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BIG DATA TECHNOLOGY IN EDUCATION: ADVANTAGES, IMPLEMENTATIONS, AND CHALLENGES

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Abstract

This study provides an in-depth review of Big Data Technology (BDT) advantages, implementations, and challenges in the education sector. BDT plays an essential role in optimizing education intelligence by facilitating institutions, management, educators, and learners improved quality of education, enhanced learning experience, predictive teaching and assessment strategy, effective decision-making and better market analysis. Moreover, BDTs are used to analyze, detect and predict learners' behaviors, risk failures and results to improve their learning outcomes and to ensure that the academic programmes undertaken are of high-quality standards. This study identified that some universities and governments had implemented BDTs for transferring traditional education to digital smart one. Despite BDT significant offerings for education still, there are several challenges regarding its full implementation such as security, privacy, ethics, lack of skilled professionals, data processing, storage, and interoperability.

Keywords: Academic analytics, Big data analytics, Educational data mining, Learning analytics.

1. Introduction

The advancement of technology and the Internet have facilitated education with various types of teaching, learning and assessment methods that can be achieved on/off campus, inside the classroom or virtualized environment. Digital technology and social media have made online and distance learning accessible ubiquitously and pervasively at low cost for everyone regardless of age, gender or employability status [1-3]. For example, online education platforms including Coursera, Show Academy, and Udemy provide online courses for anyone who wants to learn in contrast to traditional learning that requires specific age and skills besides attendance at precise location and time. The mix mode online and traditional learning environments emerged because of the development of smart digital devices and the progression of Information Communication Systems (ICT) [4]. Additionally, the existence of Social Networks and Web 4.0 have facilitated advanced learning and teaching resources for providing best education practices and improved outcomes.

The digital revolution associated with the rapid advances of innovative technologies such as ubiquitous and pervasive computing, smart devices, besides the massive open online courses with unlimited usage of social media are radically reshaping the mode and accessibility of teaching, learning and assessment methods. These all factors impacted on transforming the education to smart blended learning environments including Learning Management Systems (LMS) platforms, Bring Your Own Device (BYOD), E-learning, Intelligent Tutoring Systems (ITSs), Forums, Concept Maps, among others. Nevertheless, institutions are overburdened with the complexity of managing and analyzing the generated data from education resources efficiently and effectively for predicting the learners' performances among other educational purposes. The advancements of computing have enabled real-time automatic gathering, processing, storage, and analysis of the massive amount of data that satisfies Big Data definition terms as shown in Fig. 1 [5].

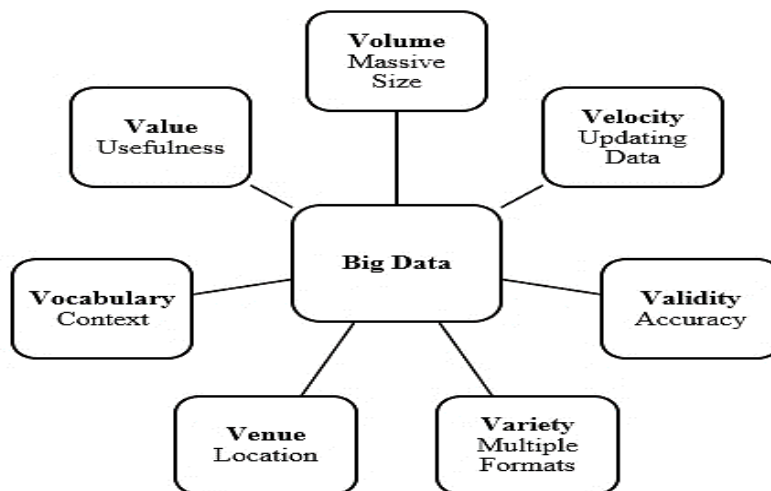


Fig. 1. Big data attributes.

Big Data refers to the process of combining enormous volumes of diversely outsourced data and analyzing them, using complex algorithms to inform decisions

[6]. Big Data Analytics (BDA) refers to the use of advanced data analytic techniques on vast data sets (Big Data) to discover patterns and meaningful use of information [7-9]. BDA automated reports facilitate increased efficiency, better insights, and improved awareness which qualifies education services to be suited to individuals and institutes requirements [10, 11]. However, BDTs are not fully implemented due to several reasons including the complexity of identifying the relevant data which requires knowledge, resources and time that slowed its implementations in the education sector.

BDT for education involves Data Mining, Data Analytics, and Web Dashboards [12]. BDA enables data collection and interpretation of evidence-based learning automated instructions and assessments environments [13]. It facilitates in-depth insights to ensure best practices that increase the productivity and profitability. The education sector is beginning to use BDT to improve their services including but not limited to gaining insights, enhanced learners' performances, grades, and retention besides customizing the learning, teaching and assessment methods and techniques according to learners' needs and capabilities within the limited resources. For example, the Australian Digital Education Revolution (DER) has allocated \$2.1 billion to transform teaching and learning through digital education in 2008.

This transformation has resulted in producing, exchanging, processing and storing huge amount of data which are beyond the traditional ways of handling it, and are creating complication of managing, analyzing and storing an enormous amount of data [14]. This study is organized as follows: Section 2 discusses the advantages of BDT for the education sector. Section 3 describes the implementations of BDT in education, whereas Section 4 describes BDT implementation challenges. Furthermore, Section 5 presents the results and discussion. Finally, Section 6 concludes the study.

2. Big Data Technology Advantages for Education

The use of BDT in education facilitates personalized education and improved learning, teaching and assessment compared to the traditional education methods [15]. This section discusses BDTs significances for the education sector as follows:

2.1. Enhanced learning experience

Education sector aims to enhance the learner experience, improve the educator effectiveness, and provide appropriate, efficient and effective teaching and learning environment that is tailored to the learner's capabilities and resources [16]. Big Data and mass education contributed to forming expectations for achievements, accountability, and access, which is required for smart societies development. This can be accomplished by providing the infrastructure and capacity for sustainable change that leads to the institutionalization of knowledge acquisition, exchange, and creation [17].

BDT facilitates the communications and accessibility for learners, educators, and administrators. Educational data can be aggregated over large numbers of learners who can be explored through data mining algorithms for model building. These developed models are utilized via constructing adaptive learning systems in which the adaptations based on model's predictions can be used to change what learners may experience next or recommend external academic services to support their learning progress.

2.2. Improved quality of education

The adoption of BDT in higher education is necessary because of increased competition, accreditation, assessments and regulations. Decision makers are bound to make critical decisions based on the meaningful information extracted from analyzing the data. They are concerned about the intelligent outcomes of the institution to identify the learners learning success rates, patterns and difficulties, besides their academic progress. BDT deals with the massive amount of educational data for analyzing and tracking learners' history from pre-K through university and work level. It stores time-stamped learners' inputs and behaviors during their learning process. BDA enables tracking learners' progress besides their future course outcomes and dropouts. It creates a new paradigm for the stakeholders to select best practices that streamline teaching processes, as well as ensuring that the institutions are accountable for learners' attritions, satisfaction, and successes. Governments such as The United States Department of Education's has adopted BDT as part of its National Education Technology model for the 21st-century learning plan to improve their quality of education instructions [18].

2.3. Improved market analysis

BDT enable the institutions to track and identify their success rate, achievements, weaknesses, and status in comparison with other benchmarked institutes. They can analyze their business situation, Key Performance Indicators (KPI's) and academic accreditation. BDT assess the institutes to plan and manage their strategy through a data lens [6]. It assists them to provide evidence of their success rates and to identify areas for improvement as it allows them to be more proactive and progressive [19]. Moreover, they can benchmark their learners, faculty and curriculum performances against similar ones, for better insights into potential future enhancements [4]. University of Florida has implemented Big Data (PureData Analytics system) for market research. The applied system reduced the processing time of 10 million in 27 hours to 100 million records in 3 seconds. This significant time reduction allowed the faculties to analyze and share their findings with others including institutions and government agencies [20].

2.4. Effective decision making

BDT enables the decision makers to detect, understand, analyze and predict learners' behaviors', educators progresses and courses outcomes among other institutional operations. For example, in an online learning environment, analyzing learners' behaviors' can be achieved while they are playing educational games, engaging in the off-task behavior, or when failing to answer a question correctly despite having the required skill, or taking a long time to answer. Analyzing their participation rate also can be achieved while they are in discussion forums. This analysis assists in identifying the learners' weaknesses and strengths and predicting who might fail or pass. Other methods used are by clustering and grouping learners based on their learning difficulties and interaction patterns to analyze their usage of LMS to recommend required actions and resources [17, 19]. As stated by Bichsel [21] that "education needs investment in analytics professionals who contribute to defining the key questions throughout all process till developing data models to design and deliver alerts, recommendations, dashboards, and reports."

2.5. Predictive teaching and assessment strategy

BDT enables educators getting instant objective feedback to evaluate the structure of their courses and the effectiveness of their teaching and assessments processes and methods. They can monitor the learning process for early detection of learners' weaknesses and failure risks according to the learners' capabilities and knowledge level [1]. BDT facilitates detection and tracking of programs, courses and contents flaws to improve the curriculums offerings, by providing data analytics and in-depth insights into the generated and gathered data [8]. BDT provides personalized instructions, responsive formative assessments, actively engaged pedagogy, and collaborative learning. It facilitates predicting learners' performances based on the analysis of their history as an indicator of future grades. Additionally, it enables tracking the module progress report to acknowledge the difficulties in teaching the related subjects [4, 22-24]. For example, the use of Moodle and Joule to collect courses information and track the learners' engagements, interactions, submissions, also deliver live presentations or making real-time online quizzes.

3. Implementations of Big Data Technology in Education

Traditional learning had three models of behavioral, cognitive and constructivist [25]. The behavioral models depend on observing the changes in the learners' behaviors to measure the learning outcomes. The cognitive models depend on the active involvement of the educator in the learning process which assists in guided learning. The constructivist models depend on self-learning from the knowledge available to the learners'. A new model "Connectivism" was introduced for learning through the extension of the personal network without the need for direct interaction with the educator.

Currently, e-learning environments, and communities such as discussion forums, online chats, Moodle, Flipped Classroom among others are reforming the education methods [6] to improve the learning experience. Moreover, the emergence of open source projects in mobile computing also has resulted in low-cost learning through the smart digital devices and mobile phones. However, the amount of data made available is enormous whereas traditional techniques are limited to processing the conventional data applications, hereafter institutions started to use BDT to process their educational data.

Several researchers have investigated BDT implementation in education. Two main identified areas were Educational Data Mining (EDM) and Learning Analytics (LA) [26] EDM is used to study the learners' behaviors and performances. Its applications assist in analyzing the learning processes by investigating their interactions with the learning environment via automated interactive LMS, ITSs, and simulations [26]. EDM is used to search for new patterns, algorithms, and models through developing statistical, machine-learning and data-mining methods. The educational data can be explored for building adaptive learning systems that are used to recommend academic services to support the learning process.

LA refers to the measurements and analysis of huge data sets and its contexts for improving the learners' success rates [27]. LA involves the interpretation of these data sets and presenting them as visualized dashboards to enable academic progression, prediction of future performances, and detection of potential issues [4]. It applies the predictive models in the instructional systems to predict the

learner's behaviors', results, performances, and future registration percentages. LA tools include Blackboard Analytics, GISMO and Meerkat-ED (a web tool that analyses users and their interactions in discussion forums) besides the social network analysis and metadata to identify the learners' engagement patterns [28].

Other researchers such as Siemens et al. [29] have classified BDA as LA and Academic Analytics (AA) to improve the learning process and learners' success. LA is performed on personal, course and department levels, while AA is performed on the institutional, regional, national or international level. Greller and Drachsler classified AA into six domains, i.e. Stakeholders, Objectives, Data, Instruments, Internal limitations, and External constraints [7]. Liñán and Pérez have classified BDA into EDM and LA [1]. Table 1. illustrates some of the application areas for EDM and LA in education [26].

Table 1. Some of the application areas for EDM and LA in education.

Application	Objectives	Type of Data for Analysis
Knowledge Modelling	Knowledge and gained skills	Response (correct or not), time spent on answering questions, repeated errors, etc.
Behavior Modelling	Behavior and motivation	Performance in the classroom, in LMS or e-learning environment
Experience Modelling	Learning satisfaction	Surveys Performances in subsequent learning units or courses
Domain Modelling	Topics and sequence	Performance on courses
Course Analysis	The effectiveness of the course and the curricula?	Domain model taxonomy Skills and problems
Adaptation and Personalization	Learning experience	Learners' academic history performances records

4. Big Data Technology Implementation Challenges in Education

BDT facilitates enhancing the education process and improving its outcomes, operational efficiency, and effectiveness. However, still several challenges must be mitigated including security, privacy, ethics, timely analysis of data, efficient and effective data capture, storage, transfer and visualization [30, 31] which are discussed as follows:

4.1. Security

CyberCoders reports stated that the digital universe would reach 40 zettabytes by the end of the decade [32]. This enormous amount of revealed information can cause disaster if misused on personal, industrial, governmental and country level. Some recent incidents happened that had a fatal impact such as WannaCry, Petya, and Goldeneye attacks [33]. Traditional security techniques such as disaster recovery plans, strong password policy, firewalls, encryption and antivirus software are not sufficient enough to secure advanced technologies such as Big Data, Internet of Things (IoT), and Cloud Computing [34]. Education institutions lack adequate policies that regulate and govern the intellectual property as well as access to data beside securing the storage, transfer, and processing of huge sets of diverse educational data types [10].

4.2. Privacy

Big Data in education requires transparency that reveals the identity of the learner to inform decisions. For example, the Massively Open Online Courses “MOOCs” collect, centralize, and analyze the learners’ data [35]. This tracking of learners’ education records, performance, and how, when, and where they click each time to log in; can also be used by a malicious insider. Additionally, using BDA tools to predict learners’ future outcomes, academic performance and engagement may violate their privacy. For example, the Edmodo education website hacking resulted in tens of millions of users’ account details being advertised for illicit sale on the dark web [36]. Other issue raise as Big Data is that it has a single cloud storage database which may lead to a privacy breach since it holds millions of learners and related educational records. The Privacy Rights Clearinghouse database have listed 777 educational breaches comprising 14.8 million records of learners’ data [37].

4.3. Ethics

Ethical challenges for BDTs include identifying the institute methods for preserving personal data privacy, individual consent, data ownership, and transparency. These challenges arise as educational data collection, and use is not subject to any formal ethical review process. Data are collected through various media (online and on campus) using various methods and devices. The analyzed educational information also raises another ethical challenge of authenticity of who is accessing the data and what is it used for, i.e. prediction systems that link learners’ demographic data with their past and current educational performances, their engagements with online course materials, or in-class participation levels, or their final grades outcomes [38-40].

4.4. Lack of skilled professionals

Since Big Data is an advanced technology, still there is a shortage of experienced staff and required skills. According to a survey conducted by Russom [41], 46% stated that *“Inadequate staffing and skills are the leading barriers to BDA”*. Educators and learners need to be trained to understand the system to be able to use it. Big Data Domains present the information in an accessible and informative way. Finding skillful experts with the required knowledge of how to extract, analyze and produce meaningful use of data, as well as to identify the constructs of the learners’ cognition to promote in technology-enhanced learning environments is a complex task [10, 42]. Not to mention the high cost of employing those experts which are yet another challenge. The International Data Corporation (IDC) predicts that currently there is a need for 181,000 experts with deep analytical skills, besides five times that number of jobs with Big Data management and interpretation skills [43].

4.5. Data processing, storage, and interoperability

Education sector generates massive amounts of data from high-volume education transactions, LMSs, sensors, online repositories, educational digital libraries, learners’ information systems, social media, individual computers and administrative systems that contain information on courses and programs completion rates and learning pathways. Moreover, data comes from disparate sources and institute internal and external departments, which may result in loss of data. Additionally, data

comes in different formats; structured, semi-structured and unstructured which poses the challenge of data integration, cleansing, and storage. The variety of data collected and stored are not always interoperable; it's hard to aggregate administrative data, classroom and online data which also pose an additional challenge [10, 44]. Furthermore, maintaining data quality is yet another challenge since there are no standardized measures and indicators for performing the international comparison. This will impact the quality of information generated as it is dependent on the quality of data collected and the robustness of the measures or indicators used.

5. Results and Discussions

Big Data for education is emerging slowly despite its significant advantages. Table 2 shows some BDT implementations scenarios. BDT is implemented for improving instructions and course recommendations based on data analytics feedbacks, the courses can be adjusted and personalized according to the learner's capabilities and resources. Also, for Improving prediction of learners' future performances based on the investigation feedbacks of learners' behaviors and results patterns to limit the risk of failure and dropping off. Additionally, improving absence tracking to decrease the absence rate. Moreover, improving educational accessibility, research, evaluation, and accountability [39].

Table 2. Examples of BDT implementations scenarios.

Implemented for	Application	Applied By
Detection of learners dropping out risk rate	Grade Performance System (GPS)	Northern Arizona University [45]
Performance Prediction	Degree Compass,	Austin Peay State University [46]
Behaviour Investigation	Course Signals	Purdue University [47, 48]
Absence Tracking	BDA and Dashboards	Hattiesburg Public School District [49]
Course Recommendations	Degree Compass	Austin Peay State University [46]
Instant Assisting and Assessments	ASSITment	University, New England [50]
Visual analytics on learners' interaction with a discussion forum	Social Networks Adapting Pedagogical Practice (SNAPP)	The University of Wollongong in Australia [44]
Improvement of accessibility, research, evaluation, and accountability	Data Mining, BDA, and Web Dashboards	United States Department of Education [43]
Identification of learners at-risk of failing	Course Signals	Purdue University's [48], [44]
Fail risk detection at the course level	Moodog System	University of California, Santa Barbara [27]

Current education system involves intermediaries for facilitating the interaction between educators and learners. BDTs facilitate the analytics and the insights, but it lacks excessive security. Using the power advanced technology such as blockchain and its intelligent secure payment platform enables learners and educators to exchange information and communicate directly to fulfill the process of teaching and learning without the involvement of intermediaries. Blockchain provides enhanced

security and data quality due to its decentralization, no one controls the data entry or its integrity. Moreover, continuous verification of blockchain sanctity by every computer on the network makes it immutable (the information remains in the same state if the network exists). Only authorized parties can access the block and benefits from its services on the same network. However, Blockchain integration in education requires developing a suitable database infrastructure, training and employing new staff, as well as convincing the directors and stakeholders that blockchain is worth the financial cost.

6. Conclusions and Future Work

Big Data improves the productivity of education outcomes using its technology all over the education systems levels, at teaching, learning, retention, administration, and reporting. It facilitates the outlook and effectiveness of education by enabling the extraction of insights from learning experiences, tracking learners learning processes and progresses, besides ensuring their retention. BDTs in education are implemented for several purposes such as:

- Detection of learners dropping out risk rates
- Performances prediction
- Behaviors investigation
- Absences tracking
- Courses recommendations
- Instant assisting and assessments
- Visual analytics on learners' interaction with a discussion forum
- Improvement of accessibility
- Research and development
- Evaluation, and accountability
- Identification of learners at-risk of failing, and at the course level.

Despite the enormous advantages of the use of BDTs in education still, there are some challenges that act as a barrier against its full implementation. The complexity of architecting Big Data especially with legacy educational systems and the shortage of experts besides the security, privacy and ethics issues should be considered when implementing BDTs in education.

Abbreviations

BDA	Big Data Analytics
BDT	Big Data Technology
BYOD	Bring Your Own Device
DER	Digital Education Revolution
EDM	Educational Data Mining
ICT	Information Communication Systems
ITSs	Intelligent Tutoring Systems
KPIs	Key Performance Indicators
LA	Learning Analytics
LMS	Learning Management Systems

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