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SERVICE-ORIENTED REFERENCE ARCHITECTURE TO SMART EDUCATION

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Abstract: - Smart education has become an essential need for everyone with its conveniences and quick-to-adopt modes. It has gathered the attention of people by interlinking various fields and disciplines of knowledge through communication for educational purposes. A lot of research involves the area of Smart Education. However, the challenges are the increase in the complexity and more interoperability between systems in the distributed environment. The lacking is reference architecture in which by reusing various technology services. It is proposed to design smart education architecture with emerging technologies services such as big data, blockchain, cloud computing, artificial intelligence, machine learning, smart computing, etc. The objective of this paper to design a service-oriented reference architecture to smart education. This research paper reviewed the existing emerging technologies applied in smart education architecture that serves as the domain. This article proposes a new architecture called service-oriented reference architecture to a smart education system. The proposed architecture is a highly scalable solution for smart education concerning applications, platforms and infrastructure.

Keywords: - *Emerging Technology, Reference Architecture, Service-oriented Architecture, Smart Computing, Smart Education, and Smart Learning.*

I INTRODUCTION

Education becomes more valuable and valued throughout the technological world. The present education system has traditional teaching methods, outdated teaching contents, boring courses, less collaboration and less learning channels. In the traditional education system, the teaching facilities are backward and self-improvement is difficult. Its lack of excellent teachers, and waste of educational resources. It has the unbalanced distribution of educational resource and backward educational in the depressed area. There are lost challenges of education exist in many factors such as educational administrators, learning campuses and government. Because of these challenges, it needs a series of new technologies to push the development of smart education.

To reshape educational spaces, it is important to support technology evolution in education. Today, technology is changing the dynamics of education including the relationship between teachers and students. Technology provides solutions to new challenges and many new opportunities for different types of educational institutions i.e., schools, colleges, universities, research institutes, etc. Technology is helping the students to advance problem solving, communication and collaboration.

The rapid integration of information and communication technologies (ICT) in education helps synchronous and asynchronous mode of lesson delivery, new ways to access information and knowledge in the teaching process (Digital Learning, 2018). In the modern education system, many smart devices have emerged in adaptation to intelligent tutoring systems (ITS) and personalized e-Learning systems (PeLS). Students can use smart devices to complete their assignments, do their research and connect with their classmates. The teacher can use smart devices to keep track of their students, check on their work, make grading them easier and more transparent. Educational apps have helped the students to connect with teachers through online at any time and anywhere. Teachers can ready their smart lesson plans easily and with accuracy. By using educational gadgets, teachers make use of smart devices to generate lessons for the smart board.

A. Technology in Education

The different technologies are taking place to acquire education with ease and comfort. The emerging technologies are beginning to transform how instruction and learning take place. Teachers are using technology to replace old models of standardized, rote learning and creating more personalized, self-directed experiences for their students.

The Internet made the explosion of information even faster. Now it can blog or tweet about anything in mere seconds. Everything happens in real-time. E-books are now being made at a quarter of the cost of traditional books. As rapid development occurs in new technologies impact the way that knowledge is transferred and embodied. From the rapid proliferation, the massive open online courses (MOOC) support a variety of

blended learning models. The MOOC is providing online experience. Higher educational institutions (HEI) can now create blended courses using MOOC content. The HEIs are picking up the offline experience of teachers interacting in person with students. Social networking, online teaching, class blogs and wikis, podcasting, interactive whiteboards, and mobile devices are also some of the new technologies are used in education.

Blogs and Wikis widen the avenue for discussion and allow students to participate outside of the classroom. Interactive whiteboards make teaching easier, giving students better visual aids and teachers an easier time in presenting lessons. Mobile devices allow teachers to deliver information to students in a lightning-fast manner. Online teaching and distance learning is a fast-growing industry. Podcasting and Websites allow students to learn and participate in discussions even when they miss classes due to sickness. The integration of Internet of Things (IoT) in education completely leads to the idea of Smart Education. The data generated by these IoT devices and mobile phones on campuses will lead to an era of Big data. These data can be analyzed to shape and create a dynamic educational system with intelligent gathering concepts. The intelligence gathered can suggest new learning patterns, curriculum re-design and better management decisions on running academic institutions based on facts.

New technologies discussed above make distance or remote learning easier. They allow for faster feedback and improved collaborative efforts between large groups of learners.

B. Smart Education & Technologies

In the modern world, the government must ensure that every student receives an excellent education. The disparities in facilities of educational institutions are teacher quality and curriculum offerings that favour more-advantaged students. Several reform efforts have attempted to address the needs of students ensuring high levels of learning and development for all students. Reforms attempted to build high-level partnerships among educational developers and educational institutions to integrate many other services for students, teachers, parents, recruiters, educational administrators, etc. It is referred to as a "smart education system". A smart education system is nimble, adaptive, and efficient. It provides differential supports to different groups of students, teachers, recruiters, researchers, and parents, depending on their needs. It collects and uses data and makes adjustments depending on what is working and what needs to be changed. A smart education system focuses on educational services (Robert Rothman, 2007) to ensure learning and support of academic achievement.

To build the 21st-century education, consider a multimedia approach to learning core content, promote essential learning and innovation skills, build information, media, and technology skills in context and, advance life and career skills. This shows in Fig.1. The smart education core solution includes academic, research, assessment & results, scholarship, hostel, payment, medical history, events, data usage, transport, feedback, etc. These solutions are designed and deployed in various servers includes an educational portal, identity, LMS, gateway, alert, storage, analytics, monitor, sport, Hyperledger, collaboration, finance, alumni, etc. The users of smart education are teachers, students, educational administrators, other educational users, parents and recruiters. The smart learning environment features of registration, access to LMS, interactive board, projector, on-demand collaboration, classroom capture, sensors for attendance, visual learning, dashboard, alerts, upload and download, etc. This requires and involves *collaborative learning*, *flexible learning environment*, *teacher as facilitator* and *technology integration.*

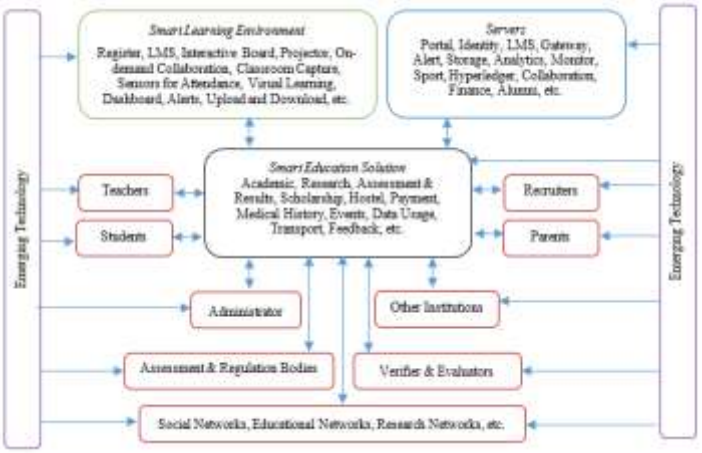

Figure 1 21st Century Education

The flexible learning environment can be changed to meet the needs of modern learners. For example, 'bring your own device' (BYOD) allow the students to use their own devices for learning. Technology plays a big role in developing most of the characteristics of 21st-century education. They are collaborative learning, flexible learning environment, teacher as a facilitator and technology integration. These characteristics can help to provide students with essential skills for the flexible learning environment. The smart education system, an advanced form of the modern educational system supported by technologies like *cloud computing*, *internet of things (IoT)*, *mobile technology*, *ubiquitous technology*, etc. With the advancement in the field of big data and learning analytics, it is possible to display content in a preferred mode of learning for each learner. Learning analytics refers to the application of analytics to the data created by each learner to track their likes and dislikes about various aspects like type, format, and depth of content coverage in the courses. This would go a long way in enhancing their learning experience. A smart education system features information collection, resource sharing, application integration and comprehensive operation can be built to meet the increasing demands at all levels in green campus development (Putra, 2019).

C. Motivation Example

Education has been influenced by technology. This evolution of technology satisfies the need of learners and resulted in the improvement of educational quality. The learners are dependent on the Internet, smartphones for their day-to-day work in the field of education. Traditional lecture methods are still in

practice, however, these practices are mixed with modern technologies like smart boards, video conferencing, virtual classroom, Internet and e-tutorials. The video conferences can be interactive and can connect with the native language. Interactive textbooks are more conducive to learning than paper versions. E-books hold unimaginable potential for education and decrease the weight of a student's backpack.

Social technologies, mobile devices, wireless communication are tools for smart learning. Smartboards and blockchain technology allows the possibility for educators to record information using information gathered about their students. Chatbots helps the students to improve communication. Admission procedures have been streamlined by the use of chatbots that have machine learning (ML) in place. Higher educational institutions (HEI) can use chatbots for easier enrolments. The teachers can use the ML capabilities to develop more personalized learning, It offers insights to the students to guide them in the right direction.

To facilitate the development of a successful modern education system on Internet platforms, it can adapt the above technologies that support an arbitrary number of users. In the modern education system, the challenges are technology adaptation, complexity and interoperability in a distributed environment.

- From the perspective of business architecture, it needs to be a seamlessly connected platform that offers valuable services to end-users, enabling them to fully utilize the benefits of such a system.
- From a technical perspective, to get the above business architecture, the building blocks of connected educational ecosystems must be united.
- Existing automation in education is highly focused on systems that promote personalized learning system. These systems are educational interventions to automate education differently and improve teaching and learning. Automation in education by 5G may be concerned with machines, devices and humans are to communicate and interact to achieve educational goals.

The main principle behind modern higher education concept should differ from other education architecture frameworks, thus removing siloes entirely. To accommodate existing and new technologies in the modern education architecture, it is suggested service-oriented architecture (SOA) approach. An efficient way of developing new smart learning systems in which development work is done repeatedly with re-using what was done in the past. Also, reference architecture addresses these issues by reusing learning contents from different domains to design the views of smart education architecture. Reference architecture using SOA guides for the development of new versions of architectures to a smart education system.

D. ***Problem Statement & Solution***

Motivated by a current lack of clear guidance for approaching the field of the smart education system, the goal of this research article is to functionally structure this space by providing a reference architecture to smart education. This reference architecture has the objective to give an overview of available technologies and to organize these technologies by placing them according to the functional components in the reference architecture. The reference architecture shall be suitable to serve as a basis for thinking and communicating about smart education solution and for giving some decision guidelines for designing them. From the above motivation, the problem is to design service-oriented reference architecture for smart education solution with emerging technology.

The solution to the above problem is to investigate if a service-oriented reference architecture to smart education (SORASE) solution. SORASES supports agility, flexibility, integration, scalability and reusability to, especially educational institutions. SORAPES can fulfil scalability requirements that harm cost and maintenance of smart education system. By using SORASES, both customers and developers can provide a better return on investment with less time and more revenue. SORASE can provide faster deployment of new technology in a flexible manner. Hence, the objective of this article is

i. to study and review the emerging technologies applied in smart education;
ii. analyze the smart education services by identifying the requirements and quality factors, and
iii. propose a smart education model and architecture with available technologies.

E. ***Research Methodology***

This research has aimed to propose a service-oriented reference architecture to smart education solution. The research methodology includes the following steps. The steps of this stage are as literature review, analysis of existing architectures if available, and analysis of requirement, propose a reference model and reference architecture and evaluation of the proposed architecture.

i. In the literature review, studied various emerging technologies used to design smart education.
ii. It is studied the existing smart education architectures available and compared them.
iii. It analyzes the requirements and quality factors required to design smart education architecture.
iv. It is proposed a model and reference architecture to a smart education system.
v. Finally, the proposed architecture is evaluated with the help of quality factors identified in stage 2.

The research paper is structured as follows. *Background section* describes the theoretical background information required to write this article. *Literature review section* reviews the work related to emerging technologies to smart education. Various architectures with emerging technologies of smart education or e-Learning were identified and studied. *Proposed System section* describes the reference architecture designed to the smart education system. This includes the requirements, services or components, quality parameters, proposed model and architecture

and evaluation. This paper ends with the conclusion and future works section.

II BACKGROUND TECHNOLOGY

This section describes the general context of this article and the reference architecture to develop. It defines smart education, characteristics, challenges and a proper scope for the reference architecture.

A. Technology Enabled Learning

ICT-based education has been applied to a variety of aspects, such as teaching, learning, research, students safety and campus management. This offers a new approach to universal, high quality, and personalized learning. With technology, educational developers provide comprehensive ICT solutions to promote modern education development. Personalized learning is essential for educational institutions because it provides opportunities for students that often are not available in many remote places. Personalized learning helps to transcend many of the limitations confronting rural students, such as geography and limited course opportunity and access.

Many higher education institutions (HIE) are now integrating new technologies with their core educational services like teaching, learning, research, management, safety and public services. Educational software developers built educational software with software-defined networking (SDN), next-generation, intelligent campus networks and data centers to bear teaching and research applications. Despite online discussion forums, many students still seek face time with their teachers. The MOOC platforms are also meeting this need for students to meet through online social networking portals. Big data and cloud computing are changing both education models and ICT development. Cloud computing encourages learning from anywhere and anytime.

Smart education (or e-Learning) changes teaching and learning in educational institutions using modern technology. The teachers can teach from anywhere and students can learn from anywhere and anytime. Teachers can adopt a flipped-classroom approach more often and students can take ownership of their learning. Teachers can upload smart contents - videos, documents, audio podcasts and interactive images for students to use. These resources can be accessed via a student's smart devices via Wi-Fi, 3G/4G and 5G.

As rapid development and new technologies impact, education is becoming even more valuable and valued throughout the world. Some factors are intense but imperative to shift teaching and learning for the students' global success [Meredith Allen, 2019] and they are budget and resources, community partnerships, curriculum, instruction, and assessment, data and privacy, personalized learning, robust infrastructure, use of space and time, etc.

B. Smart Education

Smart education is an advance form of modern education using information and communication technologies (ICT). Smart education has become of essential importance in today's world. Smart education is "a model of learning adapted to new generations of digital natives". In comparison to traditional classroom teaching models, smart education is an interactive, collaborative and visual model, designed to increase student engagement and enable teachers to adapt to students' skills, interests and learning preferences [ViewSonic, 2019]. There is a set of characteristics for a smart learning environment and they are adaptive, autonomous, effectiveness, efficiency, engaging, flexible, personalized and scalable.

The different components of smart education include smart learning, smart teaching, smart assessment, smart classroom, smart support, smart campus and smart operations. *Smart Learning* concerned with the management and delivery of learning content and resources to students. *Smart Assessment* concerned with the tracking of students' performance and providing educators and assessors with a continuous flow of indicators and diagnosis of students' progress. *Smart Classroom* concerned with establishing technology-enabled classrooms. *Smart Support* concerned with students and staff support. *Smart Operations* addresses all aspects of daily operations in an educational institute. *Smart Campus* concerned with the physical infrastructure of the university, its buildings and utilities, greenness, and safety. Smart teachers, smart pedagogy and smart environment make the learner smart and ready to face the challenges of the education.

Smart Campus. Smart campus development relies on agile and reliable ICT platforms, including complete wireless network coverage, a wireless campus, comprehensive security protection and IoT. Smart campus infrastructure solutions provide the smart campus with environment sensing, mobile Internet, Big Data analysis platform and so on. The application of computer and network technologies accelerates campus information construction into the era of digital campus construction. The modern technologies, such as cloud computing, IoT, data center and big data transforms digital campuses into smart ones. A smart campus supports teaching and research, optimizes service quality and enables unified decision-making.

Smart Classroom. Smart classroom breaks the traditional teaching model in the classroom, bringing to ICT model-based teaching. It enables teachers, students and parents to take part in the teaching process and enjoy the entire intelligent teaching experience before, in and after the class. A smart classroom is generally equipped with many multimedia components to enhance teaching and learning. A small classroom is "as an advanced implementation of technology for schools by providing tools and content for learning". The digital classrooms concepts include mostly IoT. The concepts of smart classrooms are considered during designing. The design transforms learning spaces in modern smart classrooms. The features of the smart classroom are user interface, plug-and-play, and navigation, elements of instructions, content presentation, virtual labs, voice-over and matches the latest syllabus. There are many basic concepts of a smart classroom: adaptability, comfort, connectivity, multiplicity, openness, personalization and security.

Some of the problems of designing smart classrooms are interactive smart classroom rapidly, react to the intelligent operation and maintenance of massive devices, and provide teachers and students with simple and correct access to these teaching facilities.

Smart Learning. Smart learning is a new approach of learning used by teachers and students both in the classroom and outside of the classroom [Anu Rawat, 2017]. Smart learning can also be called as Technology-enhanced learning (TEL) that provides a flexible mode of learning. Modern technologies promote smart learning in the process of education. Smart learning is a learner-centric, effective, intelligent approach to learning. For smart learning, the smart environment is necessary and it supports the teaching-learning system. Smart learning enables creativity, intelligent, critical and analytical thinking and can classify the individual differences among students. Smart Learning provides a facility to the learner that s/he can learn at any place and any time. Smart learning enhances and improves the quality of teaching and learning.

Smart Content. For any student who has struggled with content, AI-driven tutoring and smart programs can be the solution to their woes. Digitized study guides and personalized learning interfaces are some forms of smart content that are specially created for elementary and post-secondary students. The smart guides, for example, break down the textbook content and explain it through interactive content and comprehensive assessments in the form of chapter summaries, flashcards, practice tests, and true-false questions. With smart content (Deloitte, 2019), educators are not just limited to the traditional mediums of teaching but can create curriculums and customizable content that work on different devices. These platforms integrate well with self-assessments, simulation systems, gamification techniques and video conferencing.

Smart Education Framework. Smart Education allows the learners to participate in their learning process and to build their knowledge for the future society. The smart education framework identifies student attributes for a particular learning environment. It selects one or more the most suitable learning theory models that can be applied for adaptive learning. It facilitates the determination of the most suitable AI methods. The most suitable learning models have been shortlisted and trained for a particular student environment, these may be used to classify students and determine their learning styles. Learning styles can be mapped to learning content and learning paths to deliver personalized education.

The smart education framework (Richa Bajaj, 2018) offers adaptive education as cloud technology. Educational institutions and smart learning platforms can easily access cloud-based service and deliver personalized education to their students. The smart education framework suggests a multi-step process for delivering personalized smart education.

C. Technologies in Smart Education System

Educational Institutions are now starting to get on board with utilizing newer learning methods for higher education. To modernize their campuses for today's digital-native students, many educational institutions are continuing to increase investments in technology related to learning. Educational Institutions now recognize the influence of wireless and mobile technologies for teaching and learning. The emerging technology disrupts traditional education from the three aspects of *quality*, *efficiency* and *equality*. The top classroom technology trends in the current education environment [Danny Mareco, 2015] are presented below:

- *App-based Learning***.** App-based learning and gamification (Atul Temurnikar, 2020) in educational institutions helps student's access resources anytime, anywhere thus ensuring continuous education. This method can be considered priceless in students who require constant innovations in learning concepts.
- *Artificial Intelligence (AI).* AI and Robotics technologies help education transform and become more about personalization and learning rather than mugging up and studying (Atul Temurnikar, 2020). AI technology is sparing more efforts to build a smart campus. Basic tasks like grading can be done by AI thus reducing the work pressure from teachers and helping them concentrate on other productive activities. AI has immense potential in automating and expediting these tasks for the teachers and the organizations. This time can be better spent on specialized training to improve the student's education.
- *Machine Learning (ML).* ML refers to the ability of devices to learn without, being explicitly programmed. A PeLS can use ML (Daisy Wadhwa, 2017) to keep a track of what students are searching, provide this information to teachers and assess the students searching and reading. It can support time-consuming and difficult aspects of teaching and learning, such as individual project work, collaboration, tutorials and grading student assignments.
- *Deep Learning (DL)* is an innovative technology that has gained much importance today. DL is being used for auto-captioning of videos (Daisy Wadhwa, 2017). This feature is quite useful for students with hearing disability. This feature also makes possible to watch foreign language videos with subtitles.
- *Computer Vision.* The concept of computer vision is being employed in a PeLS where the system can estimate the learner's responses through continuously monitoring the individual's attention spans, facial orientation, and eye movements while viewing online course materials such as some educational videos (Daisy Wadhwa, 2017).
- *Natural Language Processing (NLP).* NLP systems can be used to understand the meaning of words in conversations and written text. Several smart learning applications use NLP to provide a deeply immersive, engaging and personalized learning environment to the students (Daisy Wadhwa, 2017). In PeLS, NLP is being

used to grade student assignments and provide detailed feedback on student drafts.

- *Speech Recognition.* Speech recognition (Daisy Wadhwa, 2017) refers to converting spoken words to text. PeLS systems come with built-in speech recognition ability. For example, Speech recognition technology can make computers act as virtual peers (chatbots) with which students can collaborate and work on assignments. It can also help students learn new languages.
- *Big Data.* Big data has remarkable flexibility and precision to change in teaching and learning. All of the mobile devices, applications and wireless technologies use on a day-to-day basis can now be linked together as big data and harnessed to deliver an almost endless supply of relevant data. Big data gives real-time information that can be applied to the classroom immediately. Big data and analytics technology provide strong data analysis for learner affairs management (Atul Temurnikar, 2020, Danny Mareco, 2015).
- *Data Analytics.* Student data gathered from various sources like application forms, admission forms, mark sheets, etc., that paint a picture of their background, learning history, health issues and any other criteria can help understand and affect their future learning prospects. Data analytics will be able to map and measure the progress of each student in sports and academics. Data analytics creates personalized plans for their academic future. Data analytics can also be used in sports. It is the perfect tool for coaches to communicate more effectively with students on their team.
- *Data Mining.* Data mining technology (Wang, Shengnan, 2019) improve the optimization of the smart education system. It is used to classify and summarize the smart education data and improve the accuracy of teaching content. In the intelligent education model, both data mining and AI can be used to improve the efficiency of learning and teaching and make the teaching content more accurate, which is worth to further promoting.
- *Data Center.* Data centers (DCs) are the cornerstone of IT in education, gathering quality educational resources and supporting many education management services.
- *Digital Textbooks.* Textbooks are getting more expensive and they are usually used for a maximum of seven years before a new edition comes out. A digital textbook (Danny Mareco, 2015) would be more cost-efficient and can easily be updated to reflect the most recent information. The students can these digital textbooks for the year anytime and anywhere.
- *Flipped Learning.* Flipped Learning (Danny Mareco, 2015) is a form of blended learning where students learn their lessons at home by watching video lectures, studying content online and then doing their homework. Students can learn from each other through Wi-Fi enabled classroom technology and various mobile-app solutions.
- *Gamification.* Gamification (Danny Mareco, 2015) is the concept of applying game-design thinking to different classroom tasks to make them more fun and engaging. The idea is to use the typical game system of providing challenges, rewarding winners, then providing harder challenges with equally bigger rewards. Gamification further challenges a student at every level by offering them innovation incentives thus making learning fun, engaging and interactive.
- *Internet of Things (IoT).* IoT can help educators in making students more aware of their surroundings and provide them with truly global education. Many mundane tasks, which require human intervention, can be replaced with devices supplemented by IoT thus helping teachers concentrate on other aspects of student development.
- *Neural Network.* Human intelligence is based on a nervous system that collects and processes information, and then gives feedback and similarly, a smart education system needs a *nervous system*. Data collection, analysis, and usage are impossible without the *nervous system* and intelligent operations are nothing but an empty promise. The smart education system needs such a nervous system to link service systems and coordinate resources.
- *Data Lakes.* Data lakes are centrally data repositories where educational organizations strategically gather from multiple sources and store all the data they need to analyze to reach a specific goal. The nature and format of the data may be semi-structured, structured, and unstructured data. The data lake needs for higher education institution to perform data analytics in a mixed environment of data. Data lakes enable an enterprise-wide view of data.
- *Mind Mapping.* Mind maps (Danny Mareco, 2015) make learning interactive and multi-dimensional instead of unidirectional and passive. It is graphic and visual and makes it easier for students to understand and recall information.
- *Remote Learning.* Remote learning (Danny Mareco, 2015) allows students who cannot make it to educational institutions still attend virtually. They attend class through video and access content online. This provides a higher quality of learning that would otherwise be unavailable due to distance or time. It needs reliable wireless and mobile technologies.
- *Smart Computing.* Smart computing (Kurmude D, 2019) technology works in a combination of latest in sensor-based technologies, IoT, edge computing, cyber-physical system, machine learning, cognitive computing, big data analytics, and AI. Smart computing integrates hardware, software and network technologies that provide systems with real-time situation awareness and automated analysis [Prabal Verma Sandeep, 2017].

- *Social Media.* Social media (Danny Mareco, 2015) is usually considered a huge distraction when it comes to the classroom. From Wikipedia, Facebook, LinkedIn, Google+, Facebook, YouTube to Twitter, many educators are fearful of its use. Social media can be a very useful and powerful tool for both students and teachers. An online group can bring students together to work on projects and assignments together for a specific subject or problem. Many educational institutions can have a digital citizenship code to use of social media in educational institutions.
- *STEM.* There is a need for science, technology, engineering and mathematics (STEM) skills as the gateway to employment opportunities (Deloitte, 2019). To cater to the fastest-growing job categories, there is a need to reimagine the education curriculum to teach students the relevant skills in the digital.
- *Virtual classrooms.* Virtual Classroom (Atul Temurnikar, 2020) bridges the gap between geographical boundaries and connects students and teachers with resources even without being physically present. The learners can connect with teachers around the globe and collaborate with peers on the other side of the world. They can attend lectures conducted in classrooms from anywhere and anytime.
- *Mobile Technology.* Mobile technology offers opportunities for delivering new and interesting methods of learning whether inside or outside the classroom. Mobile learning or M-learning supports the creative, collaborative, interactive abilities and capacities inside the learning environments. M-learning (Ahmed Al-Hunaiyyan, 2017) effectively adapt the mobile technologies in the educational systems.
- *5G Technology.* The emergence of 5G provides communication and automation within the smart classroom and administration offices where Educational Internet of Things (EIoT) is being used. 5G may have a greater impact on the concept of Smart Education (Delali Kwasi Dake, 2019). 5G technology will be a facilitator and a quickening agent of Industry 4.0 and Smart Education. 5G networks have a software-defined networking (SDN) architecture that comprises of the control and data planes to drive the smart education infrastructure.
- Other technologies can also be used including video conferencing, class forums, pre-recorded videos, social media, and email.

Today, there are intelligent spaces, location-aware, wearable solutions, IoT devices, Augmented Reality (AR) and Virtual Reality (VR) devices for teaching all connected to improve the learning experience. Education will no longer be limited to location and with the help of the Internet. A student in a remote place can gain the benefit of excellent education with the help of emerging technology.

According to the papers reviewed and analyzed, the challenges on smart education, which need more research are *connectivity*, *data visualization*, *prediction system* and *security*. There is a great reduction in performance as more devices connect to smart education systems. This entails a problem since the trend is having more and more students per classroom. There is a great demand for data visualization techniques and dashboards that deals with the large amount of data generated in smart education environments display them correctly and make this data easier to understand for students and teachers. There is also the prediction of events before they occur, such as students dropping out or failing a course in the smart education system. Using prediction system, it is possible to take corrective measures to improve teachers and students' performance. The collection of personal data of students, teachers and management personnel are very common in Smart Education environments. This includes privacy and secure data management, among others.

D. Service-Oriented Architecture

To meet the above challenges, modern higher education needs to be encompassed by the new architecture. The new architecture will focus the services, components, and interoperability and cross-platform functionality between components. The services and components can become interconnected with each other, empowering greater connectivity and other platforms, thus improving the potential of the architecture in modern higher education. This can bring together entities to create connected educational ecosystems, enabling speed and efficiency among different users. Hence, it needs to be flexible, distributed and loosely coupled which is can deal with the overwhelming complexity of existing systems.

The solution is introducing service-oriented architecture (SOA) to interconnected modern higher education. The SOA is used to integrate diversity components in modern higher education. It is an approach for distributed systems architecture for support and delivers seamless cross-platform integration. SOA (Qinghua Zheng, 2008) is an architectural paradigm for designing and building distributed system based on loosely coupled, interacting services. The central concept in an SOA is the service, which defines a mechanism that enables access to capabilities through a predefined interface. Services are discovered dynamically when needed, rather than being hardcoded into service consumers. Dynamic discovery of services is realized through the use of the so-called publish, find, bind pattern. This mechanism makes it easy to dynamically add, remove, replace or relocate services as needed without further modification of service consumers.

E. Reference Architectures

Literature offers several definitions to describe software architecture. Architecture is abstract in terms of the system it describes, but it is concrete in the sense of it describing a

concrete system. It is designed for a specific problem context and describes system components, their interaction, functionality and properties with concrete business goals and stakeholder requirements in mind. As a reference architecture (RA)is abstract and designed with generality in mind. It is applicable in different contexts, where the concrete requirements of each context guide the adoption into a concrete architecture. A reference architecture operates with components with a high degree of similarity. So they can be assembled correctly and safely, resulting in complex yet scalable solutions, providing flexibility for various application scenarios. The guiding principles can be found in different areas of architecture are h*eterogeneity, flexibility, weak coupling, scalability and security*

The reference architecture framework can be applied to guide the design of reference architectures. It can provide different architecture types placed in the classification space and congruent. When designing a new reference architecture these predefined types can be used as guidance for the general design decisions. The application of the framework starts with assessing the goal and the contextual scope and timing of the planned reference architecture. The result of these decisions can then be mapped against the framework to determine the fitting reference architecture type. A reference architecture is to facilitate and guide the future design of concrete system architectures in the smart education. This research article aims to give an overview of emerging technology in the smart education solution, put it into context and help architects designing reference architecture.

i. The goal according to the framework is *facilitation*.
ii. The scope is intended to apply to *multiple educational organizations***.**
iii. The requirements elicitation is therefore only based on a literature study.
iv. The reference architecture will be verified by mapping existing architecture onto it. This might help to reduce this weakness.

In this article, reference architecture incorporates knowledge about smart education domain, requirements, necessary functionalities and their interaction for smart education, which fulfil the requirements and provide the functionalities.

F. Reference Architecture Design Strategy & Methodology

As the reference architecture intends to give an overview of necessary functionality, existing technologies, the use of components, connectors and interfaces for the design. The design of the reference architecture is conducted in multiple phases, starting with an aggregated and abstract view and add more detail and concreteness. It decides for a *practice-driven* design strategy. Therefore, the design strategy is based on existing architectural artefacts and technologies. While developing a reference architecture, it is important to keep some of the points. The result should be relevant to a specific domain and fulfil domain requirements. It loosely follows the proposed development process, which consists of the following steps.

i. *Step 1: Decide on the reference architecture type.* It decides about a particular type of reference architecture and the context.
ii. *Step 2: Select the design strategy.* It decides if the reference architecture will be designed from scratch or based on existing architecture artefacts within smart education domain. The design strategy should be synchronized with the reference architecture type above.
iii. *Step 3: Empirical acquisition of data.* It identifies and collects data/information from several sources. It is generally proposed to gather data from people, systems and literature.
iv. *Step 4: Construction of the reference architecture.* The construction of the reference architecture consists of a set of models with views. All views together describe the system in its entity.
v. *Step 5: Enabling reference architecture with variability***.** It considers the variability to be inherited in the abstractness of the reference architecture.
vi. *Step 6: Evaluation of the reference architecture.* It allows evaluating the completeness, correctness, compliance and validity of the reference architecture.

To design a reference architecture it decides its type. It bases its framework on the three dimensions *context, goals and design*. Reference architecture types are then valid, specific value combinations within this dimensional space. Reference architecture for smart education system represents a step forward for standardization because this defines a set of guidelines in designing and implementing a smart education system.

III LITERATURE REVIEW & RELATED WORKS

Improving education is a huge issue for society. Technology can be utilized to improve teaching and learning and help the students be successful (Trust Radius Team, 2019). With learning management systems (LMS), students can access online resources to get assistance on-demand beyond the physical reach of their teacher. Teachers can make their networks, social networks and different resources to discover and share thoughts and resources, and get support from their colleagues. Technology can give teachers and students remarkable resources.

Electronic Learning or e-Learning is the use of Information and Communication Technology (ICT) to deliver information for education where teachers and learners are separated by distance, time, or both to enhance the learner's learning experience and performance (Keller et al., 2007). Horton (2011) defines e-Learning as a set of instructions delivered via the Internet. Thus, by eliminating the barriers of time and distance, individuals can now take charge of their lifelong learning. E-learning environments reduce the cost of provision and therefore increase revenues for academic institutions (Ho, Dzeng, 2010).

The technology in education seems to be changing how the students and teachers collaborate inside and outside the

classroom. The technologies can be used to improve the academic life of the students (Emerging Technology, 2017) are Social platforms, elimination of books and use of open resources of education, the luxury of online resources, PIAZZA, UDACITY, Cloud-based tools and Game-based learning.

The emerging technologies (Palanivel, 2020) that are used to design a smart education system. The emerging technologies in education are becoming intelligent, institutive and ubiquitous. The emerging technologies increased the effectiveness and enhancing the efficiency of smart education.

The Higher Educational Institutions (HEI) must decide during or before the implementation phase on the best approach to deliver education, such as online learning, face to face, or apply a blended approach. For this study, e-Learning with a particular focus on higher education institutions applies to the use of web-based learning systems to support face-to-face education. According to Wagner et al. (2008), this approach is the most successful learning approach compared to solely online and only face-to-face contact.

Learning Management Systems (LMSs) refer to the Web-based delivery applications or technologies that are adopted by higher education institutions to deliver courses' contents, provide distance learning and to manage the education process. LMS creates a variety of ways to deliver instruction and provide electronic resources for student learning. Different Web-based learning systems have been developed for Higher Education to facilitate learning in a web-based learning setting; these include Moodle, Web Course Tools (WebCT), LAMS and SAKAI, Blackboard Learn (BBL).

Personalized e-learning model (Abdessamad, 2018) introduced to provide the learners with learning resources that fit their individual preferences, after giving an overview of both e-Learning as an online educational system, and deep learning as a broader family of artificial intelligence. Online learning and technology (Thomas Nugent, 2018) impact heavily on the executive education space in the coming years, revolutionizing the way it approaches the development of our personal and professional skills.

AI receives increasing attention in developing smart digital education. The computational intelligence and ML techniques used to develop smart tutoring systems. The convergence of AI, data science and IoT is enabling the creation of a new generation of Web-based smart systems for all educational and learning tasks. AI technology makes education easier to teach students by their aptitude, shifting the goal of education from high score too high quality (Deloitte, 2019). AI technology improves students learning efficiency via personalization. AI technology give lessons without the teacher. It reviews the students' performance and exam results based on big data and ML technology. AI enables wide connectivity, cross-campus resource sharing as well as remote access to advanced teaching resources.

The Industry 4.0 paradigm (Assante, 2019) is commonly accepted that the digital shift is an essential requirement for the companies' competitiveness. The Industry 4.0 paradigm is and all its connected technologies - Big Data, IoT, Artificial Intelligence, Cloud Computing, Machine Learning, Augmented Reality, etc. are quickly and deeply affecting the companies' organization and technical capability.

The concepts of SMART education has aimed to understand the perception of perceived ease of use towards perceived usefulness on SMART education. The Technology Adoption Model (Dinesh Elango, 2018) has been used to measure the concept focusing on perceived ease of use and perceived of usefulness. A smart education model (Meeyong Kim, 2012) is developed to be able to provide a guide in the field. It is a systemic education model consisting of interrelated educational contents, method, evaluation, and environment of Smart Education organically for education goal.

A secured and agile architecture of an Internet of Everything (IoE) based Educational Model and a Learning Analytics System (LAS) model using the concept of deep learning can be used to gauge the degree of learning, retention and achievements of the learners, and suggests improvements and corrective measures (Mohd Abdul Ahad, 2018). This architecture puts forward the advantages, applications and challenges of using deep learning techniques for gaining insights from the data generated from the IoE devices within the educational domain for creating such learning analytics systems.

In smart learning technology, learning is more connected to the real world; the learner is more active than the teacher. M-learning, digital pedagogy, social media, MOOC, OER, Edutainment, Blended learning and flipped classroom are some of the examples of smart learning technology. Anu Rawat, 2017 explained the smart learning approach, technology being used in it and its pros and cons.

Salem (2019) studied to determine and explore the benefits and advantages of such intelligent paradigms to increase the effectiveness and enhancing the efficiency of the smart tutoring systems. It is addressed the challenges faced by the application developers and knowledge engineers in developing and deploying such systems.

The major study question was how technology used to develop the efficiency and quality of smart education system. The researchers found that the analysis of the information system as an online learning support platform, improved quality of knowledge flow, and recommendations for advancing work-based learning besides the encouragement of efficient knowledge management technologies.

A. Existing Reference Architectures

A reference architecture for digital ecosystems is a step toward standardization, as it defines a set of guidelines in designing and implementing a digital ecosystem. Often such architectures are very abstract, difficult to understand and implement. Author (Alexandru Averian, 2018) introduced a vendor-and technology-neutral reference architecture for digital ecosystems and apply this architecture to an actual use case.

Smart Universities Reference Architecture (SURA) is a typical example of enterprise architecture reference models applied to the Universities business (SURA, 2019). It covers the four enterprise architecture domains: business, data, applications and technology within a university-specific architecture. The reference architecture is evolvable and is targeted to be continually updated to cope with recent and up-to-date advances in technology and educational standards and best practices.

A service-oriented reference architecture for smart cities (Clement, 2017) can tackle these problems and identify some related open research questions. The abstract architecture encapsulates how different aspects of the service-oriented approach span through the layers of existing city infrastructure. Additionally, the extensible provision of services by individual systems allows for the organic growth of the smart city as required. The above architectures were reviewed, compared and shown in Table- I.

Table–I: Comparison of existing Reference Architectures.

S/N	Existing Architecture/ Infrastructure	Alexandru, 2018	SURA	Clement, 2017
1	Automated Integration	√	√	√
2	AI, VR & AR	×	×	×
3	Blockchain	×	×	×
4	Business Intelligence	×	×	√
5	Cloud Computing/ Virtualization	√	√	√
6	Data Mining & Lake	×	×	×
7	Location & Context-Aware Computation	√	√	√
8	Edge Computing	√	√	√
9	High-Performance Computing (HPC)	√	√	√
10	Internet of Anything (IoA) & Everything (IoE)	√	√	√
11	Low Power IoT	√	√	√
12	Deep & Machine Learning Methods	×	×	√
13	Software-defined Networking (SDN)	√	√	√
14	4G, 5G and LTE	√	√	√
15	Service-Oriented Architectures (SOA)	√	√	√

B. Education Cloud

As the cornerstone of educational information, the developers have attached to the design of educational cloud data center. The educational cloud data center covers all aspects of hardware, software and services, achieving seamless integration that is convenient for the unified management, operation and maintenance of cloud resources. It optimizes its management by integrating educational application system resources, integrating and sharing basic data as well as integrating the decision support system. It provides school staffs with a safe working environment, creating a one-to-one teaching environment with better interaction between the teachers and the students. Smart Cloud Library stands as a powerful knowledge-sharing center, providing rich resources for the assistance of the students' learning.

The building of the educational cloud data center can help construct an agile and flexible education cloud share platform with high efficiency and quality, allowing every student to have an equal chance of accepting education and to enjoy a good education, and making quality education stand by your side.

C. Design of Smart Education System

The design of smart education system on campus is an informatization project integrating management, mechanism and technology. *Management* is the source of control, business is the source of service, data is the source of basis, and information standard is the source of guidance. Information standards are a necessary condition to realize application service, automation service, data sharing and information exchange service.

- *Application Service.* The application service is important for the construction of a smart education system. It provides educational business service modules, including management and service modules such as educational administration, academic, scientific research, finance, student affairs, recruitment, personnel and logistics. The other services are including user management, business functions, authorization, log audit, identity authentication, reports, data exchange, inquiry statistics, workflow, information, institutional framework and network community.
- *Automation Services.* AI technology makes education easier to teach students by their aptitude, shifting the goal of education from high score too high quality [Deloitte, 2019]. Through the application of AI technology, educational institutions can provide personalized solutions, and thereby improving their learning efficiency. AI technology will disrupt traditional education from the three aspects of quality, efficiency and equality.
- *Centralized Data Service*. The centralized data service can be realized by building a unified data sharing, interaction center, uniformization of information portal, digital identity and single-sign-on. Data service can provide educational institutions with comprehensive and accurate data, data exchange between systems, provide a unified authentication service, and provide a unified and sharing data support platform. A shared data center can be established based on big data and cloud technology.
- *Information Service*. The information service system is operated on the data storage and exchange platform. This provides strong support for decision-making of all kinds of managing staff in higher educations by providing an accurate and effective comprehensive system for inquiry, report generation system and information filling system. The information service is designed based on a big data platform.
- *Network Service.* The network service is important for the construction of a smart education system. This service integrates various types of networks on campus and ensures the network and communication for different application services within the smart campus system. Use of cloud services can be effectively used for teaching, scientific research, management and living purposes, allowing them to enjoy the convenience of cloud computing services.

- *Security Service*. The security service involves physical security, operation security and information security. Various security services include operating system and application system security, network security, data and communication security, virus and Trojan prevention, encryption, identity authentication and access control.

With the rapid advances in IT as well as the increasing level of dependency on other higher education functionalities, sets new challenging goals for future modern education. Agility and flexibility are required for modern educational institutions. This expected to rely on a large ecosystem of systems where collaboration at large-scale take place. Intelligent and scalable architecture is required to provide connectivity between these silos, enabling discovery of physical sensors and interpretation of messages between the things. In addition, a gateway enabled architecture to provide interoperability between systems, which utilizes established communication and data standards.

IV PROPOSED ARCHITECTURE

This section describes the proposed reference architecture that includes requirements, architectural decisions, smart education model and architecture, challenges and finally evaluated with a set of parameters.

Smart education aims at providing holistic learning to students using modern technology to fully prepare them for a fast-changing world where adaptability is crucial. Smart education use state-of-the-art technology helping educational administrators, parents, recruiters, learners and teachers. A smart education can be done in a virtual or physical environment. It can be summarized as the use of smart devices to augment the learning outcome of traditional education. By using advanced learning methods such as online virtual classrooms, virtual learning environment, cloud servers, smartphones etc. a teacher can help students gain more out of their learning.

A. Goal & Requirements

The goal of the smart education reference architecture is to enable the stakeholders and other educational institutions to access the educational services in effective & efficient integrated Services delivery to the stakeholders anywhere, anytime with the Internet. It enables stakeholders to participate in educational policies framing and decision making, enhanced transparency, empowerment and less corruption. There smart education ecosystem [Smart Tampere, 2017) themes are analytics, connectivity, security, sustainability and user experience.

Analytics is unlocking the value of data lakes by analytics of things. It is increasing and improving fact-based decision-making capabilities and finding new application areas. Digital *connectivity* is the foundational infrastructure of each theme. It is enabling and expanding the usage of data for all possible use cases and places with high data speed and security. *Security* is the living environment but also of the information networks and personal data. *Sustainability* is the ultimate results and it acquires the technology. *User experience* is empowering and inspiring stakeholders by optimizing the human-technology interaction. It utilizes Virtual and Augmented Reality in smart education. Also, today modern learning requires that the learning can take place anywhere and anytime; and learning can use other educational institutions facilities to make learning more engaging.

To propose a smart education model, it is analyzed a broad range of smart education requirements. The requirements can be both *functional* and *non-functional*. The functional requirements are registration, access to contents, generating reports, analysis, collaboration, assessment, security, etc. The non-functional requirements are agility, availability, flexibility, interoperability, maintainability, performance, reusability, scalability, usability, etc.

Agility supports learning management demands easily and quickly. *Availability* must be robust enough to serve the diverse needs of huge numbers of learners, administrator, teachers and instructors simultaneously. *Flexibility* is concerned with the ability to change the functionality of an e-learning system because of the changing requirements of the customer. Changing functionality should be possible to add, remove or change components to the solution without being forced to rebuild the complete architecture of the solution. *Interoperability* requires industry standardization of formats, protocols, services and the ability to exchange data and request functionality.

Smart education solution needs upgrading and maintenance. *Maintainability* is the ability to upgrade quickly and cost-effectively. *Performance* is the ability of the components that comprise the solution to respond promptly. The performance is expected that all users of the solution consistently enjoy the good performance. *Reusability* refers to the learning contents are highly reusable with other educational institutions. *Salability* deals with short-term growth and long-term growth. The infrastructure of an e-learning system should be able to expand or scale to meet future growth, both in terms of the volume of courses and the number of learners. *Usability* is especially important for the end-users of smart education as they are responsible for performing day-to-day tasks using the solution. The above requirements (both functional and non-functional) have an impact on one another.

A robust smart education architecture should have the features of presentation/channels, analytics and automation, data platform, integration, enterprise applications, infrastructure, security and risk, Modular, adaptive, flexible, and intelligent and

B. Architectural Decisions

The quality of education has become the focal point in the design of smart education system. The key architectural decisions included in this architecture are central platform, use of open standards, integration with existing systems, platform independence, smart education model, core education applications, security, central database architecture, service-oriented approach, etc.

Its focus on key principles that foster a connected and consumer-grade experience for anyone who interacts with the

smart education system. They are (i) intuitive and simple to use; (ii) design thinking and persona-centric; (iii) Modular, adaptive, flexible, and intelligent; and (iv) adaptable and scalable.

i. *Adaptable and scalable*. The smart education system allows HEIs to collaborate with peers and scale massively. A smart campus solution allows for global scalability to meet the HEI's goals. The solution can be able to leverage digital tools and technologies to provide data-driven experiences while enabling access and scale.
ii. *Design thinking and persona-centric*. Interaction with the platform should be touchless and enabled by multiple interfaces including video, voice, gesture, touch, etc.
iii. *Intuitive and simple to use*. In the technology world, students are digital natives, and other higher education constituents shall interact with a system that is instinctive and effortless to use.
iv. *Modular, adaptive, flexible, and intelligent*: Smart education needs and the technology to support them will constantly evolve. A smart campus solution can use a domain-driven design architecture that would be based on microservices that guide smart campus transformation.

The above quality factors common in all design is the importance of interconnectivity and the benefits it provides.

C. Technology Capabilities View

The smart education system is flexible enough to house any additional future innovative technology services. The technology capability view shows the capabilities of the underlying technology platform to support the schools and colleges/universities, collaboration, data management and managing mission-critical operations. Some of the modern technologies that are used to support smart education services are listed below.

For example, *Artificial intelligence* (AI) is stirring up exciting changes and digital humans are leading the way in brand and customer experience, beyond what can be accomplished by a mere chatbot. Smart education needs to use *biometric technology* in customer service. This technology protects the bank from financial losses caused by cheaters. The customers can use this type of authentication when logging into their account to ensure the safety of their savings. *Big data & analytics* is used to handle huge volumes of data generated by smart banks. *Blockchain* allows for verification without having to be dependent on third parties.

Cloud computing technology provides bank software service, platform service, storage service, etc. *Data Mining & Warehousing* is used to find the patterns in the customer's transactions in smart education. *Internet of Things (IoT)* collects the data from the smart devices installed in the smart education, store and process in the bank cloud. *Machine learning (ML)* & *Deep learning (DL)* technologies are used to avoid human intervention in smart education. *Mobile technology* provides a platform to send messages, e-mails, sensor, and mobile. *Software-Defined Network (SDN)* may be considered the priority of a transaction request. This minimizes the response time to provide priority-based transaction.

As a result, today's customers have the chance to contact the bank and manage their accounts through smart devices. This technology capability view is intended to highlight the capabilities of the smart education platform and serve as a reference in enterprise planning.

D. Smart Education Model

Regarding technology acceptance, general structural model (Huang et al. 2007) aims at verifying whether their extended Technology Acceptance Model (TAM) could be used to predict learning acceptance at a higher education level (Dinesh Elango, 2018). The contribution of this model lies in its focus on learning in the technology context, and its learners' acceptance of the emerging technologies as tools for learning. The use of TAM helped to explain and to predict learners' acceptance the technology-enabled learning at the higher education level. The proposed smart education model is shown in Fig. 2.

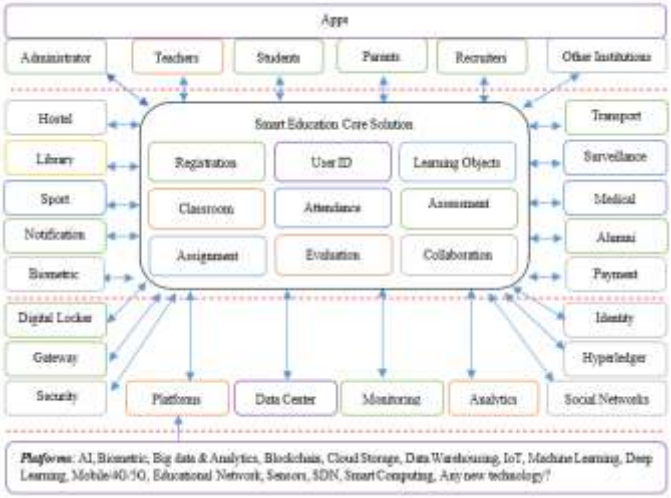

Figure 2. Smart Education Model

The *end users* are students, teachers, staff, content creators, educational administrators, parents, recruiters, verifiers, researchers, other educational institutes, governing bodies, etc. The end-users are interested to register or unregister in the core education solution. The end-users have a seamless experience if it comes to the usage of the different modules of the solution. The end users can connect to a smart education system through Apps, Gadgets, browsers, etc.

The *applications servers* include an educational portal, LMS, gateway, data warehouse/ data lake, content storage, blockchain contracts, notification, publish & subscribe, monitoring, digital identity, etc. The *data providers* are digital locker, unique identity (Aadhaar in India), gateways – SMS, e-Mail, Payment, etc. Hyperledger, security, data center, analytics, research network (ResearchGate, Academia, Google Scholars,e tc.), social networks data. The *infrastructure* supports various modern technologies required to deploy smart education solution,

cloud storage, virtualization, educational networks, research networks, mobile network, etc.

In a smart education system, the students can learn actively, interact with teachers and learn from any time and anywhere. The teachers get more opportunities for advancement, the study of outstanding teachers teaching experience and enrich the teaching contents, stimulate students' enthusiasm. The educational institutions can improve the management level and efficiency, provide a basis for decision-making and save money, reduce operation cost. The smart management system includes student management, academic management, and teacher management and decision support systems. In student's management, educators could use the student management system to manage the student's information etc. enrollment, attendance and score management.

The decision support system has statistical analysis in three dimensions - teaching, students and resources. The teaching includes teaching quality, teacher evaluation, exam analysis, graduation statistics, semester statistics, excellent rate, course statistics, etc. The student includes sex statistics, classroom statistics, score statistics, student growth curve, regional statistics, health statistics, etc. The resource includes resource growth statistics, resource popularity, resource usage statistics, and course statistics.

E. Smart Education Services

A lot of smart services have been identified during the study and these services have been incorporated in the proposed solution and discussed below.

- *Analytics-as-a-Service (AaaS).* The educational data have been collected and stored large amounts of data. Educational organizations that need to carry out more analytics may need many more additional servers, amongst other kinds of expensive hardware. AaaS helps to bypass these new costs and business requirements. AaaS can use Web technologies to carry out educational analysis (Palanivel, 2018) opposed to the traditional method of developing an onsite hardware warehouse to collect, store, and analyze the data.
- *Blockchain-as-a-Service (Baas).* BaaS service allows business organizations that are trying to get started with this burgeoning technology. The educational institutions may make the BaaS more useful for business customers (Palanivel 2019b).
- *Cloud-as-a-Service (CaaS).* Cloud services are offered by integrating education applications, servers, networks, and services based on demand to educational users. CaaS can be easily scaled up or scaled down in response to demand peaks and troughs. Cloud services fall into three basic categories. They are Software-as-a-Service (SaaS) model**,** the Platform-as-a-Service (PaaS) model and Infrastructure-as-a-Service (IaaS) model**.**
- *Education-as-a-Service (EaaS).* EaaS offers students an alternative to more expensive programs and it helps businesses and HEIs, making it a revolutionary model for technology-enabled education. Many educational institutions make the transition from simply selling courses to providing educational content 'on-demand' within the next couple of years. EaaS allows students to gain accreditation by choosing modules that are relevant to their career goals and only paying for what they need. The EaaS model enables academic institutions and businesses to utilize courses that align with their offering without having to purchase excessive learning materials in its program. The EaaS model needs to deliver customized learning opportunities for students. EaaS acts as a smart agent between students and teachers (Siddharth Shrotriya, 2018). This EaaS has more number of cloud service providers such as educational institutes, content publisher (teachers) and content subscribers (Students).
- *Gateway-as-a-Service (GaaS).* GaaS integrates data such as SMS, e-Mails, payment, data exchange, etc., with smart education solution. It develops necessary applications to send mass data to groups/individuals, wherever required. It is envisaged that the educational institutions propose to leverage smart education solutions for this purpose.
- *IoT-as-a-Service* (IoTaaS). With the development of IoT, many educational organizations are designing their businesses model in a more flexible and scalable way. As the Internet became more readily available and reliable, the educational organizations realized that they could reduce costs by accessing applications located in the Data Center. IoT solutions are designed to provide a smart education solution with an inexpensive way to utilize IoT (Palanivel 2019a). This IoT value contribution could be better ongoing or preventative maintenance on appliances or physical assets.
- *Monitoring-as-a-Service (MaaS).* MaaS is the provisioning of security service primarily on business platforms that leverage the Internet to conduct business. Monitoring involves protecting educational organizations or end-users from cyber threats. Many educational organizations monitor their security environment, server logs, and other information assets to ensure the integrity of these systems. MaaS help to protect critical information assets of their end-users.
- *Notification-as-a-Service (NaaS).* Notification service pushes the uploaded learning content to subscribers (students) according to students' configuration in the customized module of the Learning Portal system. Subscribers (students) can acquire the resources they need at the best time, which greatly enhance the efficiency of digital resources and the quality of e-Learning service. NaaS pushes the appropriate subject navigation database resources to subscribers (students) according to subscribers (students) classes registered. NaaS reduces the complexity of the communication

between publishers (teachers) and subscribers (students) and realizes the asynchronous communication.

- *Publish/Subscribe-as-a-Service (PSaaS).* PSaaS is scalable message-based communication mechanism decoupling sender (teacher) and receiver (student), that can be used both to communicate entities of the same application or different and heterogeneous services. This paradigm is used for building smart education solution composed of dynamic entities that produce and consume data events according to complex and unpredictable workflows. Publish/Subscribe offers an indirect, decoupled communication model between smart education components that act as either publisher of, or subscribers to, data. It is then the responsibility of the publish/subscribe system to appropriately route each content publication towards all students (subscribers) with matching interests, as expressed in their respective subscriptions.
- *Registration-as-a-Service (RaaS).* The RaaS allows users to register or unregister for virtual learning. This service updates the existing registration information. This service allows learners to register for specific events and producers from publishing certain events that reach a specific number of learners.
- *Security-as-a-Service (SecaaS).* SecaaS handles and manages security to the educational organizations and end-users. With SecaaS, security solutions are no longer delivered locally. The SecaaS installs virus protection, spam filtering, and other security tools on each machine, the network and server in the educational organization. SecaaS allows educational organizations to use the same tools using only a Web browser, making it direct and affordable.
- *Technology-as-a-Service (TaaS).* TaaS represents an enormous opportunity for both service providers and users or consumers who rely on their services. TaaS allows consumers (end-users) to access technology on-demand. Instead of purchasing large technology assets to grow into, an educational organization purchases access to technology resources that meet the current need. If needs change, access can be scaled up or down with the demand. TaaS decrease time to innovation, reduce costs, scale storage and computing needs, improve uptime and expand their technology footprint around the world. From a development perspective, building code that is both technically scalable and allows for development scalability is another key to a successful transition. Besides, importantly, TaaS does not remove the need to monitor compliance and security.

All the above smart education services are registered in the service registry as mentioned in SOA.

F. Smart Education Architecture

To fulfil the above requirements for smart education solution a multi-layer architecture is proposed. This architecture is suitable for smart education solutions development and integration with other requirements. The multi-layer application architecture is characterized by the functional decomposition of device integration, educational applications, service components and their distributed deployment. As shown in Fig. 3, the multi-layer architecture consists of the smart presentation layer, smart application layer, smart data layer and smart infrastructure layer. The proposed multi-layer architecture for smart education is designed with emerging technologies including smart computing architecture.

Smart Presentation Layer. The smart education app layer uses apps, gadgets, chatbots, channels, tools and methodologies to improve user efficiency. The smart devices have rich end-user functionality through a consistent, secure and well-managed infrastructure. They allow educational institutions to explore new access channels and devices to reach learners in any situation. This layer enables many emerging technologies in smart education to one that is more interactive, insightful, and collaborative. Educational applications deliver expanded functionality including real-time insights, collaboration, communication and social networking capabilities. The client comprises of smart education suite, common business object, and components. There are external third-party applications for integration on the parallel level.

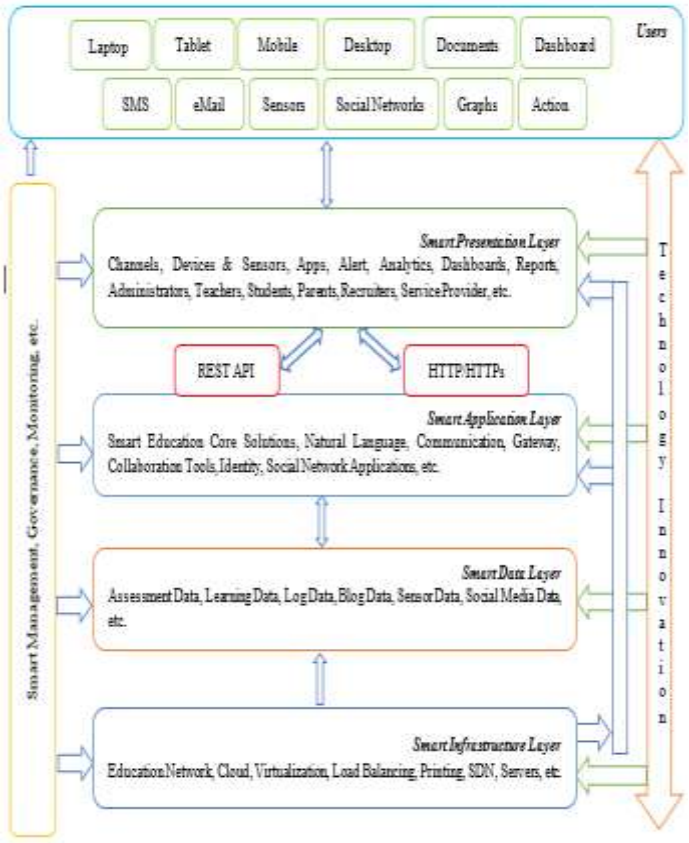

Figure 3 Smart Education Architecture

Smart Application Layer. The smart application layer contains functional business logic, which drives smart education core capabilities. This layer may also be referred to as the business logic tier. This layer contains the business logic that supports the smart education application's core functions. This layer can be hosted in the education cloud as required by the educational application. The smart application layer serves to map the business layer into the format which each user or application wants to consume the data and services. This layer creates views with different alias names that match the way the learners and their data.

Smart Data Layer. The smart data layer contains gather data generated from various sources such as core solution, Web media, sensors and transactional data, social data, etc. It integrates different types of data and deals with improved reliability, availability, and accessibility by messaging and shared information between different resources. This layer contains database functions for flexibly storing and processing massive amounts of data. The distributed data store realizes the processing of massive amounts of data that realizes high scalability and flexibility are contained in this layer. The smart data layer enables access to the local database, document vault and other third-party systems, which hold the core educational data.

Smart Infrastructure Layer. The smart infrastructure layer supports teaching and research, optimizes service quality and enables unified decision-making. The smart infrastructure layer is established with both wired and wireless networks, cloud, virtualization, servers, SDN, etc. It provided integrated transmission of multiple devices using the Internet, Wireless, RFID and IoT technologies. Intelligent technologies ensure the safety of students, teachers and staff on campus. The Intelligent technologies facilitate the management of assets, attendance of student, staff and teachers, transport or vehicle movement and their locations.

The proposed architecture offers many advantages over traditional educational architectures. It integrates smart education systems and all related to the offered degree of reusing including high reusability, efficient integration, avoiding redundancy, service sharing and information sharing, easy to define and update educational services, high agility, easy accessibility and high availability. The benefits also include the speed of development, scalability, performance, and availability.

G. Results and Discussions

The proposed architecture helps to improve *development efficiency* by allowing teams to focus on their core competencies. *Scalability* is another great advantage of the above multi-layered architecture. This allows load balancing in each layer independently, improving overall performance with minimal resources. By having disparate layers, it can *increase reliability and availability* by hosting different parts of business application on different servers and utilizing cached results. The proposed architecture is compared with some existing architectures and shown in Table II.

Table – II: Comparison with existing Reference Architectures

S/N	Existing Architecture/ Infrastructure	Alexandru, (2018)	SURA (2018)	Clement, (2017)	Proposed Architecture
1	Automated Integration	√	√	√	√
2	AI, VR & AR	×	×	×	√
3	Blockchain	×	×	×	√
4	Business Intelligence (BI)	×	×	√	√
5	Cloud Computing/ Virtualization	√	√	√	√
6	Data Mining & Data Lake	×	×	×	√
7	Location & Context-Aware Computation	×	×	√	√
8	Edge Computing & Smart Computing	×	×	√	√
9	High-Performance Computing (HPC)	√	√	√	√
10	Internet of Anything (IoA) & Everything (IoE)	√	√	√	√
11	Low Power IoT	√	√	√	√
12	Deep & Machine Learning Methods	×	×	√	√
13	Software-defined Networking (SDN)	√	√	√	√
14	4G, 5G and LTE	√	√	√	√
15	Service-Oriented Architectures (SOA)	√	√	√	√

Among the different challenges, the most critical difficulties identified with smart education architecture are bandwidth, workforce, interoperability and privacy & security. The challenges of the proposed architecture are shown in Table-III.

Table-III: Challenges of the Proposed Architecture.

S/N	Challenges	Explanation
1	*Availability*	Availability, processing and presentation of data are one of the biggest challenges faced by the educational organizations.
2	*Cost*	The cost involved in setting up of the proposed architecture with IoT can be a major overhead in small educational institutes.
3	*Data Formats.*	The sensors capture a huge amount of data in different formats.
4	*Data Generation*	The devices in smart learning environment capture and generate data at a very fast rate may be a challenging task.
5	*Data Mining*	The architecture allows to store huge volume of data, classification, clustering, data cleaning, pruning etc. plays a vital role.
6	*Data Storage*	The architecture should be able to store the huge volumes of learning data produced by the teachers and learners.
7	*Data Types*	Since it supports multiple devices including sensors, the architecture should be robust and handle heterogeneous data types.
8	*Network Latencies*	Since the architecture relies on the connection of a large number of components in a smart learning environment, the network latency is obvious.
9	*Security.*	Security remains the primary concerns for handling a large amount of data in each layer.

H. Evaluation

Based on the above-mentioned requirements and features, the proposed reference architecture evaluated and shown in Table-IV below:

S/N	Requirements/Features	Availability	Rating
1	Architectural patterns used	Yes	Medium
2	Context & Location Awareness	Yes	Medium
3	Cost Range	No	High
4	Digital Identity	Yes	High
5	Hardware Size	Any	Low
6	Number of Connected Devices	Any	High
7	Range of the Physical Devices	Limited	Low
8	Data Reliability	Yes	High
9	Data Storage	Yes	High
10	Data Visualization	Yes	High
11	Device Management	Yes	High
12	Data Management for Huge Volumes	Yes	High
13	Adaptability/Flexibility	Yes	High
14	Heterogeneity	Yes	High
15	Interoperability	Yes	High
16	Open Source	Yes	Medium
17	Scalability	Yes	High
18	Security, Privacy and Integrity	Yes	High
19	Compatibility with emerging Technology	Yes	High
20	SOA approach	Yes	High

I. Use-Cases

ViewSonic [ViewSonic, 2019], a next-generation solution for smart education offers a wide range of innovative display solutions for next-generation teaching and learning. ViewSonic's education solutions transform classrooms into immersive learning environments and enable teachers and students to connect and collaborate. ViewSonic believes interactive learning is an all-encompassing approach to education. By emphasizing student engagement with new material, interactive class structures are more holistic.

VI CONCLUSION & FUTURE ENHANCEMENTS

This research article provided an overview of smart education system. A smart education system featuring information collection, resource sharing, application integration and comprehensive operation can be built to meet the increasing demands at all levels in higher education. It is analyzed that on the unified smart education platform, highly efficient campus management and intelligent teaching process could be realized to improve the well-being of end-users. Various emerging technologies were successfully applied to improve teaching quality in HEI. These technologies analyzed the behaviours of students in a campus network and public opinions, which would effectively promote the in-depth integration of technology and teaching.

This article started by researching common requirements from literature and identified relationships between those requirements. Based on this requirement, it is a reference architecture including a functional and a more implementation-oriented view and discussed different technologies and how they can be applied to components within the reference architecture. The evaluation gave a good indication that the reference architecture is a proper fit for space, relevant and provides utility for designing systems within the space. The proposed architecture is more evolutionary than revolutionary adding components and technology to the core of enterprise smart education to tackle the new challenges resulting from the newly emerging architecture above. As a future work, it is proposed to introduce smart computing reference architcgture to introduce integrated smart education system.

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