



Utilization of Big Data in Educational Technology Research

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Abstract

This study critically examines the implementation of big data analytics within the field of Educational Technology, with a specific focus on its application at the Faculty of Engineering, Langlangbuana University. The research is prompted by the unprecedented shift from traditional, in-person instruction to online learning environments, a transition significantly expedited by the COVID-19 pandemic. This paper explores how big data can be systematically utilized to develop advanced educational strategies that address the complexities of modern learning environments. Through an extensive review of relevant local and international literature, the study highlights the potential of big data to offer granular insights into student engagement, learning outcomes, and instructional effectiveness. The findings suggest that the strategic integration of big data in educational research not only facilitates personalized learning and improves pedagogical practices but also enhances institutional decision-making processes. This research underscores the critical role of big data in fostering an adaptive, evidence-based approach to contemporary educational challenges.

Keywords: Big Data; Educational Technology; Online Learning; Learning Analytics; Student Performance.

Introduction

Learning is a complex process that has been developed and implemented through various theoretical approaches, with three main models forming the foundation: behaviorism, cognitivism, and constructivism. These models have played a crucial role in shaping teaching and learning methods in academic environments, particularly in engineering faculties. The behaviorist model focuses on observable behavioral changes as measurable outcomes of learning. This approach emphasizes the importance of stimulus and response in controlling students' learning behavior, where the success of learning is gauged by observing the behavioral changes that occur after instructional interventions. In the context of engineering education, behaviorism is often used to assess learning achievements based on students' ability to demonstrate new skills or knowledge after the learning process. On the other hand, cognitivism offers a deeper perspective on how individuals process information and construct knowledge. This model highlights the critical role of instructors in facilitating students' cognitive processes, such as thinking, understanding, and memory retention. Cognitivism views learning as an active process involving the brain's information processing, where students are expected to relate new knowledge to existing cognitive schemas. In engineering education, this approach is employed to design instructional strategies that stimulate students' cognitive activities, such as the use of concept maps, diagrams, and complex problem-solving techniques. The objective of this approach is to develop students' critical and analytical thinking skills, enabling them to master the subject matter in a more profound and applicable manner.

Meanwhile, constructivism proposes that knowledge is not passively received but actively constructed by individuals through interaction with their environment. This model emphasizes the importance of direct experience and active student involvement in the learning process. Constructivism teaches that each individual builds their understanding based on personal experiences and interpretations, influenced by their background, culture, and social context. In the context of an engineering faculty, this approach requires students to actively participate in learning, developing their



knowledge through experimentation, discussion, and collaboration with peers. The use of technology, such as big data in e-learning, can enhance this process by providing relevant data on student interactions with learning materials, allowing instructors to tailor their teaching approaches to meet individual student needs. The constructivist approach has proven effective in enhancing students' understanding and critical thinking abilities. For example, Fakhira *et al.* (2020) demonstrated that constructivism is effective in helping students gradually build and enhance their knowledge from simple to more complex concepts. This approach has also been shown to be beneficial in promoting active learning, which involves direct student engagement in the learning process, ensuring that they do not passively receive information but also internalize it (Nisa *et al.*, 2021). In engineering education, the application of constructivism can be achieved through various methods, including collaborative learning facilitated by e-learning systems (Gitakarma & Tjahyanti, 2012). This method enables students to work in groups, share information, and utilize peers as learning resources. Fitriasisari and Ningsih (2021) also emphasize the benefits of constructivism in mathematics education, where students are encouraged to observe, work in groups, and use various learning resources to build a more comprehensive understanding.

The transformation in research methods at Langlangbuana University has occurred due to the rapid development of e-learning technology. This technology provides easy access to various forms of learning materials and teaching media, such as infographics, audiovisual content, text, and interactive programs. The COVID-19 pandemic, which has affected the world, including Indonesia, has accelerated the adoption of e-learning as an alternative solution to face-to-face learning. This sudden change has had a significant impact on various aspects of life, including education. At Langlangbuana University, face-to-face learning has been replaced by online learning, offering flexibility but also posing new challenges in terms of teaching and learning effectiveness. Although e-learning offers many advantages, its implementation is often limited to content delivery without considering the variations in individual student characteristics. In many conventional e-learning systems, learning materials are presented with the assumption that all students have similar abilities, motivation, and learning styles. This homogeneous approach is not always effective, especially in diverse student populations, where each individual has different backgrounds, knowledge levels, and learning preferences. This can lead to various issues, such as a lack of student engagement in learning, low motivation, and difficulties in understanding the material presented.

As a result of these limitations, the existing e-learning systems have not been able to guarantee effective learning transformation or the optimal application of learning strategies. These systems have also not fully functioned to enhance students' independent learning intensity, which should be one of the advantages of online learning. Therefore, there is a need for the development of more dynamic and adaptive e-learning systems that can not only adjust to individual student characteristics but also adapt to changing learning needs over time. An ideal e-learning system should be able to utilize big data to provide more accurate and relevant feedback to students, instructors, and education managers. By analyzing data generated from student interactions with the e-learning system, instructors can identify learning patterns, levels of understanding, and areas where students require further assistance. This system should also be designed to support personalization in the learning process, allowing each student to learn in the way that best suits their needs and abilities. The use of big data in e-learning enables the development of more effective teaching methods by providing the information needed to make informed decisions in designing learning interventions tailored to the specific needs of each student. Considering all these factors, the development and implementation of dynamic and adaptive e-learning systems become imperative in efforts to improve the quality of education in the digital era. E-learning technology that can adjust to individual student characteristics will open new opportunities in the learning process, enabling more inclusive and effective education for all students, regardless of their background or abilities. This will not only enhance learning outcomes but also provide a strong foundation for further research in educational technology, particularly in the context of utilizing big data to support more effective and efficient learning.



Literature Review

In the Field of Education and Research

Big data represents a new opportunity to tailor education to the needs and learning processes of students. The application of big data in education is no longer a theoretical concept but a practice that has been implemented in various institutions. With the aid of software that analyzes students' interactions, it is now possible to track their learning progress. This software collects information from the devices used by students, including their grades, learning skills, strengths, weaknesses, and even hesitation patterns when using a computer mouse. The implementation of big data in education enables personalized learning, which, in turn, impacts teaching by providing instructors with more time to support students individually and better understand their needs. The rise of technological innovations and the increasing mobility of students have facilitated a significant transformation in education. The popularity of Massive Open Online Courses (MOOCs) is a testament to this shift, with 70 institutions in the United States currently offering MOOC courses, making it one of the largest online education platforms. Coursera, for example, has over 470,000 student enrollments. To fully harness the potential of big data in education, investment is required to develop new pedagogical approaches that can scale effectively while addressing the complexities involved in creative thinking (Cusumano, 2013). In Europe, the adoption of online teaching and the integration of big data technology have enhanced competitiveness in the educational sector. However, the implementation of big data in education raises important ethical and moral considerations, particularly in the development of robust data anonymization tools. Several key issues must be addressed in the context of big data application in research:

- 1) Data Privacy

Privacy pertains to an individual's control over the extent, timing, and conditions under which their personal information (physical, behavioral, or intellectual) is shared with others. In the realm of information privacy, it refers to the ability of organizations or individuals to determine which data about them can be shared within computer systems.

- 2) Confidentiality

Confidentiality involves the treatment of information disclosed in a trust relationship, with the expectation that it will not be revealed to others without consent or in a manner inconsistent with the original understanding.

- 3) Data Security

Data security concerns the measures taken to protect data from unauthorized access and ensure it is stored and used securely. This includes adhering to standards that define appropriate access to data.

- 4) Security Breaches

This issue relates to the actions taken following incidents of theft or unauthorized access to sensitive personal data, which may compromise the confidentiality of the information.

Big Data in Research

Big data techniques can be employed in various ways to analyze learning and research processes. Some of these applications include:

- 1) Performance Prediction

By analyzing student interactions, both among themselves and with instructors within the learning environment, it is possible to predict student performance.

- 2) Attrition Risk Detection

Through the analysis of student behavior, the risk of students dropping out can be identified and measured early in the learning process, thereby minimizing dropout rates.

- 3) Data Visualization

As educational data continues to grow in size and complexity, visualization techniques can be employed to identify trends and relationships within the data, making it easier to interpret through visual reports.

- 4) Intelligent Feedback

Learning systems can provide intelligent feedback that responds immediately to student inputs, enhancing interaction and performance.

- 5) Course Recommendation



New courses can be recommended based on students' interests, identified through the analysis of their activities, ensuring that students do not lose their way when choosing areas of study.

6) Student Skill Estimation

The system can estimate the level of students' skills based on their interactions and performance.

7) Behavior Detection

The system can detect student behavior within the learning environment, based on activities and game models that assist in personal development.

8) Grouping and Collaboration

The system can facilitate student grouping and collaboration, social network analysis, the development of concept maps, courseware construction, and planning and scheduling.

The integration of big data in educational settings has been extensively studied, revealing its potential to transform teaching methods, learning experiences, and institutional practices. Bai (2024) explores the design and application of decision support systems based on big data for educational management, highlighting how such systems can facilitate strategic planning, resource allocation, and personalized student interventions. This aligns with Akrami's (2024) investigation into the integration of big data technologies in higher education, which underscores the capacity of big data to enhance institutional efficiency by identifying learning patterns and supporting at-risk students. Personalized learning is a recurring theme in the literature. Zhao (2023) and Zhong (2024) emphasize the construction of personalized learning systems supported by big data, which are tailored to meet individual student needs, thereby improving engagement and academic performance. Similarly, Xiao (2023) demonstrates the effectiveness of personalized learning paths based on big data in a language learning context, showing that these methods can significantly enhance student outcomes. The role of big data in curriculum development and teaching innovation is also prominent. Gao (2024) discusses how cloud computing and big data can support curriculum teaching and research, leading to improvements in teaching effectiveness and educational innovation. This is further supported by Hu (2023), who highlights the use of big data in developing personalized teaching models, particularly in language education, which can cater to individual learning objectives and improve instructional outcomes. Despite its potential, the implementation of big data in education presents significant challenges, particularly in the areas of data privacy, security, and ethical considerations. Al-Rahmi *et al.* (2019) emphasize the importance of adopting robust data management practices to ensure that student data is protected, while Elam (2024) explores the future directions of big data and AI in education, highlighting the ethical implications of their use. Moreover, the risk of data overload is a critical concern in the application of big data in education. Roberts *et al.* (2016) discuss how the sheer volume of data can lead to analysis paralysis, where educators are overwhelmed by excessive information, hindering effective decision-making. To address this, Šmitienė (2024) suggests the implementation of learning analytics systems that can filter and prioritize data, making it more accessible and actionable for educators. This is echoed by Fischer *et al.* (2020), who highlight the affordances and challenges of mining big data in education, particularly in how these technologies can be used to support informed decision-making processes. The literature highlights both the opportunities and challenges associated with the use of big data in education. While big data offers significant potential for personalized learning, curriculum innovation, and improved educational management, its implementation requires careful consideration of ethical issues, data management practices, and the risk of data overload. Addressing these challenges is crucial for realizing the full benefits of big data in educational.

Methodology

This study encompasses the analysis and potential implementation of big data within the realm of Educational Technology research through a comprehensive literature review. The data used in this research were obtained from local and international journals that discuss the implementation of big data in Educational Technology research. Big data has become a significant phenomenon in the digital age, where nearly every human activity—whether done, spoken, or observed—generates large amounts of data (Hoy, 2014). Big data refers to data sets that exceed the processing capacity of conventional database systems. This data is characterized by its large volume, high velocity, or complex structure that does not conform to traditional database architectures, necessitating alternative



approaches for processing (Dumbil, 2013). In general, big data is widely recognized for its three key characteristics, often referred to as the "3Vs": variety, volume, and velocity. Variety refers to the diverse types of data collected and generated, while volume pertains to the massive amounts of data produced. Velocity, on the other hand, describes the rapidly increasing speed at which data is generated (Laney, 2001). Big data presents a significant challenge in data management due to its vast volume, diverse variety, and exponential growth rate, rendering traditional database management systems inadequate. According to IDC, big data represents a new generation of technology that leverages data architecture to efficiently extract and process large quantities of data from various sources. Big data not only comprises enormous data sets but also exhibits high variability and rapid movement, making it difficult to manage with traditional tools. The sources of big data are highly diverse, including information collected by governments, private companies, social media websites, and various other entities. Every day, an estimated 2.5 quintillion bits of new data are generated, with approximately 90 percent of this data produced in the past two years alone. This data originates from a variety of sources, such as social media platforms (Facebook, Twitter, Google+), as well as data in the form of videos, images, text, audio, and more. Additionally, government websites and private companies also generate large volumes of data daily (Gondaliya, 2015). Various scientific devices and instruments, including media and mobile devices, also serve as primary sources of big data, generating vast amounts of data. The main challenge posed by big data lies in how to effectively analyze, store, and visualize this data. This challenge extends beyond individual organizations or companies, requiring specialized discussions on how to address these challenges using the array of big data tools and technologies available. Big data has been described as the "dashboard of human behavior" by Rick Smolan and Jennifer Erwitte, the lead authors of the illustrated book *The Human Face of Big Data*. Big data methods and analysis contribute to understanding human behavior by measuring and analyzing the constant flow of data captured through sensors, satellites, and GPS-enabled devices. Today, big data is also considered the "new gold" of the digital era. Numerous technological innovations have enabled the collection and analysis of data on an unprecedented scale. The implementation of big data was first applied to Google's web search algorithms to analyze user search behavior (Rheinhalter, 2014). Another example is Netflix, which has revolutionized the way people select and consume films and television shows through recommendation engines powered by big data.

Results and Discussion

Results

Several key stakeholders are involved in research within the domain of Educational Technology, including students, instructors, and administrative staff. The implementation of big data in educational research can identify both potential and challenges in a detailed manner. This section discusses the role and contribution of big data implementation in enhancing the quality of research in Educational Technology, with a focus on students, instructors, and the administrators of learning programs.

Students

The implementation of big data allows for the extraction of information from research, providing insights into student performance and holistic learning approaches. Instructors and learning administrators can progressively monitor all students and initiate approaches that engage them more effectively with their chosen subjects. This method offers students a better understanding of their subjects. The use of MOOCs also enhances access to digital reading materials and enables flexible course planning for students. MOOC algorithms can filter large amounts of data related to how students interact with learning materials (text, audiovisual, images, etc.). Big data algorithms can identify which parts of the material are difficult to understand, unclear, or simple. This data can be presented in real-time, allowing for immediate monitoring and providing an overview of the learning process. Big data implementation enables broader monitoring and evaluation of student activities, such as how much time they spend reading, where they source electronic resources, and how quickly they grasp key concepts. This feedback can guide students in adjusting their reading patterns and study habits to address the challenges they face, ultimately improving learning outcomes. Big data analysis can offer insights into the quality of a student's learning, and when combined with periodic test performance, instructors can analyze what students know and determine the most effective techniques for each student. By focusing on data analytics, students can learn in more varied ways. Currently, research in Indonesia



remains largely theoretical, with face-to-face methods still prevalent, although MOOC-based implementation is beginning to take place. MOOC-based education will require time for students to adapt, necessitating specific approaches to support online research. While research findings in several countries indicate that MOOC technology is more effective for certain types of research—particularly those related to computer and internet use, information resource courses, and the application of new technology in Educational Technology research—there are considerations that must be addressed. One such consideration is the commitment to learning using e-learning methods. A strong commitment will influence not only the learning outcomes but also the research data obtained and generated.

Instructors

A productive learning environment requires that student learning data be readily accessible to instructors. The implementation of big data provides instructors with powerful tools to quickly understand how learning works and apply these insights across various learner types and learning situations. With big data, instructors can obtain summary reports on student progress. For example, when students access learning materials or tutorials and complete exercises, the data is collected and made available to instructors through graphical reports and other interactive visual tools. These tools not only allow instructors to review learning progress but also help them determine how to personalize learning for students who need additional support in certain areas. In this competitive era, research in Educational Technology is crucial. One natural response to the challenges faced is the introduction of new technologies to support MOOC-based big data initiatives. The use of big data in Educational Technology research offers new perspectives on assessing research, especially for instructors and library staff. This innovation enables both students and instructors to make better decisions, ensuring that no student is left behind. Instructors can modify (customize) learning if students encounter difficulties based on the data collected. This data allows instructors to better understand students' needs through visualizations, such as color-coded charts that quickly reveal gaps in achievement or widespread strengths and weaknesses. Big data dashboards can clarify which students need extra help and which ones require more challenging work, giving instructors the opportunity to tailor their lesson plans accordingly.

Learning Administrators

For learning administrators, big data implementation can support data-driven decision-making. Administrators can build models of the learning experience by collecting student satisfaction surveys or analyzing scale data. Data collection can also involve building empirical models of students and instructors by analyzing attendance, performance, behavior, course preferences, and the overall learning system. For instance, by constructing a model of the learning experience, conducting online course evaluations, and then designing courses based on large data sets, administrators can significantly enhance both student academic performance and instructor teaching effectiveness. Big data can study student learning behavior and teaching outcomes by collecting data on behavioral changes in school situations, course completion status, the time students spend on web-based learning systems, and final test scores. Ultimately, a student learning behavior model can be established. By building a big data learning platform and developing a learning behavior model, it is possible to predict student failure with over 75% accuracy. Furthermore, learning administrators can collect interactive student data within online data systems. This includes the nature and number of student requests for assistance, student practice answering questions, the repetition rate of students who answer incorrectly, and the accuracy rate of question responses. By mining data and analyzing the learning models built, data at the unit, curriculum, and knowledge point levels can be analyzed with either manual or automated feedback to choose the appropriate mode and fully consider learning time. This provides students with suitable learning content, delivering detailed learning feedback and advice through granular data from each knowledge point on each mobile device. Learning administrators can also make decisions through big data mining and educational learning analysis, revising existing domain knowledge models to study relationships between students and learning points, such as knowledge points, learning units, and courses. By building domain knowledge models, collecting and processing relevant student data, drawing learning curves, and then analyzing this data, administrators can significantly improve both student academic performance and instructional efficiency. By collecting basic learning information and establishing baseline data, students with similar learning characteristics can be grouped and categorized according to these characteristics through data mining, learning analysis, and machine learning.



algorithms. A learner profile can then be established, providing various types of students with personalized learning environments that stimulate their initiative and motivation to learn. For example, by using data mining technology on online learning platforms to analyze learning logs, administrators can understand different student characteristics and interaction types, subsequently building learner profiles that fully stimulate learning initiative, thereby significantly improving student learning efficiency.

Discussion

This research examines the transformative role of big data in Educational Technology, emphasizing both its potential and the challenges it presents in enhancing educational outcomes. Big data has become a crucial tool in the digital era, providing opportunities to customize educational experiences according to the unique needs of individual students. Through the analysis of extensive data derived from student interactions with learning platforms, educators and administrators can gain valuable insights into learning behaviors, academic performance, and areas where students require additional support (Akrami, 2024). The integration of big data into educational settings has the potential to revolutionize how educational processes are managed and optimized. For instance, Bai (2024) discusses the design and application of decision support systems for educational management based on big data, which can facilitate strategic planning, resource allocation, and student interventions. By utilizing big data, universities can identify learning patterns, support at-risk students, and personalize interventions, thereby enhancing student success and institutional efficiency (Bai, 2024; Syed, 2024). One significant advantage of big data in education is its ability to enable personalized learning. With data analytics, educational institutions can move beyond the traditional one-size-fits-all approach, adopting strategies tailored to the diverse learning styles and needs of students. The real-time monitoring and evaluation of student performance allow for timely interventions, ensuring that students who struggle with specific concepts receive the necessary assistance before falling behind. This adaptability is crucial in modern education, where the diversity of student backgrounds and learning preferences is more pronounced than ever (Williamson, 2017).

Moreover, the integration of big data into educational research facilitates the development of personalized learning systems. Research by Zhao (2023) and Zhong (2024) highlights the construction of personalized learning systems supported by big data, which can adapt to students' unique requirements and significantly enhance their educational experience. These systems can analyze vast amounts of data to create personalized learning paths, improving student engagement and academic performance (Xiao, 2023). Additionally, Hu (2023) explores the application of big data in personalized language teaching models, further demonstrating the versatility and potential of big data in tailoring educational experiences.

However, the implementation of big data in education also brings forth significant challenges, particularly concerning data privacy, security, and ethical considerations. Al-Rahmi *et al.* (2019) emphasize the importance of adopting robust data management practices to ensure that student data is protected from unauthorized access and misuse. As the volume of personal information collected through educational platforms grows, ensuring data security and maintaining student trust becomes increasingly critical. The ethical implications of big data usage must be carefully considered to protect the privacy and confidentiality of student information (Elam, 2024). The complexity of big data analytics also requires that educators and administrators possess a certain level of technical proficiency to effectively interpret and apply the insights generated. This need for technical skills presents a challenge in terms of professional development and training. Educational institutions must invest in programs that equip educators with the knowledge and tools needed to leverage big data effectively (Zhong, 2024). Without the appropriate training, there is a risk that the benefits of big data may not be fully realized, potentially limiting its impact on educational practices (Zhang, 2024). Another significant challenge associated with big data in education is the risk of data overload. As large volumes of data are generated, there is a danger that educators could become overwhelmed, leading to analysis paralysis, where the abundance of information hinders decision-making rather than supporting it (Roberts *et al.*, 2016). It is essential to develop systems that can filter and prioritize data, presenting it in a manner that is accessible and actionable. These systems would enable educators to focus on the most relevant information, facilitating data-driven decisions that enhance educational outcomes (Ehlenz *et al.*, 2022).



Furthermore, Gao (2024) discusses how cloud computing and big data can support curriculum teaching and research, demonstrating that these technologies can enhance teaching effectiveness, educational innovation, and students' information literacy. The practical impacts of these technologies are evident in the improvements seen in educational practices, as they enable more informed decision-making and foster innovation in teaching methods (Fischer *et al.*, 2020). The implications of big data for educational equity are also critical. While big data has the potential to level the educational playing field by providing personalized learning experiences, there is also a risk that it could exacerbate existing inequalities. For example, students in underfunded schools may not have access to the same quality of data-driven resources as their peers in more affluent areas (Di *et al.*, 2021). Addressing these disparities requires concerted efforts to ensure that the benefits of big data are accessible to all students, regardless of their socioeconomic background (Yang, 2024). The integration of big data into Educational Technology offers extensive opportunities to enhance teaching methods, improve learning experiences, and optimize institutional practices. However, to fully realize these benefits, it is essential to address the challenges associated with data privacy, professional development, and data overload. By developing robust systems and ensuring equitable access to data-driven resources, educational institutions can harness the power of big data to drive positive educational outcomes. The research conducted by Bai (2024), Akrami (2024), and others provides a strong foundation for understanding the potential and challenges of big data in education, highlighting the importance of strategic implementation to achieve the desired outcomes.

Conclusion

The primary objective of using big data in education is to assist educators in formulating more effective teaching strategies and analyzing information collected from students. Big data enables the exploration of various components within the learning system and the analysis of student learning outcomes and teaching strategies. Through data mining and learning analytics, decision-making systems can provide systematic, intelligent, and dynamic evaluations of the teaching and learning processes, thereby enhancing their efficiency and effectiveness. The implementation of big data offers significant benefits not only for students but also for educators and educational administrators. Big data can create a more efficient learning environment, optimize educational management and research strategies, and significantly improve the efficiency of educational activities through the personalization of adaptive learning systems. Moreover, big data has the potential to transform the ways in which educators teach and students learn by providing targeted solutions to specific challenges faced during the learning process. This capability helps prevent students from failing to reach their full potential.

Furthermore, big data provides the necessary tools for educators to gain a deeper understanding of student needs, which in turn can improve their chances of academic success. The implementation of big data in online educational technology represents a significant innovation with great potential, supported by improving internet infrastructure, increasingly prepared human resources, and diverse learning content. The development of big data-based educational applications will enable educational administrators to identify both the potential and challenges faced by students, educators, learning materials, and program implementation. With the data generated, educational administrators can more effectively monitor and evaluate various aspects of the educational process. This data can also serve as a foundation for future policy-making and decision-making, aimed at enhancing the quality and efficiency of educational programs within the institution.

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