

# Development and Challenges of Big Data and Performance Metrics for Undergraduate Learner Management

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Abstract -The use of Big Data analytics has become increasingly pivotal in managing and optimizing educational processes, particularly in undergraduate student management. This paper explores the development, challenges, and performance metrics associated with integrating Big Data analytics into university management systems. It examines the evolution of Big Data tools, methodologies, and their application in tracking student performance, engagement, and overall academic success. This paper highlights significant challenges, including issues related to data privacy, the complexity of data integration, and the requirement for specialized infrastructure to manage large data volumes."The role of performance metrics in evaluating student outcomes, faculty effectiveness, and institutional performance is also discussed. By addressing these facets, the paper aims to provide insights into how Big Data can improve decisionmaking processes, enhance personalized learning, and promote operational efficiency in higher education institutions.

*Key Words:* Big Data Analytics, Undergraduate Student Management, Performance Metrics, Data Privacy, Data Integration

# **1. INTRODUCTION**

In recent years, the rapid growth of digital technologies and the increasing availability of large datasets have revolutionized various sectors, including higher education. The application of Big Data analytics in university management has emerged as a transformative approach for enhancing the educational experience and optimizing institutional performance. Big Data analytics enables educational institutions to collect, process, and analyze vast amounts of data from a variety of sources, such as student performance, course engagement, and learning behaviors. By leveraging these insights, universities can make more informed decisions, improve student outcomes, and streamline administrative processes. Despite the potential benefits, the integration of Big Data analytics into undergraduate student management presents several challenges. The sheer volume, variety, and velocity of the data pose significant obstacles for data storage, processing, and analysis. Furthermore, issues related to data privacy, security, and ethical considerations must be carefully addressed to ensure that students' personal information is protected. Additionally, the need for specialized infrastructure, skilled personnel, and effective data governance mechanisms remains a critical challenge for many institutions.

This paper seeks to explore the development of Big Data analytics in the context of undergraduate student management, examining the tools and techniques that have been developed to harness its power. It will also address the challenges that institutions face in adopting these technologies, particularly concerning data integration, privacy concerns, and the readiness of existing systems. Moreover, the paper will delve into the role of performance metrics in evaluating student success, faculty performance, and the overall effectiveness of educational programs. Ultimately, the goal is to provide a comprehensive understanding of how Big Data can be utilized to enhance decision-making, improve personalized learning, and promote operational efficiency within the higher education sector.

# 2. Challenges of Big Data Analytics in Undergraduate Learner Management

While Big Data analytics offers significant potential for enhancing the management of undergraduate students, its integration into higher education systems comes with a set of complex challenges. These challenges need to be addressed for Big Data tools to be effectively implemented and utilized in academic institutions.

Data Privacy and Security Concerns: One of the most critical challenges in managing Big Data in education is



ensuring the privacy and security of student data. With the increasing volume of personal, academic, and behavioral data collected from students, institutions must comply with stringent data protection laws and regulations, such as GDPR (General Data Protection Regulation) and FERPA (Family Educational Rights and Privacy Act). Mishandling or unauthorized access to student data can result in significant legal consequences, damage to institutional reputation, and loss of student trust. Institutions must establish robust security protocols and data governance practices to protect sensitive information.

**Data Integration and Standardization:** Educational institutions often rely on multiple, disconnected data systems to store student information. These include learning management systems (LMS), student information systems (SIS), and various assessment platforms. Integrating data from these disparate sources into a cohesive and usable format can be a technical challenge. Furthermore, inconsistent data formats and varying quality across systems can hinder the ability to derive meaningful insights from the data. Standardizing data formats and developing efficient integration strategies are crucial steps in ensuring data consistency and reliability for analytics.

**Data Quality and Accuracy:** Big Data analytics is only as good as the quality of the data being analyzed. Inaccurate, incomplete, or biased data can lead to misleading conclusions, which can ultimately affect decision-making and policy formulation in educational settings. Ensuring data quality involves continuous monitoring, data cleaning, and validation processes to remove errors and inconsistencies. Institutions must also establish protocols to address issues related to missing or ambiguous data, which can otherwise compromis the insights generated from the analysis.

**Scalability and Infrastructure Limitations:** Th processing and storage requirements for Big Data analytics ar substantial. Many higher education institutions face challenge in scaling their infrastructure to handle large volumes of dat effectively. Legacy systems may not be designed t accommodate the rapid growth of data, and upgrading c replacing these systems can be costly and time-consuming Additionally, institutions must invest in specialized tool: platforms, and skilled personnel to manage Big Data analytic: which can be a significant financial burden for smaller c resource-constrained universities.

Lack of Skilled Personnel: The effective implementatio of Big Data analytics requires skilled professionals wh understand both the technical aspects of data science and th educational context in which the data is being applied Universities often face a shortage of qualified data scientists analysts, and IT personnel capable of managing an interpreting Big Data. Furthermore, faculty and administrator may lack the necessary training to effectively utilize analytica insights in their decision-making processes. Bridging thi skills gap is essential for the successful adoption of Big Data analytics in undergraduate student management.

Ethical Issues in Data Usage: The use of student data for analytics raises ethical concerns regarding the potential for discrimination, bias, and unintended consequences. For instance, predictive models may unintentionally favor certain groups of students over others or perpetuate existing biases. There is also the risk that data analytics could be used in ways that negatively impact students' academic experiences, such as making decisions based on incomplete or overly simplistic metrics. Institutions must implement ethical guidelines and practices to ensure that data usage aligns with fairness, transparency, and equity.

Resistance to Change Adoption: and The implementation of Big Data analytics often requires a cultural shift within institutions. Faculty, staff, and administrators may be resistant to change due to concerns over the complexity of new systems or skepticism about the value of data-driven decision-making. Overcoming this resistance requires effective change management strategies, including education, training, and communication about the benefits of Big Data analytics. Building a culture that embraces data-driven approaches is essential for the successful adoption and integration of Big Data in student management.

**Real-Time Data Processing and Decision-Making:** Another challenge is the ability to process and analyze data in real time to make timely decisions. In educational settings, student behavior, performance, and engagement can change quickly. Institutions must develop systems capable of handling real-time data streams to allow for prompt intervention and personalized support. However, the infrastructure and algorithms needed for real-time analytics can be complex and expensive to implement.



Fig-1: Challenges of Big Data



# **3.** Role of Big Data Analytics in Undergraduate Learner Management

Big Data analytics plays a significant role in improving various aspects of student management in higher education. Here's how it can be used effectively:

**Personalized Learning and Support:** Big Data analytics allows institutions to track and analyze individual student performance, engagement, and learning behaviors. By processing this data, universities can tailor personalized learning plans and interventions to support students, helping them succeed academically. For instance, identifying at-risk students based on early signs like attendance or grades can trigger timely interventions from academic advisors or tutors.

**Predictive Analytics for Student Success:** Predictive models powered by Big Data can forecast student outcomes such as graduation rates, retention, or performance in specific courses. This enables institutions to proactively address potential issues, such as low retention rates, by offering targeted support before problems escalate.

**Enhancing Operational Efficiency:** Big Data analytics helps streamline administrative functions, such as course scheduling, resource allocation, and faculty performance evaluation. By analyzing patterns in course enrollments, class sizes, and faculty workloads, universities can optimize their operations, ensuring that resources are used effectively and efficiently.

**Improving Decision-Making:** Big Data provides decision-makers with insights that are data-driven and evidence-based. Whether it's adjusting teaching methods, improving curriculum design, or allocating scholarships, the ability to make informed decisions backed by data can lead to better outcomes for both students and institutions.

**Tracking Student Engagement:** Universities can monitor student engagement through various metrics, such as participation in extracurricular activities, attendance, or digital interactions with learning platforms. Analyzing these behaviors can provide a more holistic view of student development, leading to improvements in student satisfaction and retention.

# 4. Development of Big Data Analytics for Undergraduate Learner Management

The development of Big Data analytics for undergraduate student management has evolved significantly in recent years. With the increasing availability of data sources and advancements in technology, educational institutions now have more opportunities to leverage Big Data to enhance student management processes. Below is an overview of the development of Big Data analytics in this context, highlighting key milestones, technologies, and trends.

# Early Stages: Collection and Storage of Data

Initially, universities collected basic student data such as enrollment, grades, and attendance. This data was mostly stored in separate systems like **Student Information Systems** (**SIS**) and **Learning Management Systems** (**LMS**). During this early stage, the focus was primarily on maintaining records rather than deriving actionable insights.

### Key Development Milestones:

**Database Management Systems (DBMS):** Universities adopted DBMS to organize and store student data in a centralized manner.

**Data Warehousing:** Institutions began to consolidate data from different sources (e.g., grades, course enrollment, and financial aid) into data warehouses to streamline access and analysis.

#### The Rise of Advanced Analytics

As data became more plentiful and diverse, universities began using advanced analytics to identify trends, patterns, and anomalies within student data. This transition marked a shift from simple record-keeping to deeper analytical insights.

#### **Key Development Milestones:**

**Predictive Analytics:** Educational institutions began using predictive models to forecast student success, retention rates, and graduation likelihood. These models used historical data to predict future outcomes, helping administrators take proactive steps in student management.

**Machine Learning:** Machine learning algorithms allowed institutions to automate the analysis of vast data sets, improving predictions and discovering hidden patterns. This helped universities identify at-risk students, optimize resource allocation, and improve curriculum delivery.

#### **Big Data Tools and Infrastructure:**

With the rapid growth in data volume, variety, and velocity, universities needed more sophisticated tools and infrastructure to handle Big Data. The development of cloud computing and distributed data processing made it feasible to scale student data analysis.

#### **Key Development Milestones:**

**Big Data Platforms (e.g., Hadoop, Spark):** These platforms enabled educational institutions to handle large and complex data sets across distributed systems. Big Data tools allowed universities to analyze not only structured data (e.g., grades, attendance) but also unstructured data (e.g., student feedback, forum discussions).

**Data Lakes:** Data lakes, which store raw and unprocessed data, emerged as a solution for universities to store large quantities of data from different sources, including social media activity, online course interactions, and behavioral data.

**Real-time Analytics:** Real-time analytics systems were developed to monitor student engagement and performance as it happens, allowing for timely interventions and dynamic adjustments to student management strategies.

# **Data Integration and Interoperability:**

As Big Data tools advanced, the need for data integration across multiple platforms became more apparent. Educational institutions began working on solutions to integrate data from various sources, including academic performance, learning behavior, extracurricular activities, and personal data.

# **Key Development Milestones:**

**Interoperable Systems:** Universities started adopting tools that could integrate data from diverse systems (e.g., SIS, LMS, student engagement platforms). This allowed for a holistic view of each student's journey, from enrollment to graduation.

**Student Data Portals:** Integrated data platforms provided a unified view of student data, helping administrators, advisors, and faculty members track individual students' progress and performance in real time.

# Personalized Learning and Adaptive Systems:

One of the most significant developments in Big Data analytics for undergraduate student management has been the shift toward personalized learning. By analyzing individual students' learning patterns and preferences, universities have been able to create tailored learning experiences.

# Key Development Milestones:

Adaptive Learning Systems: These systems adjust the content, pace, and delivery method based on real-time analytics of a student's performance and engagement. Adaptive learning tools have been used to optimize learning paths for students, helping them to focus on areas where they struggle.

**Learning Analytics Dashboards:** Visual dashboards that display a student's academic progress, engagement levels, and risk factors have become common. These dashboards allow both students and educators to make data-informed decisions about how to improve learning outcomes.

#### **Ethical Considerations and Data Governance:**

As Big Data analytics became more integral to student management, universities began developing ethical guidelines and data governance frameworks to ensure responsible use of student data. Ethical considerations have become a central part of the development process.

# Key Development Milestones:

Data Privacy Regulations: With the introduction of data privacy laws like GDPR and FERPA, universities had to

adopt more stringent data protection practices to ensure compliance and protect student privacy.

Ethical AI & Bias Mitigation: Universities have worked on ensuring that the machine learning algorithms used in predictive analytics are fair and unbiased. Efforts have been made to ensure that decisions regarding student success, funding, and opportunities are not based on discriminatory practices or flawed data.

### **Future Trends:**

The future of Big Data analytics in undergraduate student management is driven by continuous advancements in technology and new opportunities for data-driven personalization.

# **Emerging Trends:**

Artificial Intelligence (AI) and Chat bots: AI-powered chat bots are being developed to assist students with personalized advice, reminders, and course recommendations. These systems analyze student behavior and academic records to offer tailored suggestions and support.

**Block chain for Academic Records:** Blockchain technology has the potential to securely store and share academic credentials and achievements, ensuring the integrity and authenticity of student records.

**Predictive and Prescriptive Analytics:** Moving beyond prediction, universities will incorporate prescriptive analytics to recommend actions that improve student outcomes (e.g., tailored tutoring, course interventions).

**Student-Centric Data Ecosystem:** A more integrated, student-centric approach will emerge, where students have access to their own data analytics and can actively engage with the system to make informed decisions about their education.

# **5. Performance metrics**

Here is some common performance metrics used in the context of student management:

#### **Student Performance Metrics:**

**Grade Point Average (GPA):** A widely used metric to evaluate a student's academic performance across courses.

**Course Completion Rates:** The percentage of students successfully completing a course or program. Low completion rates may indicate issues with course design or student engagement.

Retention Rate: The percentage of students who remain enrolled in a program or university after a specific period

(e.g., after one year). High retention rates are a sign of student satisfaction and academic support.

**Graduation Rate:** The percentage of students who successfully complete their program within a given timeframe. It reflects the overall success of students in meeting academic requirements.

**Test Scores and Assessments:** Performance on exams, quizzes, and assignments that provide insights into student learning and understanding of subject matter.

**Student Engagement:** Metrics tracking students' participation in activities such as class discussions, extracurricular activities, group projects, and online forums.

**Time to Degree:** The average time it takes for students to complete their degree program. Shorter times suggest efficient learning pathways, while longer times may signal academic or logistical barriers.

Faculty and Teaching Effectiveness Metrics:

**Student Feedback and Course Evaluations:** Surveys and reviews from students regarding the quality of teaching, course structure, and learning environment. These evaluations are used to measure faculty performance and identify areas for improvement.

**Teaching Load:** The number of courses or students a faculty member is responsible for. An excessive teaching load might impact the quality of instruction or faculty availability for student support.

**Pass Rates:** The percentage of students who pass a specific course or exam under a faculty member's instruction. High pass rates suggest effective teaching methods.

**Faculty Research Output:** The number and impact of publications, presentations, and research projects by faculty members. While indirectly related to student success, faculty research can contribute to the academic reputation of the institution.

### **Institutional Performance Metrics:**

**Student Satisfaction:** Surveys or assessments that gauge student satisfaction with the institution's services, academic quality, and overall experience. High satisfaction correlates with positive retention and engagement.

**Resource Utilization:** The efficiency with which institutional resources (e.g., classrooms, technology, faculty, staff) are

used. Proper resource management improves operational efficiency.

Alumni Success and Employment Rate: The percentage of graduates who secure employment or pursue further education within a certain timeframe after graduation. This reflects the effectiveness of the education in preparing students for the workforce.

**Financial Aid Utilization:** Metrics on how effectively financial aid is distributed to students and the impact on student retention and graduation rates.

**Institutional Diversity and Inclusion:** Metrics that measure diversity in the student body, faculty, and staff, as well as the inclusion and support mechanisms in place for underrepresented groups.

# **Big Data-Specific Performance Metrics:**

**Data Quality:** The accuracy, completeness, consistency, and timeliness of data used in Big Data analytics. Poor data quality can lead to incorrect conclusions and decisions.

**Data Processing Speed:** The time it takes to process and analyze large volumes of data. Faster processing allows for real-time analytics and quicker interventions.

**Analytics Adoption Rate:** The percentage of students, faculty, and staff who actively use and rely on data analytics tools and platforms for decision-making and student support.

**Predictive Model Accuracy:** The accuracy of predictive models in forecasting student success, retention, or risk factors. More accurate models help ensure better-targeted interventions.

# **Real-Time and Predictive Performance Metrics:**

**Early Alert System Metrics:** These metrics track the effectiveness of systems that identify at-risk students based on early indicators such as attendance, grades, and engagement levels. Timely alerts allow for intervention to improve student outcomes.

**Intervention Success Rate:** The percentage of students who show improvement after receiving intervention based on datadriven recommendations (e.g., tutoring, counseling, academic advising).

**Real-Time Engagement Metrics:** Metrics that monitor student engagement in real time, such as participation in virtual classrooms, online discussions, or engagement with



digital learning materials. Real-time data can trigger immediate feedback or support.

# 6. Tools and Technologies for Undergraduate student Management of Big Data

In the context of **Big Data analytics for undergraduate student management**, a variety of **tools and technologies** can be employed to collect, analyze, and interpret student data. These tools are essential for handling large volumes of data, ensuring data quality, generating insights, and facilitating real-time decision-making. Below is an overview of the **tools** commonly used for Big Data analytics in student management.

#### **Data Collection and Management Tools:**

These tools are used to gather, store, and manage data from various sources such as Learning Management Systems (LMS), Student Information Systems (SIS), and other administrative platforms.

#### **Student Information Systems (SIS):**

**Ellucian**: A widely used SIS platform that stores and organizes student records and academic history. It integrates with other tools to provide a centralized data source for analytics.

**PeopleSoft Campus Solutions (by Oracle)**: A popular SIS used to manage student data, including admissions, grades, and course registration.

# Learning Management Systems (LMS):

**Moodle**: An open-source LMS that enables the tracking of student performance, participation, and engagement in courses. Data from Moodle can be used in analytics to assess learning outcomes.

**Canvas:** A cloud-based LMS that provides data on student engagement, assignment submissions, and exam results. It integrates well with analytics tools to track performance.

#### Data Warehouses:

**Amazon Redshift**: A data warehouse solution that helps institutions store and query large datasets. It's used for storing historical data and integrating it with Big Data analytics platforms.

**Google Big Query**: A cloud-based data warehouse for handling massive datasets. It allows institutions to perform analytics on large amounts of student data in real time.

**Data Analytics and Visualization Tools:** Once data is collected and stored, these tools help in processing, analyzing, and visualizing the data to extract meaningful insights.

# **Data Analytics Tools:**

**Apache Hadoop**: A framework for distributed storage and processing of large datasets. It can be used to store student data across multiple nodes, allowing for efficient parallel processing of Big Data.

**Apache Spark**: A fast, in-memory data processing engine that works on top of Hadoop. It is commonly used for real-time data processing and analytics, making it suitable for tracking student performance or engagement in real-time.

**R** (**Programming Language**): A statistical programming language that is widely used for data analysis and visualization. R can be used to analyze student data for predictive modeling, regression analysis, and hypothesis testing.

**Python**: A programming language with rich libraries (e.g., Pandas, NumPy, Matplotlib) for data manipulation, analysis, and visualization. It is often used in educational institutions for data science tasks, including building predictive models for student success.

#### **Business Intelligence (BI) and Visualization Tools:**

**Tableau**: A powerful BI tool that allows users to create interactive dashboards to visualize student data, such as performance trends, retention rates, and demographic breakdowns. It can be integrated with data sources like SIS and LMS.

**Power BI (by Microsoft)**: A data visualization tool that helps universities create reports and dashboards for student performance tracking and institutional analysis. It's userfriendly and integrates with other Microsoft tools.

**Qlik Sense**: Self-service BI tools that can help universities analyze student data, create dashboards, and perform ad-hoc analysis. It's particularly useful for interactive reporting.

# Machine Learning and Predictive Analytics Tools:

**SAS Analytics**: A suite of analytics tools used for predictive modeling, machine learning, and data mining. It's particularly useful for developing models to predict student performance, retention, or success.

**IBM SPSS Modeler**: A data mining tool that uses machine learning algorithms to analyze data and predict trends, such as identifying students at risk of failing or dropping out.

**Google Cloud AI & Machine Learning Tools**: Google provides various machine learning tools that can be used to build predictive models for student success, course completion, and retention prediction.

**Real-Time Analytics Tools:** For monitoring student activities, performance, and engagement in real-time, these tools allow institutions to take immediate actions based on the data collected.

**Apache Kafka**: A distributed event streaming platform used to handle real-time data feeds. It is commonly used in student engagement platforms to capture real-time data from online discussions, attendance, and assignment submissions.

**StreamSets**: A data integration platform that handles realtime data streams, enabling universities to process real-time student data such as interactions with learning materials, discussions, or assessments.

**Splunk**: A tool for real-time data monitoring and analysis. It can be used to track student engagement across various digital platforms and identify trends or issues in real time.

**Cloud-Based Platforms:** Many universities are moving their Big Data storage and analytics tasks to the cloud to handle scalability, cost, and accessibility issues.

**Microsoft Azure**: A cloud computing service that provides Big Data and machine learning tools. Azure's services can be used for data storage, analytics, predictive modeling, and more, all integrated within the university's IT infrastructure.

Amazon Web Services (AWS): AWS offers a suite of tools for managing and analyzing Big Data, including AWS S3 (storage), AWS Lambda (server less computing), AWS Sage Maker (machine learning), and AWS Quick Sight (visualization). These tools help universities perform largescale data analytics.

Google Cloud Platform (GCP): A cloud service that provides tools like Google Cloud BigQuery, Google Data Studio, and AI & machine learning tools for large-scale analytics.

**Data Integration Tools:** These tools help combine data from multiple sources to create a unified view of student performance, engagement, and other factors.

Talend: A data integration tool that allows institutions to connect multiple data sources (e.g., LMS, SIS, attendance

systems) and ensure data consistency and accuracy for analysis.

**Informatics**: A popular data integration tool that can connect disparate data sources, standardize and clean data, and ensure it is ready for Big Data analysis.

**MuleSoft**: A platform for integrating data across different systems and applications. It helps connect student information systems, learning management systems, and analytics platforms to create a unified data ecosystem.

# **Data Governance and Compliance Tools:**

To ensure that student data is handled responsibly and in compliance with regulations like **FERPA** or **GDPR**, these tools help manage privacy, security, and compliance requirements.

**Collibra**: A data governance tool that ensures the quality, security, and compliance of institutional data. It helps maintain data privacy standards and manage access control.

**Vera**: A data security and encryption tool that protects student data while maintaining compliance with regulations such as GDPR and FERPA.

**OneTrust**: A platform that helps institutions manage data privacy, risk, and compliance, ensuring they adhere to legal standards for student data protection.

# 7. Conclusion:

This paper has highlighted the transformative role of Big Data analytics in managing undergraduate student performance, providing valuable insights for universities aiming to optimize student success, improve teaching strategies, and make datadriven decisions. Big Data tools enable institutions to track student progress, predict outcomes, and tailor interventions to individual needs, creating a more personalized and efficient learning experience. However, the adoption of Big Data analytics also brings challenges, including ensuring data privacy, maintaining data quality, and integrating diverse data sources. Addressing these challenges is critical to leveraging the full potential of Big Data while safeguarding ethical and legal considerations. As Big Data technologies continue to evolve, they hold the promise of enhancing real-time student monitoring, enabling predictive models for early intervention, and fostering a more responsive and adaptive academic environment. The continued development and refinement of these tools will empower universities to address the diverse needs of students and improve overall institutional performance.

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In conclusion, Big Data analytics plays a pivotal role in shaping the future of student management, offering the opportunity to drive positive change in educational outcomes. By overcoming existing challenges and embracing the full potential of these technologies, universities can provide students with the resources and support needed to achieve academic success.

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