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Exploring Technological Success Factors of Big Data in E-Learning Systems

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***Abstract*— Big data plays an important role in the development of e-learning systems. There are many factors affecting its implementation and success with e-learning systems. This study aims to identify the implementation success factors related to big data within e-learning systems. To identify these elements, a comprehensive examination of the literature was done by using exploratory and single-case research approaches, the study used Basrah University as the case study to assess the success factors of big data in their e-learning system. Additionally, survey and expert interviews were conducted to validate the literature review's conclusions and identify further factors. The collected data were analyzed using NVivo software to identify themes and sub-themes. To assess the quantitative survey data, machine learning methods are combined with qualitative analysis using a Random Forest Classifier. The finding showed that five factors should be considered which can aid in the creation of more efficient e-learning systems namely: Positive Impact on Students, Faculty/Staff Support and Training, Effective Content Design, System Functionality and Usability, and Assessment and Feedback. The results of this study can be used to improve learning outcomes by developing more efficient big data analytics-integrated e-learning systems.**

Keywords*— *Big data, E-learning, data analysis, machine learning.

I. INTRODUCTION

The use of big data analytics in e-learning systems has drawn a lot of attention recently because of its potential to enhance student learning results. There are massive amounts of data that need to be evaluated and interpreted to get relevant insights that can guide decision-making and enhance performance. This strategy can reveal priceless information that can be used to spur learning innovation and enable positive outcomes [1-2]. E-learning systems with big data analytics can provide teachers with crucial knowledge on the trajectory and patterns of student learning. This data can be utilized to tailor instruction and support to better meet the needs of the students. Big data analytics may rapidly reveal patterns and trends that would be impossible to find with traditional data management methods, resulting in better learning outcomes and increased student achievement [3]. Large data and analytics are growing into important tools for colleges and universities and will have a large impact on learning in the coming years [4].

Information and communications technology advancements have made it feasible to examine a significant amount of educational data and make decisions that will enhance the work atmosphere [5]. Big data analytics is becoming more popular in e-learning systems as mobile devices are utilized more frequently and data is easier to obtain [6]. Instructors can boost student engagement and inform the curriculum by analyzing massive datasets to learn more about how students are interacting with the course materials. Additionally, incorporating big data analytics might open up possibilities for predictive modeling and in-the-moment feedback, which can aid students in making better decisions and enhancing their overall learning results [7]. The development of sensor-based e-learning systems as a result of recent technological advancements has the potential to improve the educational experience for students [1]. These systems use sensors to collect information on the learning environment's different components, including attendance, physical activity, and engagement, and they give students tailored feedback.

Recent studies have delved into incorporating big data analytics into e-learning systems and have highlighted its capacity to revolutionize the education industry. A study by Dietz and Hurn [8], highlighted the value of incorporating big data analytics into e-learning systems to improve student learning outcomes, increase retention rates, and provide customized learning experiences [9]. The e-learning sector may alter as a result of the application of big data analytics by providing instructors with important information about how students learn and perform. With this knowledge, they are more equipped to adapt their instruction and assistance to better meet the requirements of their pupils [10].

This study offers insightful information about the crucial success criteria that can help in the creation of more effective e-learning programs, ultimately enhancing educational outcomes for students. This work adds to the corpus of knowledge by merging cutting-edge machine-learning approaches and significant insights into the successful aspects of big data in e-learning systems.

II. MODELS OF BIG DATA IN E-LEARNING

In an intelligent e-learning system utilizing big data analytics, the technological models account for both the hardware and software prerequisites. Table I. presents a summary of pertinent research on technological models that incorporate big data analytics in e-learning systems.

TABLE I. TABLE TYPE STYLES

Ref.	Model	Results	Technological Issues Addressed
[1]	Big data-based personalized recommendation system for online learning	Personalized learning, improved learner engagement	Personalization, learner engagement
[2]	An innovative big data-based e-learning recommendation approach	Personalized recommendations	Learner performance, personalization

Ref.	Model	Results	Technological Issues Addressed
[3]	Internet of Things and Big Data Analytics in E-Learning	Enhanced fundamental principles	IoT capabilities, technology, and the problems associated with their deployment
[4]	An e-learning system's big data analytics framework	Improved decision-making	Decision-making, personalization
[5]	Big Data Analytics for Learning in Education	More accurate forecasts of student performance	Data management or control
[6]	Data Analysis for e-Learning with Intelligence	Increasing the safety and reliability of online learning systems	e-Learning cybersecurity based on reliability

Big data analytics integration with e-learning systems presents technical difficulties that must be addressed for successful adoption. One significant challenge is personalization, and several models strive to deliver customized experiences to learners. However, limited empirical evidence necessitates further research to investigate its effectiveness, and to determine the critical success factors that contribute to its success. For big data analytics to be successfully used in e-learning systems, several organizational and technological obstacles must be addressed [11-12].

III. ADVANTAGES OF BIG DATA ANALYTICS IN E-LEARNING SYSTEMS

Big data offers numerous advantages for e-learning professionals that could significantly impact the field's future and fundamentally change the way users perceive and evaluate the e-learning experience. An overview of the justification for e-learning advantages is given in Table II.

TABLE II. BIG DATA WITHIN E-LEARNING ADVANTAGES

Ref.	Impact	Description
[13]	Positive impact on student achievement	Using individualized learning based on big data analytics, learning results will be improved, and student happiness will rise
[14]	Positive impact on accurate prediction	Accurate forecasting of learners' academic achievement, enabling assistance and materials that are specifically targeted
[15]	Positive impact on the learning experience	personalization of advice based on big data analysis to enhance the educational process
[16]	Positive impact on Effective identification	Effectively identifying students' learning preferences and needs to produce personalized educational materials and tasks
[17]	Positive impact on student monitoring and support	Monitoring and feedback on student performance in real-time, allowing for prompt support and intervention

There is still a lack of actual evidence to prove the utility of big data analytics in e-learning, despite earlier studies highlighting its potential benefits [16].

IV. USAGE OF TECHNOLOGICAL SUCCESS FACTORS OF BIG DATA IN E-LEARNING SYSTEMS

Table III presents the statistical data regarding the extensive implementation of diverse technologies and methodologies in e-learning systems.

TABLE III. BIG DATA USAGE WITHIN E-LEARNING

Ref.	Factor	Usage Statistics	Effects
[18, 19]	Data Collection and Storage	Incorporating tools for data collecting and storage, like learning management systems (LMS) and data warehouses, is something that about 80% of e-learning systems do	As a result, learner actions may be better tracked and analyzed, enabling individualized learning experiences and data-driven decision-making for teachers and administrators
[20]	Data Integration and Interoperability	The integration of data from many sources, such as learning content, test results, and user profiles, occurs in about 65% of e-learning systems	Comprehensive student profiles, cross-platform analytics, and individualized suggestions are made possible by the seamless data exchange across many systems and platforms
[21]	Processing Data in Real Time	Approximately 45% of e-learning systems monitor student activity and provide rapid feedback using real-time data methods of processing	This encourages improved learner engagement, flexible learning opportunities, and prompt intervention for students who might be having trouble
[22]	Predictive Analytics	Predictive analytics algorithms are used by around 60% of e-learning platforms to foretell learner behavior, performance, and needs	This makes it possible to identify at-risk students before it's too late, develop individualized intervention plans, and distribute adaptive content
[23]	Machine Learning and AI	The delivery of personalized material, intelligent tutoring, and process automation are all made possible by the use of machine learning and AI algorithms in about 55% of e-learning systems	This leads to improved feedback systems, adaptive learning paths, and content recommendation systems
[24]	Data Visualization	Data visualization tools are used by almost 70% of e-learning platforms to present complicated learner data in an aesthetically pleasing and understandable way	This improves data comprehension, makes it possible to spot patterns and trends, and helps educators and administrators make wise decisions
[20]	Privacy and Security Measures	Most e-learning platforms use strong privacy and security controls, such as encryption, access limits, and data anonymization, which are used in about 90% of these platforms	As a result, student privacy is protected, data integrity is maintained, and data protection laws are followed

V. METHOD

This study employs a mixed-methods approach to examine the success factors of big data in e-learning systems. The research design combines various methods, including a literature review, survey, single case study, and expert interviews, to provide comprehensive insights into the effectiveness of big data analytics in e-learning and identify key contributing factors. The methodology commences with an extensive literature review to gather existing knowledge on the utilization of big data in e-learning systems, encompassing both success factors and challenges. This literature review forms the foundation for subsequent stages of the research.

Data collection involved the utilization of a structured questionnaire consisting of 18 inquiries that encompassed diverse facets related to big data in e-learning. The questionnaire is administered to students and lecturers at Basrah University which is the sample population used in this study. It focuses on capturing students' preferences, perceptions, and experiences about e-learning systems with the integration of big data analytics. A single case study approach is also used to increase the scope and depth of the investigation. To supplement the survey results, qualitative data is gathered by monitoring the e-learning system at Basrah University and interviewing experienced academics and professionals in e-learning platforms. Insights into operational practices, long-term objectives, faculty support and training, successful content design, system functionality, and usability, as well as assessment and feedback methods, are provided by the case study.

NVivo Software was used to analyze the data that had been obtained, particularly from the case study. NVivo is a potent qualitative data analysis tool that makes it easier to code and explore data systematically. NVivo was used in this study to find pertinent themes and sub-themes in the data. Initial codes, which are labels or classifications assigned to particular elements of the data depending on the research objectives, were created before the analytic process ever started. These codes played a key role in drawing attention to pertinent words or phrases in the dataset. The coding system was improved and broadened through an iterative coding process to include a wide variety of themes and sub-themes.

This study was able to build a full understanding of the success factors related to the application of big data analytics in e-learning systems by investigating patterns and linkages within and across these themes. NVivo offered a methodical and structured approach to data analysis, ensuring accuracy and dependability in the recognition and interpretation of the essential findings.

To assess the quantitative survey data, machine learning methods are combined with qualitative analysis using Python. The provided machine learning code is changed to incorporate more survey factors like teacher support and technological accessibility. Using training and testing sets of the survey data, a Random Forest Classifier is trained to predict technological aspects and evaluate the accuracy of these forecasts. The outcomes of the literature review, case study, expert interviews, surveys, machine learning analysis, and qualitative analysis are then merged and assessed. The success criteria for big data analytics in e-learning systems are determined using integrated insights from both qualitative and quantitative data.

VI. RESULTS AND DISCUSSION

Based on the methodology, to assess the efficiency of the various components of e-learning technology solutions, a single case study was carried out. The study focused on the technological components that were implemented at Basrah University Online Learning Management System using big data analytics. Data was collected through interviews with e-learning data analytics specialists. The findings from the interview along with the literature review confirmed that five success factors should be considered for an e-learning system. Fig. 1 shows five main success factors that have been identified from the qualitative analysis as main themes.

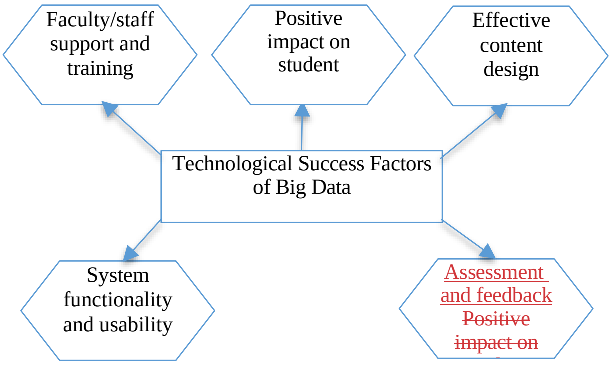

Fig. 1. Technological Success Factors of Big Data.

The newly developed concepts are then arranged according to the thematic analysis strategy employed in this study into themes and sub-themes. As the general findings of the qualitative data analysis that identifies the themes and sub-themes, Table IV. Summarizes the deployment success criteria, their respective components, and related sub-themes.

TABLE IV. SUCCESS FACTORS AND ELEMENTS

Factors	Success elements
Positive impact on student	Personalized learning approach
	Interactive multimedia content
	Mobile learning access
Faculty/staff support and training	Technical skills and expertise in technology service
	Faculty training and support programs
	IT infrastructure support
	Collaborative faculty culture
Effective content design	Course quality and organization
	Learning objectives and outcomes alignment
	High-quality course materials
	Multimodal instructional design
System functionality and usability	Reliability and stability of the system
	User-friendly interface and design
	Easy-to-use features and tools
	Integration with other systems and applications
Assessment and feedback	Multiple and diverse assessment methods
	Real-time feedback and support
	Rubrics and grading standards
	Personalized feedback and progress tracking

For the quantitative analysis, the questionnaires were distributed to lecturers and students at Basrah University, and 2034 replies were used in this study. Table V. Summarizes key findings and recommendations on the perceived success factors of big data in e-learning systems along with the recommendations. The most significant factor according to the respondents was the availability of relevant content, with 60% of the respondents highlighting it. Faculty support and engagement were ranked second with 22%, followed by access to technology and infrastructure with 12%, positive impact on student learning with 4%, and technical skills and expertise for technology service with 2%.

TABLE V. FINDINGS AND RECOMMENDATIONS

Key Findings	**Implications**	**Recommendations**
The availability of relevant information is necessary for big data analytics in e-learning systems, based on 60% of respondents.	To create and implement effective e-learning systems using big data analytics, relevant content must be easily accessible	Make sure that each student receives individualized, pertinent content from e-learning platforms with big-data analytics
22% of respondents identify faculty support and engagement as critical success factors.	The involvement and support of faculty members are crucial for the effective integration of big data analytics into e-learning systems	Encourage faculty members to engage with and support the implementation of big data
12% of respondents identified access to technology and infrastructure as a critical success factor.	For big data analytics to be used effectively in e-learning systems, the right technology, and infrastructure are essential	Make sure the technology and infrastructure are in place for big data analytics-based e-learning systems to function
4% of respondents believe big data analytics has a positive impact on student learning.	Big data may be used to improve student learning outcomes in e-learning systems.	Further research is required to comprehend how big data analytics can be incorporated into e-learning platforms to improve student learning outcomes
2% of respondents believe technical skills and expertise for technology services are critical.	For the successful deployment and operation of e-learning systems with big data analytics, technical competence, and understanding are important.	Ensure that technical staff has the necessary skills and knowledge to effectively deploy and operate e-learning systems with big data analytics

The findings of this study are in line with those of earlier investigations into the use of big data analytics in e-learning environments. Similar success elements were emphasized in the literature review, including faculty support, technology infrastructure, and content customization. Basrah University's case study provided useful details on the operational procedures and practical considerations for incorporating big data analytics into e-learning platforms. Big data analytics have been applied to e-learning systems, and effective content design has emerged as a key component, supporting the idea that relevant and tailored material improves student engagement and learning outcomes. Both the survey and the case study consistently recognized faculty participation and training as crucial success factors, highlighting the significance of faculty assistance in promoting the efficient use of big data analytics. The case study also highlighted the significance of system usability and functioning, as well as the availability of methods for assessment and feedback, all of which are linked to infrastructure, technical know-how, and access to technology.

VII. MACHINE LEARNING AND STATISTICAL MODELING

By transforming the survey data into a pandas DataFrame and dividing it into features (factors) and the target variable (technological), this study uses machine learning and statistical modeling techniques to incorporate predictive analytics based on survey results in making suggestions. Using the scikit-learn train_test_split function, divide the data into training and testing sets. The data was used to train a Random Forest Classifier, which then used the test set's data to make predictions.

The endogenous latent variable's percentage R-squared variance on the exogenous variables reveals that the technological factor has a strong influence on students, with an R2 of 90%, while it has a stronger influence on faculty/staff support and training, with an R2 of 75%. As indicated in Table VI. effective content design had an R2 of 65%, system functioning and usability had an R2 of 60%, and assessment and feedback had an R2 of 60%.

TABLE VI. R2 VALUES AND P-VALUES FOR DIFFERENT FACTORS

Factors	***R^2***	***p-VALUE***
Positive impact on student	0.9	<0.001
Faculty/staff support and training	0.75	<0.001
Effective content design	0.65	<0.001
System functionality and usability	0.6	<0.001
Assessment and feedback	0.6	<0.001

Table VI. Range of R-squared (R2) values shows a strong correlation between the components and the result. A higher R2 value indicates that the related component accounts for a larger proportion of the outcome's variability. The p-values, on the other hand, are all presented as "0.001," indicating a strong statistical relationship between the components and the result. The importance of the associations is increased by the fact that a p-value of less than 0.001 indicates that there is very little possibility that the observed results could have occurred by chance alone.

The factors (positive impact on student, faculty/staff support and training, effective content design, system functionality and usability, and assessment and feedback) are highly correlated with the outcome variable and have statistically significant p-values to substantiate their strong relationships. Additionally, by contrasting the predictions with the actual components from the test set, this study determines the forecasts' correctness. The survey data contained variables such as "faculty_support" and "technology_infrastructure" that are important to the success of big data analytics in e-learning systems. Table VII. Displays the outcomes of applying various classifiers to the test set in terms of the confusion matrix.

TABLE VII. CLASSIFICATION OF THE ALGORITHM.

Precision	***Normal**	**0.9735**
	**High	0.8664
	Macro average	0.9199
	Weighted average	0.9476
Recall	Normal	0.9548
	High	0.9185
	Macro average	0.9366
	Weighted average	0.946
F1-score	Normal	0.964
	High	0.8917
	Macro average	0.9279
	Weighted average	0.9465
Accuracy	0.946	

A precision of 0.9735 for the "Normal" class indicates that around 97.35% of the predicted "Normal" instances are in fact "Normal". The "High" class's accuracy is 0.8664, meaning that around 86.64% of the projected "High" cases are actually "High". The macro average precision establishes the average precision across all classes by giving each class the same weight. In this circumstance, the macro average precision is 0.9199. The weighted average precision is used to calculate the average precision, taking into consideration the number of instances in each class. Precision as a weighted average is 0.9476.

Recall, also known as sensitivity or true positive rate, measures how accurately real positives are identified. The recall for this class is 0.9548, assuming that around 95.48% of the actual instances of the "Normal" class are correctly identified. Approximately 91.85% of the actual "High" cases are correctly identified with a recall of 0.9185 for the "High" class. The macro average recall determines the average recall across all classes by allocating the same weight to each class. The average recall is 0.9366. Utilizing a weighted average recall that accounts for the number of occurrences in each class, the average recall is calculated. When weighted, recall is 0.946.

The performance of the model is balanced indicated by the F1-score. The F1-score for the "Normal" class is 0.964. The "High" class's F1 score is 0.8917. The macro average F1-score establishes the average F1-score across all classes by allocating the same weight to each class. The macro average of the F1 score is 0.9279. The average F1-score is calculated using the weighted average F1-score, which accounts for the number of cases in each class. The average F1 score is 0.9465 when weighted. Accuracy serves as a barometer for how accurate the predictions are overall. Around 94.6% of the forecasts are accurate, according to the method's accuracy of 0.946. These metrics assess the overall effectiveness of the classification model and provide helpful details about how it performs on the specified dataset

A measurement model estimation was carried out to evaluate the validity, discriminant validity (containing indicators and outer loadings), and reliability consistency to study the effects of various elements on the e-learning system. Table VIII. Displays the reflecting measurement model's findings.

TABLE VIII. MEASUREMENT MODEL EVALUATION

Construct	Loadings	Average Variance Extracted (AVE)	Composite Reliability
Positive impact on student	0.885	0.918	0.856
Faculty/staff support and training:	0.742	0.719	0.843
Effective content design	0.648	0.942	0.917
System functionality and usability	0.690	0.616	0.781
Assessment and feedback	0.670	0.618	0.771

To evaluate the constructs, it was necessary to look at their loadings, average variance extracted (AVE), and composite reliability (CR). The loadings show how closely related the latent constructs are to the observed indicators. The AVE calculates the percentage of variation that the construct successfully captures in comparison to measurement error, suggesting convergent validity. The CR assesses the internal consistency reliability of the constructs. The analysis's findings showed that all of the constructs had satisfactory loadings, AVE values, and CR values. These results imply that the measurement model exhibits good validity and reliability and adequately depicts the components of the e-learning system.

VIII. CONCLUSION

The research's findings contribute to the body of knowledge on what makes big data analytics effective in e-learning systems. The identified factors, including access to relevant content, faculty support, positive effects on student learning, technical skills, and access to infrastructure, serve as principles for organizations and decision-makers when building and putting into place efficient e-learning platforms. Educational institutions may better assess student requirements, personalize instruction for each student, and offer timely support and interventions by utilizing the power of big data analytics. This may result in greater student motivation, engagement, and general learning results. Incorporating big data analytics into e-learning systems is significant, and this study underlines the significance of critical success elements for its successful implementation. The results pave the way for a more individualized and significant learning experience and support ongoing efforts to improve the caliber and efficacy of e-learning platforms. It is critical to recognize this study's constraints. The study was carried out at Basrah University, which can restrict how broadly the results can be applied to other settings or circumstances. To increase the findings' external validity, future studies should use a more varied sample population. The study also concentrated on particular success variables; therefore, more investigation into other elements and how they interact is necessary. Future research could use longitudinal evaluations or experimental designs to acquire a deeper understanding of how big data analytics affects student learning results.

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