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A COMPARATIVE ANALYSIS OF SMART EDUCATION HUB IN TERMS OF COST-EFFECTIVE INFRASTRUCTURE MODELLING AND SYSTEM DESIGN

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Abstract

Smart education hub has drawn more attention as a term to define education in the digital age. Framework for smart pedagogy encompasses mass-based generative learning, group-based collaborative learning, individual-based individualized learning, and class-based differentiated instruction. This paper gives a conceptual framework on Smart Education Hub integrating Smart City features synchronizing with Education 4.0 aligned to Industry 4.0. The development of smart learners who need to master the knowledge and skills of 21st-century learning is suggested using a framework of smart pedagogies and ten essential elements of smart learning environments. The paper also gives in depth explanation of all the segments of SEH and a technical comparison of existing `SEH cases focusing their strength and weak points.

Keywords: Design, modelling and framework, Education 4.0, Smart campus, Smart city, Smart education hub.

1. Introduction

Humans have yearned for better comfort as they have evolved, which has prompted them to seek out information and technologies. A smart city is made up of sophisticated computational technologies that enable it to keep track of all of its citizens and infrastructure, handle any crises, and come up with solutions. Additionally, smart cities guarantee that intelligent inhabitants participate in advancing governance and the economy through innovation and entrepreneurship. Smart Education Hub is one of the most important elements of smart city planning [1-4]. For students, the learning experience has become more thorough and straightforward thanks to these advancements.

Today's Information Technology (IT) emphasis is on transforming schools and universities through certain key themes like adaptability, decision-making, and student outcomes [4-7]. ICT and contemporary education allow for customization and customization based on the needs of the pupils. Institutions of higher learning (HEI) have begun to use contemporary technologies to enhance productivity, transformation, completeness, and social experience. Today's HEI must overcome obstacles to digital equality advancement [7-10] and organizational model adaptation to advance the workplace of the future.

Still there are some gaps in the developed system for smart education hub and the modelling is a new technological concept which is implant to education4.0. There are isolated works in protype level has been done in different countries and different universities and education hubs. But a combined data in a comparative more have not been yet conducted. In addition, low-cost infrastructure modelling to develop the smart education system in developing countries or rural areas also is a time needs which is not observed in a systematic processing in a general research sector in this field.

The main objective of this research is to fill up the gap. The following sections provide a technical investigation of the linked study areas for the development of smart education hub; A conceptual framework for research on smart education as well as the framework of smart education hub are proposed with diversify segments. Therefore. the objective of this research is to provide the technical investigation of the linked study areas for the development of smart education hub; A conceptual framework for research on smart education as well as the framework of smart education hub are proposed with diverse segments.

A research framework for smart education hub is also shown. Furthermore, the importance of smart computing is illustrated along with the technological framework for smart education. In order to motivate academics and educators who are interested in designing and developing smart education, the difficulties of facilitating smart education are finally given.

2. SEH: Smart Education Hub

Smart Education Hub is the educational institute aligned to Smart City Planning along with the implementation of Education 4.0. There are three important segments to classify the features of SEH- Physical Layout, Network and Security and Teaching Learning Methods considering the post-Covid scenario.

3. Physical Features of SEH

3.1. Segment 1- Smart Environment and Monitoring:

3.1.1. Sensors:

A sensor is a device that detects input of any kind from the physical world and reacts to it. They make it feasible to develop an ecosystem for gathering information about a particular environment. We can use earthquake sensors, temperature and humidity sensors, smoke sensors, and other sensors to create a smart environment and monitoring.

3.1.2. Integrated Software:

Integrated software is a group of applications created to cooperate. All programs contained in an integrated bundle are accessed via a single launcher.

3.1.3. Actuators:

A machine's actuator is a part in charge of moving and directing a mechanism or system.

3.1.4. Waste management:

An organization's approach for disposing of, reducing, recycling, and preventing trash is called a waste management system. Recyclables, compost, waste to energy, landfills, incineration, bioremediation, and waste minimization are all potential waste disposal techniques.

Figure 1 represents the segment 1 of the Smart Education Hub as follows.

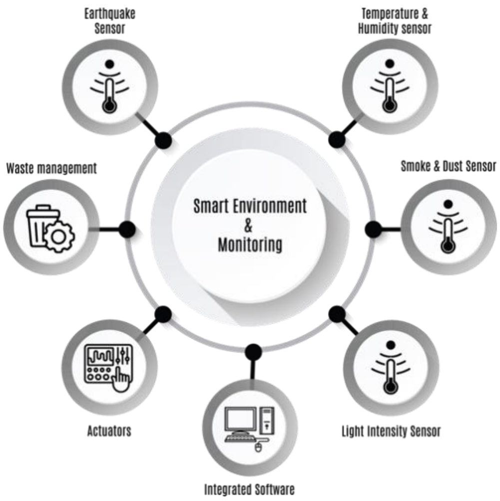

Fig. 1. Physical layout of SEH- Segment 1.

3.2. Segment 2- Smart Campus Economy:

3.2.1. Banking Facilities:

A user can also use internet banking to carry out financial transactions over the Internet. For students, having access to internet or mobile banking is a necessity.

3.2.2. Financial Record Portal:

Each student will have a separate financial dossier maintained by the authority. All documents must be uploaded to the integrated financial record system and be current.

3.2.3. Financial Audit:

The authorities should check each student's individual files using the integrated financial record portal. The technology would immediately alert the concerned person.

Figure 2 represents segment 2 of SEH (Smart Education Hub) as follows.

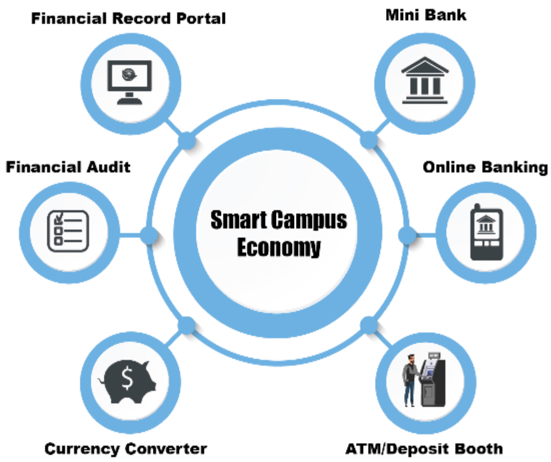

Fig. 2. SEH- Segment 2 (Smart Campus Economy).

3.3. Segment 3- Smart Living and Smart Operation:

3.3.1. Campus Facilities Access Control:

Student and department will be able to book or take the access permission of swimming pool, auditorium, gym, sports field etc. online or remotely.

3.3.2. Smart and Self-Service Library:

Authorized individuals may have the access of a smart library 24/7.

3.3.3. Smart utility Control System:

Electricity, Water etc. usage will be controlled according to the presence and necessity of people to minimize the percentage of Waste.

3.3.4. Faults detection and indication system:

Any faults in any part of the campus will be detected to avoid any kind of accident. (Leakage in water line, faulty sensors, damaged infrastructure)

3.3.5. Smart Locker:

For students, faculty and staff there may be a smart locker system, also could pls be door locker.

3.3.6. Smart Helping robot:

Smart Robot Helping system could be an impactful facility for smart campus, such as we may use in our lab for critical circuit fabrication**.**

Figure 3 shows the layout of segment 3 of Smart Education Hub.

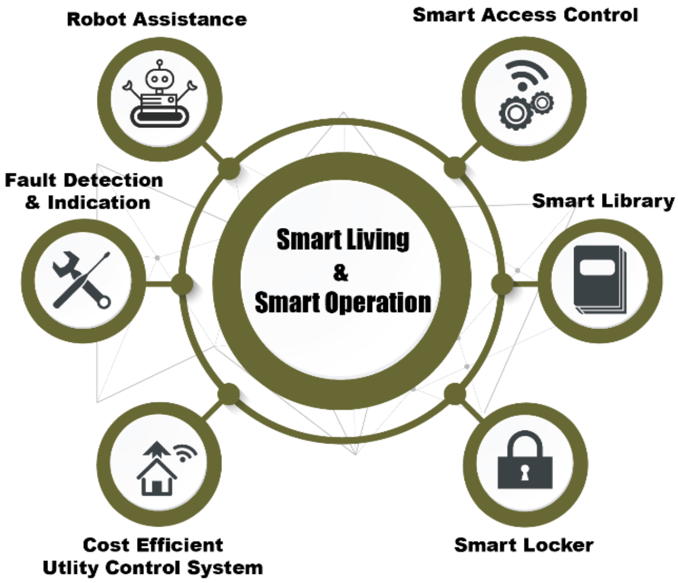

Fig. 3. SEH- Segment 3 (Smart Living and Operation).

3.4. Segment 4 of SEH- Smart Mobility and Traffic Management:

3.4.1. Transportation Facility:

All campus buses and minibuses must be tracked in real time. Each vehicle's departure and arrival times need to be updated through an internal traffic management system.

3.4.2. Parking Assistance:

There will be separate parking areas for registered and unregistered vehicles. Unauthorized vehicles will be directed to the parking lot by an automated system**.**

3.4.3. Internal Campus Transportation Facilities:

For student mobility, there may be transportation facility on campus, such as authorized bicycles**.**

Figure 4 indicates the 4th segment of SHE, the details of which are given as follows.

Fig. 4. SEH- Segment 4 (Smart Mobility and Traffic Management).

3.5. Segment 5 of SEH- Network and Security:

3.5.1. Biometric Authorization:

For automated attendance reporting, biometric authorization will be used for both staff and students.

3.5.2. Central Announcement System:

For any type of emergency alert or the central announcement, there should be both a central announcement system and individual speakers available in the campus.

3.5.3. Data Security Management:

Any type of student data should be protected from illegal access and corruption while in the custody and use of the campus, to the authority.

3.5.4. PABX Line:

An internal PABX (Private Automatic Branch Exchange) line should be available for communication and emergency purposes.

3.5.5. Internet Router and Wi-Fi Access:

The campus must have constant connectivity to the internet in order to ensure smart education.

3.5.6. Security Management:

For campus security and to prevent any unwelcome situations, motion sensors, fire alarms, and CCTV must be installed in the campus.

Figure 5 above indicates the network and security control system of SHE, segment 5.

Fig. 5. SEH- Segment 5 (Network and Security).

3.6. Segment 6 of SEH- Hybrid Teaching and Learning:

3.6.1. Internet of Things:

International Smart education efforts are made possible by the new Internet of Things (IoT) applications. Through the use of vast real-time data streams, it allows for the remote monitoring, management, and control of equipment as well as the production of fresh insights and useful information [1, 2].

3.6.2. Digital cloud – big data handling:

A cloud-based education platform also facilitates easier physical and online resource access [3, 4].

3.6.3. Flipped Classroom:

An example of blended learning is the "flipped classroom," where students are given the material at home and practice using it in class**.** Video lessons can be viewed online or on a DVD or flash drive [5, 6].

3.6.4. Web 2.0:

Web 2.0 refers to websites and apps that employ user-generated content to provide value to end users [7, 8].

3.6.5. Extended Reality:

The phrase "extended reality" refers to any real-and-virtual mixed settings and interactions enabled by digital technology and gadgets [9].

3.6.6. Learning Management Systems:

A learning management system (LMS) is a software program or web-based technology that is used to organize, execute, and evaluate a particular process of learning [10, 11].

3.6.7. Smart Glasses:

Smart glasses enable the incorporation of smartphones and computer capabilities, graphics, and wireless networking into eyeglasses **[**12,13**].**

3.6.8. RFID:

Radio Frequency Identification tags are a sort of tracking system that searches, identifies, tracks, and communicates with goods and people using radio waves [14, 15]**.**

3.6.9. Remote Classroom Access:

Remote learning occurs when the teacher and the student are not physically present in a traditional classroom setting [16, 17].

3.6.10. Interactive Display:

An interactive display is a wall-mounted gadget that allows users to create spectacular visual demonstrations and manipulate on-screen content using digital touchpad gestures [18].

Figure 6 explains the last segment of our SHE research finding that is the blended learning with flipped classroom - hybrid teaching and learning interface.

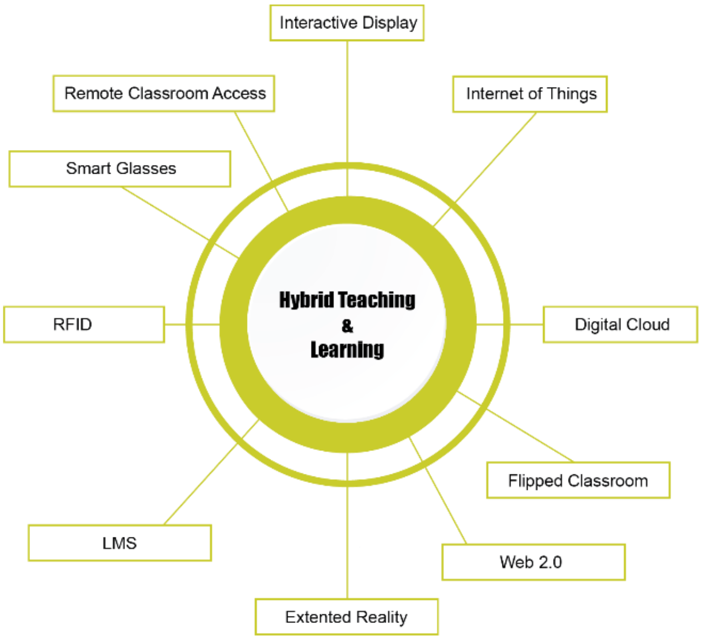

Fig. 6. SEH- Segment 6 (Hybrid Teaching and Learning).

4. Global Case Analysis of SEH

Galimullina et al. [11] in Universitas PGRI Yogyakarta, Indonesia developed a smart campus framework with regards to education, parking and room management. The smart education platform uses an online system for asynchronous learning and teleconferencing when face to face interaction of student-teachers is necessary. This kind of virtual class with live video is useful for practical lessons. The authors designed a university smart parking system for their three parking lots. Cameras and ultrasound sensors at the entrance of the parking lots are used to detect the entry and exit of each vehicle. This information is used keep track the total number of vehicles and subsequently the number of available parking spots which is displayed on a notice board for the users. The smart campus framework also uses PIR sensors, cameras and RFID for tracking students and for presence detection in relevant rooms. Student tracking information is kept in a database and the presence information is used to automatically turn on and off room lights. The strength of this framework is that it is very simple to implement with readily available technologies. But at the same time it does not add many features which makes it difficult to justify its implementation. For example, the presence detection for automatic light switch can be achieved using PIR switches which does not need IoT or internet connectivity.

Celdrán et al. [12] in University of Modena and Reggio Emilia, Italy developed a speech interface app using Amazon Alexa voice assistant for accessing relevant information from the departmental website. The main objective was ease of access to existing information such as class routine, exam schedule, faculty office hours etc. Speech development using Alexa requires designing the vocal keywords, context, answers and prompts. The strength of the speech interface is that most students in the survey preferred the voice assistant method of retrieving said information than using the website. Visually impaired students especially benefitted from this approach. But one of the weaknesses of this interface is that it would take similar effort and time to update the interface when new categories are added on the website. Khan et al. [13] in Instituto Superior Técnico, Lisbon, Portugal designed a software abstraction layer over a wide variety of vendor hardware and software for controlling HVAC and lighting of different parts of the campus.

Figure 7 shows the architecture of the speech interface of the project.

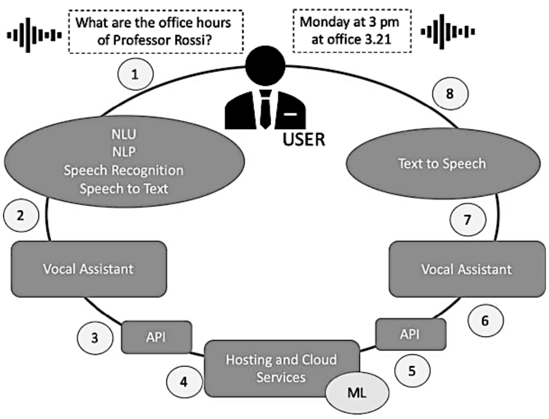

Fig. 7. The architecture of the Speech Interface.

The objective of the project was energy efficient control of lighting, air conditioning and other classroom equipment in the campus library, auditorium and a group of offices. For this purpose, different sensors, web app and user comfort level and intention feedback were used to intelligently and efficiently control lighting and indoor temperature. The authors first conducted surveys with all stakeholders to design the system. The software abstraction layer used daylight sensors for efficient use of natural light where possible. User feedback of comfortable temperature and lighting in addition to occupancy was used to automatically adjust the HVAC and light fixtures. Feedback from faculty and staff was used to further improve the control software. The strength of the software control abstraction for lighting and HVAC control was the achievement of improved energy efficiency and user comfort in spite of a wide variety of hardware vendors. But the projects weakness is that the return on investment of the smart system compared to the savings is quite high which may be improved with better algorithms.

Khan et al. [14] in University of Bologna, Italy developed an interactive kiosk to display the map and real time data of a new building of the campus. The project consists of sensor, database, web server and data visualization layers. The sensors collected several environmental parameters such as temperature, pressure, humidity, lighting, CO_2, noise level, occupancy etc. which were stored in the database layer and displayed in the kiosk. The 2D map layout of all the floors in the building was developed using open-source software in SVG format which showed all relevant information such as classroom locations and other points of interests. Although a search option was available, but students mostly used the touch based visual method. The strength of the interactive map is that students preferred the touch based visual method.

Figure 8 shows the finding analysis of smart education hub segments in a combined platform which is hereby indicated as the proposed framework of the SHE for Education 4.0. Followed by proposing the framework of SHE.

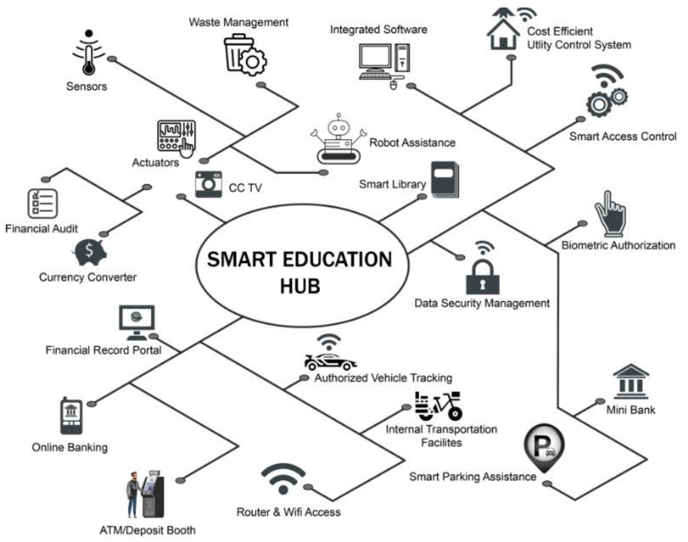

Fig. 8. Proposed framework of smart education hub integrating smart city segments and Education 4.0.

Figure 9 displays the location mapping of all the SHE related case studies which would be described in a later section.

Fig. 9. SEH case study location.

SVG map compared to the text-based search method. But one of the weaknesses would be that the students rarely used the real time sensor data since the environmental numbers did not provide any relevant information. Also, classroom location only helped new students, although occupancy information would be helpful to all. Gomes et al [5] in Cesena Campus, University of Bologna, Italy designed a web interface to display real time occupancy information of classrooms for COVID-19 social distancing purposes and for sustainable use of classrooms. The web interface visually presented class occupancy information with visual cues indicating whether the classroom was following COVID-19 guidelines or not so that hybrid class scheduling can be done safely. The strength of the web interface for occupancy information is that it provides evidence for compliance of social distancing guidelines which is difficult to achieve in most cases. It also enables better scheduling of classes for better room management. Although a weakness could be that a low occupancy may not necessarily imply proper social distancing in the room. For this purpose, better computer vision and machine learning algorithms can be used to determine the actual distance between occupants.

Prandi et al. [6] in Chonbuk National University, Jeonju, South Korea designed a smart parking EV charging scheme using Knapsack algorithm for efficient utilization of EV capacity and grid's variable charging rate. The system was designed in such a way that power flow to and from the grid and EVs would depend on EV battery level, current grid charging price and EV's willingness to sell or buy energy. This resulted in, on average 44%, more profit for the parking lot compared to a first come first served model. The strength of the design is that the smart parking charging mechanism will generate revenue for the university at a higher rate compared to the first come first serve method. The profit margin will increase with the number of EVs.

Ceccarini et al. [7] in University of Brescia, Italy developed an IoT based building management system using environmental and occupancy sensors. The classroom CO_2 levels can be used to control HVAC systems since a higher concentration of CO_2 can decrease cognitive functions. Online interfaces can also collect user feedback regarding comfort level to use air conditioning more efficiently. Augmented reality can enable location specific information using QR codes such as updated menus in cafeterias, classroom information etc. The strength of the building management system is that only off the SHE, if sensors and equipment are needed. On the other hand, effective forecasting will require a large dataset to be collected beforehand.

Ahmed and Kim [8] in University of Brescia, Italy designed an IoT based distributed energy resource and asset management system with LoRaWAN (Long range wide area network) communication protocol to cover the whole campus. The campus has several photovoltaic power plants and battery storage locations which are continuously monitored using sensors to measure solar irradiance, PV power output, environmental data etc. These data are used for controlling and maintaining high efficiency and for documentation purposes. The IoT infrastructure is also used for classroom location visualization and controlling of devices using web interfaces. The strength of the LoRaWAN communication scheme is that it has better coverage and lower latency compared to other long range communication protocols.

Ciribini et al. [9] in Kazan Federal University, Elabuga, Russian developed a new curriculum to teach mathematics using smart technologies for asynchronous learning, communication between peers, mathematics modelling, interactive lessons etc. The effectiveness of the new curriculum was determined using detailed student and teacher feedback including self-assessments. The use of ICT in mathematics teaching was encouraged for better development of soft skills, documentation of evidence of student's learning, creativity in problem solving etc. The strength of the ICT based mathematics curriculum is that it does not require any special equipment or software. But demonstration of its effectiveness compared to traditional methods.

Pasetti et al. [10] in Waterford Institute of Technology, Waterford, Ireland developed a remote laboratory controlling mechanism for a smart campus. The system uses virtualization on a common hardware platform and controlling software to manage several instances of lab experiments. The strength of the application is that remote lab work is possible, which can be helpful if the experiment is dangerous or when social distancing is necessary for COVID-19. But not all experiments can be controlled remotely and delay in starting of the experiment will increase significantly with a large number of users. Summary of case study locations is displayed in Fig. 9.

Table 1 represents the details of observation case according to country, Institute, Category wise, Hardware and physical layout, Software architecture and digital platform with observation opinion.

This essay discussed concept research that could be useful in creating a smart education hub. Furthermore, it is clear that most institutes have not yet completed integrating the entire structure. Complete cost comparison, which should take at least a year. The research made a technical investigation of existing SEH with limitations and strengths after an in. depth analysis of its segments.

Table 1. Summary with observation of the case study analysis of existing Smart Education Hub.

Country and Institute	Category	Hardware and physical layout	Software architecture and digital platform	Observation
Universitas PGRI Yogyakarta, Indonesia	Smart Education Smart Parking Smart Room	Internet, Webcam, Computer Camera, ultrasound sensor PIR, Camera, RFID	e-Learning system Cloud application, IoT portal Database, Cloud application	Sparse on technical details. Room for improvement since it only includes basic smart functionality
University of Modena and Reggio Emilia, Italy	Speech interface for Smart Campus	Amazon Echo Dot, Smartphone	AWS Lambda hosting, DynamoDB, CloudWatch, Alexa app	The interface requires a smart speaker (in this case, Amazon Echo) which limits availability. Can improve availability a lot if it can function with only a smartphone.
Instituto Superior Técnico, Portugal	Software control for Smart Campus HVAC and lighting	Daylight sensors, motion sensor, lighting timer, energy meter, smartphone, HVAC, lights, temperature sensor, humidity sensor	KNX, CAN, Lon/Schneider, Modbus, Light protocol, Service oriented architecture	Not applicable or less effective for regions where central air conditioning is uncommon. Extra cost of smart system may not be justified for small campuses.
University of Bologna, Italy	Data visualization for Smart Campus Smart campus occupancy data for Safety and efficiency	Environmental sensor stations, USB microphone, Raspberry Pi 2, Touch panel monitor Camera, Raspberry Pi 2, PC, smartphone, Environmental sensor stations	MySQL, ckan, socket.io, web-based map interface MySQL, ckan, Node.js, web interface	Although a dedicated large display is useful for people with poor vision, but most would prefer their smartphones. Occupancy data collection may introduce privacy concerns, so it should be handled carefully.

Chonbuk National Universit, South Korea	EV charging scheme for a Smart parking lot	Power system equipment, EV charging stations, Network equipment	Knapsack algorithm	Not applicable for regions where market penetration of EV is low.
University of Brescia, Italy	Smart building management	Environmental and occupancy sensors, Smartphone, Z-wave equipment	Java, web protocols	Occupancy data has inherent privacy concerns. User feedback regarding air conditioning may not reflect the needs of everyone equally.
				Not applicable for small campuses or where wired communication is feasible.
	Smart campus energy asset management	Power meters, Rasberry Pi 3, Environmental sensors, LoRaWAN network equipment	LoRa Server software architecture, web application	There is scope for increased ICT use in
	Smart learning		Wolfram Mathematica	
Kazan Federal University,Russian	Smart learning for mathematics		Wolfram Mathematica, web applications	There is scope for increased ICT use in other related subject areas.
Waterford Institute of Technology, Ireland	Remote Lab	Servo motor, PC, Camera	Moodle, Docker, Browser	Remote lab work may not be ideal for first time learners except in exceptional cases e.g., disabled students, quarantined etc.

5. Limitations, Future Work, and Conclusion

Smart education hub is the current advance technology and a part of smart city planning which is being implemented in most of the countries and also as per as our 10 case studies, it is also obvious that most of the institutes have not finished implementing the entire setup. Therefore, the cost analysis also could not be provided due to incomplete project. Also, for the increase of dollar rate and the work between Ukraine and Russia the price of all the IOT base sensor and other technical equipment's of education hub are drastically fluctuated. That is also another reason not to give a complete analysis of cost comparison. Any field can develop IoT technology. Education 4.0 and smart education is an integrated part of smart city. The system's design has produced a plan for implementing a smart education hub that focuses on smart education, smart parking, smart lockers etc.

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