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E-Learning Digitalization, Evolution and Transformation

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ABSTRACT

A notable development that has revolutionised teaching and learning is the implementation of e-learning in higher education. Originally intended to enable people to advance personally without physically attending any traditional classroom or University settings, the COVID-19 pandemic has made it the sole means to complete the education process owing to social distance adoption to halt the virus' spread. The incorporation of ICTs and the growth of data have given e-learning a lift in reaching the modern level of digitalization while maintaining its effectiveness and adaptability as a teaching and learning method. Unfortunately, impediments referred to as "application-centric" have slowed and prevented the development because of the various technological limitations in the architecture. This article identifies the limitations of application-centric architecture, strategies that have helped other sectors get beyond these limitations, and the benefits of adopting these strategies, which range from advanced analytics to a data-centric approach. The study further discusses the challenges involved in adopting a data-centric approach in e-learning Universities and ways to overcome them.

Keywords: Application-centric, Data-centric, E-learning, Digitalization

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1. INTRODUCTION

E-learning offers several advantages to students. It allows them to utilize electronic devices to learn anytime, anywhere, and in the comfort of their homes and offices rather than being physically present in a traditional classroom.

Furthermore, a well-designed e-learning system provides learning materials and facilitates additional activities such as quizzes, written examinations, and discussion forums. This means that e-learning students lack nothing essentially in comparison to face-to-face learners. Before COVID-19, e-learning was expanding in educational institutions worldwide at around 15.4% annually, with no added pressure on those institutions (Sara, 2020). However, the onset of the pandemic has drastically altered the situation due to international restrictions on imposing social distance designed to stop the spread of the virus.

This makes educational institutions offer the majority of their services online, including lectures and various assessments via many platforms (UNESCO, 2020). This makes e-learning the only viable option to continue the education process in universities. The adoption of e-learning demonstrates that even after COVID, e-learning will continue to be used in universities. As a result, it is imperative to find a way to modernize all facets of universities for them to reach the highest level of digitalization. The current application-centric architecture used by universities was created by giving applications complete freedom to have specific data that is not available to other applications (Darrah et al., 2022; Sinan et al., 2022). However, the introduction of data silos and data lakes makes things worse where data automation becomes extensively tricky, if not impossible (Coughlin, 2021; DeMers, 2021).

Furthermore, a lack of accurate and incomplete data for analysis might be hazardous and have unforeseen effects on the institution's objectives or budget. These flaws affected several organizations. Still, they overcame these obstacles by introducing data-centric architecture (Coughlin, 2021; DeMers, 2021; William morse, 2021). However, due to the peculiarities of e-learning, recommending a data-centric approach is not as straightforward as it may seem. Instead, one must first examine the evolution of e-learning to comprehend the stages of transition from various eras, the features of e-learning, and how data is generated in digital learning universities, as well as the limitations of the application-centric approach, benefits of the data-centric approach, and identified the challenges and remedies associated with making the switch, these will breach the gap between e-learning and digital age. As a result, the following. Research questions were developed R1: What technical aspects have been included in the development of e-learning? R2: What are the limitations of the application-centric approach? R3: What benefits can data-centric architectures offer? R4: What challenges do e-learning universities face as they transition from application-centric to data-centric architecture?

2. PREVIOUS WORKS

This section will discuss prior efforts to digitalize e-learning in higher education institutions. Almost all of our findings suggested a data-driven approach, which is also an application-centric approach, with a data-centric approach being recommended in higher education institutions once. Details of this article are provided below.

Data-centric architecture is the only option, according to (William morse, 2021), for digitalizing and enhancing e-learning universities. This research raised challenging concerns about student performance and university budget, and only organizations adopting data-centric cultures can provide satisfactory answers. (Grant, 2012) demonstrates the need for data analytics in e-learning by contrasting academic analytics with learning analytics and listing the advantages of data analytics in online learning. The need for data-driven capabilities in e-learning universities is highlighted by (James, 2022) by discussing three essential suggestions to help with the transformation.

(Macken, 2020) highlights seven principles of a data-driven university and emphasizes the advantages of a data-driven approach and the importance of e-learning adoption in universities. (Blog, 2019) highlighted six strategies that would help the transition while underlining the significance of upgrading course material using a data-driven approach. (Du, 2022) examined the use of data-driven education, emphasized the need to transition from a traditional classroom to a modern system, and developed a system for data-driven educational decision-making that included course content and fuzzy logic. (Solutions, 2020) discusses how big data analytics, real-time data, and microlearning material are used to advance the e-learning and learning professions. (Wise, 2021)examines online enrolments using a data-driven methodology by identifying obstacles, countermeasures, and development prospects using marketing analytics. (Lynch, 2022) shows the advantages of data-driven e-learning for students.

3. E-LEARNING

3.1 Evolution

Due to the unique advantages of learning remotely without using a traditional classroom, e-learning is now a dominant educational approach in many universities worldwide (Aslam et al., 2021). It is defined as the process of teaching students using digital media, such as the internet, corporate networks, computers, satellite broadcasts, audiotapes, videotapes, interactive television, and compact disks (Chansanam et al., 2021). Using digital tools to access digital teaching resources for online or offline learning activities across wired or wireless networks is another definition of e-learning provided by (Dehghan et al., 2022). A more modern definition of e-learning is provided by (Hu et al., 2022), who describes it as a kind of education in which technology mediates the learning process, instruction is completely offered online, and students and instructors are not required to be accessible at the same time and location.

To better understand the evolution of e-learning, which has taken on many forms since its inception in 1954, we have divided it into six categories. (i) 1954-1985 (ii) 1983-1990 (iii) 1990-1995 (iv) 1995-2005 (v) 2005-date (iv) 2010-date (Table 1). In literature, the development of e-learning began in 1954 when Doyen decided to use technology in higher education to broaden the options available to their students through the development of the PLATO (Cope & Kalantzis, 2021). Since then, it has changed in various ways that impact businesses, education, and the training sector. During that time, there weren't many computer programs being utilized in higher education. Students were studying through computer-assisted learning, which included software design tools created for personal teachings. To move to the next stage, computer-based instruction models dominated by collaborating multimedia courseware were introduced between 1983 and 1990. In addition, the development of instructive software was initiated and influenced by the constructivist learning philosophy, instructions were passive, and there was no opportunity for students to ask for or get feedback from the instructor (Bezovski & Poorani, 2016; Nicholson, 2007).

Furthermore, between 1990 and 1995, content is delivered online using functional learner models with limited end-to-end interactions. The constructivist approach was fundamental to both the education and learning (Bond et al., 2018; Chai et al., 2017; Hwang et al., 2015). Data generation begin to surge between 1990 and 1995, and adaptable interactive internet-based training is generally available, online multimedia courseware is extensively utilized, social networking is emerging, remote user access is achievable, and intellectual and constructivist approaches to learning dominate (Bezovski & Poorani, 2016; Nicholson, 2007).

The next stage from 2005 upward brings about improved social networking, remote user access, and collaborating internet-based multimedia courseware. Additionally, accessible, portable, pervasive, and potentially contextualized communication was developed. Cognitive, constructionist, and social constructivist methodologies are profoundly ingrained in learning instruction (Al-Emran et al., 2016; Briz-Ponce et al., 2016; Kearney et al., 2012; Kukulska-Hulme et al., 2009; Pimmer et al., 2016). From 2010 - to date, availability, flexibility, ubiquity, communication, context-learning, and conventional social communication were introduced, collaborating design that supports both 2D and 3D formats and combines the real and virtual worlds was introduced, and learning and teaching are supported by cognitive, constructionist, and social constructivist techniques (Al-Azawi et al., 2019; Marcel, 2019; Pellas et al., 2019; Yip et al., 2019). This stage revolutionised the way that educational materials are delivered at all levels, from public outreach initiatives to expert-level instruction at the undergraduate and graduate levels

Table 1 Evolution of E-Learning

PERIOD	TECHNOLOGIES
1954 – 1985	Programmed Instructions (Lim) Drill and Practice Computer-Assisted Learning (CAL) (Cope & Kalantzis, 2021)
1983 -1990	Computer-Based Training (CBT): Multimedia (Bezovski & Poorani, 2016; Nicholson, 2007).
1990 – 1995	Web-Based Training (WBT) (Bond et al., 2018; Chai et al., 2017; Hwang et al., 2015).
1995 – 2005	e-Learning (Smart Learning Environments (SLEs) (Bezovski & Poorani, 2016; Nicholson, 2007)
2005 – date	Mobile-Learning (m-Learning - SLEs and Ubiquity Learning (UL)) (Al-Emran et al., 2016; Briz-Ponce et al., 2016; Kearney et al., 2012; Kukulska-Hulme et al., 2009; Pimmer et al., 2016)
2010 – date	Augmented Reality (AR), Virtual Reality (VR) (Al-Azawi et al., 2019; Marcel, 2019; Pellas et al., 2019; Yip et al., 2019)

3.2. Features and Data Generation

Many studies have discussed the attributes of e-learning and suggested that it has many features and components that make it an effective learning method. (Cheung & Vogel, 2013) asserted that it contains four useful components that support all e-learning platforms. (i) curriculum design, which examines how the design of the syllabus, study schedule, class activities, and study sequences, as well as the production of learning tools and materials, promotes teaching and learning. (ii) Discussion and information sharing that emphasizes the use of both real-time and non-real-time channels, including chat rooms, forums, and electronic mail. (iii) performance evaluation, which is the evaluation and grading of homework and exams; and (iv) course administration, which is the upkeep of student data and assistance with system administration.

In addition, (Nicholson, 2007) recommended four features of online learning based on learners' needs, skills, and backgrounds. These include networking or connectivity, flexibility in learning schedules, interaction and teamwork between teachers and students, and virtual learning environments (VLEs), which provide easy access to educational resources from a distance. Mobile learning is a new generation of e-learning (M-Learning). This e-learning method uses wire-free technology to transmit information and facilitate learning. M-learning enables students to cooperatively combine their educational experiences in a communal setting (Farooq et al.,

2002). With the internet and web availability, learners can currently communicate with teachers from any location, making mobile learning the most cutting-edge in remote education. Mobile devices like smartphones and tablets are widely used, which creates a learning environment that caters to the many demands of the student. The main goal of the next generation of e-learning platforms is to employ newly developed technology to offer innovative methods for training, teaching, and learning (Sarrab et al., 2012). Moreover, according to (Otoo-Arthur & van Zyl, 2020), the advent of the revolutionary COVID-19 has increased the rate of data generation in e-learning universities. In higher education, e-learning has two sources of data, which are system/machine automated and human-mediated forms (Maatuk et al., 2022), and each has several origins and categories (Table 2).

Table 2 Data Generation In E-Learning Universities

Category	Source(s) of Data	Type(s) of Data
System/Machine Generated	Camera	CCTV, web cameras
	Mobile communication	M-learning, mobile phone
	Sensed	Access data, e.g. ICAM, wifi, LAN etc., Hearing/visual aids, security alarms, e.g. fire detectors, Security, e.g. IDS, IPS etc.
	Operational	System-log data, e.g. fingerprint, retina and iris patterns, DNA, voice waves, signature etc., Web-log data
Human-mediated	Administrative	Staff/Faculty and Student Record, e.g. HR system data, SIS, Admission data, admin and planning, etc.
	E-learning Applications	WBT data, e.g. MOOCs, LMS, LCMS
	Websites	Click streams, web searches, web scraping
	Social media	Streaming audio and video, collaborative learning, social media including Facebook, Twitter, LinkedIn etc.

3.3. Limitations of Application-centric and Benefits of Moving to Data-centric

Application-centric (APC) approach binds data to applications, allows programs to control their own data, and needs big data conversion for each new project (Della Corte & Della Corte, 2021). These approaches centre everything around the application, and developers have to develop applications around this functionality, which has been there for a very long time evolving from traditional architecture to data-informed architecture to data-driven architecture (Ascend, 2020), and they are pleased with it. But as technology advanced and the amount of data generated increased, several issues with the application-centric approach started to emerge.

This prompted researchers to perform many studies into the APC's inadequacies, (Della Corte & Della Corte, 2021) highlights the shortcomings of APC in pharmaceutical laboratories, including improper interoperability, a lack of data integration between internal and external data, challenges with data cleansing due to data redundancy, ineffective automation, and expensive maintenance costs. (Pingen et al., 2020) found that the APC's processing took longer than expected, was unreliable, and lamented the lack of data available for reusing purposes in military contexts due to the presence of data silos and a data lake, (Dave, 2020) associates APC with a lack of data ownership and integration in his article.

(Coughlin, 2021) also highlighted specific security vulnerabilities, improper automation, and a lack of system integration, (Al-Naser et al., 2013) outlined the difficulties data scientists have when preparing data for analysis because of redundancy and improper integration, while (DeMers, 2021) noted problems with data copying and data security. (Analytics, 2022) highlighted APC's lack of data integrity, difficulties in cleansing the data, security vulnerabilities, and poor latency. Additionally, (Kevin Doubley, 2020) found data errors and slow responses from APC. Fig 1 shows the comparison between the application-centric approach and the data-centric approach

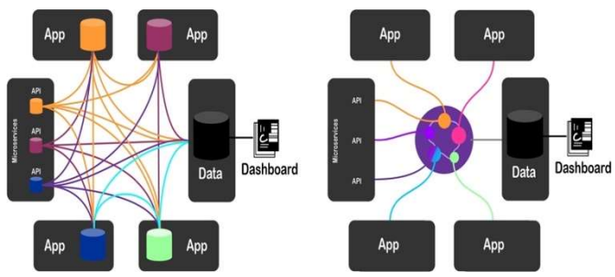

Fig 1. Data-centric approach (right) VS Application-centric approach (left)

A key idea in data-centric architecture (DCA) is the concept of a data-centric viewpoint, in which data is seen as a crucial and permanent asset that is utilized to support applications and generate deliverables. In a DCA, the data model exists before any specific application is implemented and endures long after the application has been abandoned (Vista, 2021). It is defined as an architecture where organizations and institutions create a single data model that is shared by all of the organization's information systems, data science is used as the bedrock for decision-making, and all data are linked and connected using a graph database to eliminate data silos and redundancy (Dave, 2020; Della Corte & Della Corte, 2021). Additionally, industries and academics consider it to be the solution to practically all of the challenges that an application-centric approach has brought to institutions and organizations, switching to a data-centric approach will reap tremendous rewards.

Here are some of the benefits from literature. (Analytics, 2022) highlights the benefits of adopting DCA in industries, stating that it would give data integrity, effective data management, and access to efficient data analysis that will reduce risk decisions, to reach the automobile industry's highest degree of data transformation (Alvarez-Coello et al., 2021) recommended DCA because it can reduce data redundancy and improve data analysis since it can share its data with all applications. According to (Kevin, 2021), DCA streamlines data security, integration, portability, and analysis and provides rapid insights throughout the value chain. (Dennis, 2020) emphasized the advantages of DCA and praised its capacity for attaining data traceability and improved data protection, as well as handling authentication, authorization, and query management that used to be handled by applications in APC. Table 3 highlights the issues with APC and the fixes offered by DCA.

Table 3: Summary of APC Issues and The Remedies Brought by The DCA Approach

Application-centric limitation	Data-centric remedies
Present of data silos	Absent of data silos
Unreasonable cost of change	Reasonable cost of change
Applications own the data	Data is a resource that is open and endures beyond any one application.
Every new project has a significant data conversion project attached to it.	Each new project makes use of data stores already in place.
There are many different heterogeneous forms, structures, semantics, and terminologies for data.	Data is exported from a common source in the required format and is globally integrated with a common format.
Budget for IT is heavily spent on data integration.	Integration of data will be almost free.
Integrating external data with internal data is challenging or impossible	Easily integrating both internal and external data

4. CHALLENGES OF MOVING TO DATA-CENTRIC

Adopting a data-centric approach to e-learning is challenging, considering that most institutions abruptly embraced e-learning without being thoroughly prepared and technologically equipped (Maatuk et al., 2022). Additionally, modernizing universities to achieve their goals is essential for the advancement of any civilization. This research examines the following issues for effectively transitioning from application-centric to data-centric institutions.

4.1 Culture

Many institutions are considering switching to data-centric due to application-centric limitations. However, there are certain people at the University and even entire departments whose principal activities are based on a non-data-centric method of working. It will take some time to change these people over to data-centric thinking. Universities can quickly resolve this by making university staff members feel less anxious. Some employees would perceive the shift to data-centric procedures as a threat to their job since they did not understand how they would fit into the new paradigm. Universities should be wise enough to ensure that everyone in the institution understands the exact reasons for the change, how all staff fit into the new approach, and what the University hopes to benefit from. They should also persuade them that the University will provide adequate training and support for everyone to ensure they continue to be valuable within the University.

4.2 Process

This is essential to switch to DCA; if wholly accomplished, it would bring the entire institution into the current era of digitization. It encompasses several technological efforts and certain administrative tasks. Some of the actions to take are listed below:

1. Architecture: Because universities now store their data in many locations, some on computer hard drives and others on external hard disks, only a few departments use the services of cloud providers, e.g. IT units, and data-centric architecture cannot be implemented with the existing state of university architecture. This shows a lack of data integration; thus, the University's whole architecture must be redesigned to have an adequate flow and integration of data. Additionally, emerging technologies, such as Kubernetes, Docker, etc., and microservices, should be integrated.

2. Security: Universities manage sensitive data ranging from personal to research data; if the integrity is compromised, it will impact the whole generation's future. Therefore, Security is the foundation of any institution. Researchers are working hard researching protect universities from cyberattacks. However, to effectively safeguard institutions, a cybersecurity framework must be created to defend against cybercriminals and traditional criminals who can steal storage devices and destroy hardware to benefit themselves financially and personally

3. Training: Training must be provided to the whole university staff to understand how the new system functions properly. Additionally, it will be advisable to break the implementation steps into manageable pieces, and staff should accompany the process at each level to ensure that they fully comprehend the new system.

4. Maintenance: Every new system implemented looks great at first, but without adequate routine maintenance, it would begin to deteriorate and eventually would collapse. This is also true of DCA; universities must regularly maintain it and ensure they take advantage of upgrades whenever they become available. This will guarantee that e-learning institutions have a proper, robust, efficient, and reliable architecture for their daily operations.

5. CONCLUSION

In this study, we highlighted the constraint of application-centric architecture as the factor that prevents the advancement of e-learning to a contemporary level of digitalization, including lack of data integrity, noisy data creation, improper interoperability, the existence of data redundancy, presence of data silos, long processing time, lack of data ownership, and presence of security vulnerabilities. Additionally, we recommend data-centric architecture as a solution to these constraints due to its special capabilities that eliminate data silos, reduce data redundancy, streamline data management, simplify application development, improve data quality, improve data reliability, reduce data errors, reduce data inconsistencies, eliminate complex data transformations, make data more accessible to key stakeholders, and simplify Security. Also, we discussed the challenges associated with moving from an application-centric to a data-centric perspective and how to overcome these challenges.

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