholders in higher education to remain competitive in the global market of data science and network science disciplines.

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