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Impact of Internet of Things (IoT) on Academic Institutions

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Biographical information

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Abstract*: - Internet of Things (IoT) is an emerging technology that continues to transform the digital environment. It is mainly based on the concept of increased connectivity, improved efficiency and better accessibility. Globally, it is estimated that approximately fifty billion devices are connected to the internet through wired or wireless networks. Iot is progressively becoming a critical tool in academics. Its integration in the learning programs at various levels of education has significantly contributed to improved student performance. The main objective of this study is to explore the impact of the IoT in monitoring students' health, energy management, enhancement of teaching and learning, classroom access control, and ecosystem monitoring. A case study of Riga Technical University (RTU) is presented. The use of IoT technology in education improves the use the technology in online streaming for sustainability, and in monitoring student's health. It also enhances the easy connection between students, teachers, administrators, and sensors. It has also promoted cloud computing in education, big data, wearable technology, and augmented reality. However, this has not gone without several challenges. IoT is highly suspensible to security threats, such as a distributed denial of service attacks and malware attacks. This has made it critical for IoT service providers to continuously improve cyber security capabilities of IoT. In a bid to improve the use of IoT in education institutions, it is important to adequately secure the system and hence get the best out of this technology. Detailed analysis of these aspects of IoT integration in academic institutions are based on a case study of RTU, Latvia. Latest global findings (2019) indicate that 28 per cent of IoT apps are attributed to other institutions; followed by libraries with per cent; with pre and post-secondary following third with 16 per cent each and secondary institutions with 14 per cent.*

Keywords*: - IoT, cyber security, academic-institutions, devices, big-data, Latvia*

Introduction

An article by Aldowah, Rehman, Ghazal, and Umar (2017) discusses use of IoT in higher learning education and future learning expectations under the technology. The authors explain the importance of the IoT in learning, especially in improving learning environments, and how technology improves performance outcomes. On the other hand, the authors explain how educational institutions can balance technology's benefits and risk factors, such As cyber security issues. According to Aldowah et al. (2017), IoT plays a huge part in enhancing leadership skills among students and staff and understanding the world of technology. For instance, the technology helps students and staff learn various software, applications, and IoT services in recent times, and how to upgrade and use the applications as shown in Table 1.

Gul et al. (2017) in their study explore the role of the IoT in education through a survey conducted to provide up to date data on the impact on student performance and management efficiency most. For instance, IoT will be a great tool in enhancing learning and teaching through various technical skills, such as smartwatches and PowerPoint pointer. The article also explains the cost of devices, as a challenge for educational institutions when interacting with the IoT technology. If the current trends are any indication, the falling prices and constantly improving technology are cause for celebration. The onus therefore is on the developers to keep up the momentum and by providing more innovative products.

Trequattrini, Shams, Lardo, and Lombardi (2016) in their study explain the legal aspect of the IoT and risks that underlip the technology, especially in educational institutions. According to the authors, the IoT is important, especially the use of radio frequency identification (RDIF). Technology in authorization and other aspects in promoting economic growth in education as a business model. Some of the risks associated with the use of the IoT include data protection, privacy, security, safety, and governance. Monitoring the use of the systems is an extreme sport for the institutional security administration, especially biometrics. The use of the IoT poses significant cybersecurity risks to confidential data such as the online learning materials, performance reports, financial information, and personally identifiable information belonging to the staff and students.

Lee (2019) explores the ecosystem, architectural, and IoT service business model. The paper explains the need and importance of machine learning and the interconnection of the IoT systems to the institution's system network (See Figure 1). However, IoT has become the leading and growing sector in education facilities. For instance, the use of wireless sensors monitors the classroom environment, such as temperature and humidity, hence enabling learners to adjust and easing the learning process. Technology creates and improves value, especially in ecosystems and architecture. For instance, the use of IoT-driven devices such as smartwatches, which can be used by teachers to aid learning processes as a reliable source of information.

According to Alam and Benaida (2020), the use of blockchain architecture in education institutions is essential in securing educational data for the academic institutions from unauthorized access or loss. The author also explains the use of the 5G network in connection with IoT devices to the blockchain architecture network. Alam and Benaida (2020) further explain the importance of blockchain in the IoT, especially in promoting interaction between students and teachers. Mobile technology is used to create an application based on blockchain to the IoT.

Life Case Study (Riga Technical University, Latvia)

Riga Technical University (RTU) (Located in Latvia) has successfully integrated IoT technologies into core student and staff operations to provide web-based access to online resources over internet-enabled devices (Pinka, Kampars, & Minkevičs, 2017). This has significantly contributed to improved student performance. Latvia is ranked as the fourth poorest country in the EU with a GDP of 15,920 euros and a population of 1.92 million people. The literacy rate in Latvia is 99.89%, which implies highly efficient educational systems and technologies. The rationale for selecting Riga Technical University for the case study was to explore IoT implementation in the education sector from the perspective of a country with advanced academic systems. Additionally, an outline and process layout criteria was used in the selection of RTU as thw preferred institution for the case study. The outline and process layout entailed analysis of the design constraints for the technology applications and aligning the implementation requirements to the academic standards in a way that is replicable to other insititutions globally. The first institution that met the outline was selected for the project. The evolving technology has provided the RTU students several learning opportunities through improved access to quality and reliable learning resources hence enhancing their academic experiences. For instance, IoT has been used to improve access to education in hidden and remote campuses by enabling the university to offer distant-education using web applications and in-house applications with video conferencing functionalities. IoT in education has been extended to the classroom level, impacting overall performance through advanced teaching and learning methods. The explosive growth in the use of internet-enabled devices such as smartphones and laptops in the past decade has significantly favored the integration of IoT into the IT systems of the Riga Technical University (Pinka et al., 2017). The project provided a better platform for ensuring everyone gets information, and knowledge with regard to the impact of the Internet on education, especially on how it enhances security, academic performance, health, safety, efficient energy consumption, and importantly acquires data from all areas, such as information on health and students learning patterns. Figure 2 shows some of the key functions of IoT technologies in academic institutions:

The paper explores the IoT technologies in educational institutions (See Figure 3a, 3b and 3c) that use the technology. Using data provided by the following link - Level -, the author was able to develop graphic and quantitative analyses. In addition to the graphs, the data set was also used to produce annual averages (100K) of Apps of .64. 1.012, 1.27, 1.852 for 2016, 2017, 2018 and 2019 for the different institution levels respectively. With regard to the different academic institution levels, the following averages – library, post-secondary school, secondary school, pre-scondary school and other - were respectively computed: 1.75, 0.8125, 0.7125, 0.7675, and 1.925.

The general objective of the article is to review and explore the extent to which the IoT has transformed academic institutions and how this level of transformation has led to the ubiquitous proliferation of the different invaluable platforms. While available literature provides different perspectives of the IoT and academic institutions, not many present a comprehensive, inclusive and compelling case as illustrated in this paper. And that makes this review unique because of its targeted approach. This characterization notwithstanding, there remain significant gaps that can only be identified and addressed by future research strategies. For example, what does the future hold for remote academic institutions? Especially taking into consideration the lessons learned with COVID-19 pandemic. Different responses on this and other IoT thematic questions will be driven by different strategies and stake holders. And, given current levels and trends, there is every indication that exponential and evolutionary transformations in information technology in general and IoT in particular to the new normal with unknown and escalating challenges.

Aim of the Riga Technical University Study (RTUS)

As an illustrative and practical example, the author identified the RTUS. The specific objective of this study was to improve thematic service deliveries like education, health security energy and more using an IoT data integration solution for the institution. The project promoted, enhanced and served as a catalyst in transforming the organization's mission of nurturing a new generation of IT professionals. The project also aimed at testing the integration of IoT solution into social media platforms to make it more appealing to the students (Pinka et al., 2017).

Target Audience

The project primarily targeted students and staff at Riga Technical University as well as other stakeholders with a likelihood of interacting with the institution's IT systems. The contextual strategy for teachers and students aimed at exploring the capabilities of IoT technologies in the teaching and learning processes. Targeting the administrative roles performed by the University staff, the IoT solution offered RTU important insights on process automation and global cybersecurity issues and terrorism, which have potentially harmful impacts on the digital educational systems.

IoT Project Development Process

The integration of IoT solution at Riga Technical University followed all phases of the System Development Life Cycle (SDLC) to optimize functional efficiency of the final system and enhance the organization's ability to achieve the designed objectives and goals. Figure 4 illustrates the system development process;

Problem

The advancement in information and communication technology gave rise to the growth of Internet of Things, which has been extensively applied in a range of fields including manufacturing, finance, and healthcare. However, little evidence exists on the application of IoT in academic institutions. The knowledge gap makes it difficult for the aspiring institutions to understand the opportunities, challenges, and the requirements for IoT integration in the administrative and learning programs. The RTU case study offers important insight on the integration of IoT in educational systems.

Inception Phase

At the inception stage, the RTU project teams formulated the scope of the IoT technology, which included assessing for the organizational needs and resource requirements. The technical teams performed a risk assessment and developed a contingency plan for efficient risk mitigation. The project plan and cost-benefit analysis was also performed at this stage.

The purpose of needs assessment was to understand the impacts of the technology; for instance. The education business model requires technology to improve stakeholder relationships and enhance performance management. The relationship between students and teachers, teachers and teachers, and parents and teachers can be enhanced through the use of the IoT technology (Aldowah et al., 2017). The IoT solution was projected to significantly contribute to the growth and development of the education business model, such as making better decisions and developing business policies, such as the purchase of resources, such as books. Additionally, visualization of the proposed IoT solution for Riga Technical University sought to assess for capabilities such as enhanced data-driven decisions making, enhancing the development of a reasonable curriculum, customizable curriculum, and other needs for performance improvement. According to the key business activity segment, RTU intended to use the IoT solution to enhance teaching-learning, research, and academic assessment as key business activities. The educational institution also required an integrated IoT solution to improve the learning environment for security purposes, enhance teaching and learning, and improve overall performance.

The IoT solution is projected to promote the creation of a smart learning and smart teaching environment through e-books, fitness bands, tablets, sensors, and augmented reality (Songsom, Nilsook, & Wannapiroon, 2019). The systems also allow the institution's security, health, and academic administrators to monitor students through smart devices. For instance, academics can use the devices to monitor students' various learning patterns, discipline, and health patterns. The technical team conducted reconnaissance on the use of applications such as PowerPoint slide controller to boost online learning and teaching efficiency including improving the teachers’ ability to multi-task. Such applications also enabled students to engage in activities such as monitoring students, controlling the display of notes on the board, and explaining important points to students.

RTU also planned to use the IoT solution to monitory student’s health using specialized devices for the management of various diseases and pandemics. Health is key for every student. It enhances students' performance and education as a business model (Abdel-Basset, Manogaran, Mohamed, & Rushdy, 2019). The security design of the RTU’s IoT solution aimed at systems installed in the libraries, laboratories, and classrooms. The technology would assist through Radio-Frequency Identification (RFID) to enhance access control, which improves the institution's security status. Also, near field communication, Radio-Frequency Identification was used in developing classroom or library access control through assistive technology (Pal, Hitchens, & Varadharajan, 2020). Through the classroom registration system, the security administrator is able to capture classroom attendants and collect other information showing viability for the modules. The registration system allows the access control authorization system to use the information to review and offer access in various sections of the institution, such as the library.

System Design

At this stage, the system developers analyzed the functionality of various components based on the organizational needs and the design requirements. The evaluation focused on the required hardware, software, and network capabilities to enhance various teaching, learning, and administrative processes. Riga Technical University sought to leverage IoT-enabled devices with automated energy optimization functions to deliver the desired resource efficiency and cost reduction. A review of the design specifications was performed to ensure that the essential components were appropriately aligned prior to the actual integration into the RTU's existing information technology and network developed in-house by the university's technical teams.

Outsourced Development Stage

The project was internally funded by the university administration as part of the digitization program initiated years ago. The estimated total cost of implementing the program was $9,000 for the three months in which the project was completed. The costs were not broken down into the respective project completion phases but commutatively estimated. The first step of the development stage was deploying the control node of the IoT solution to the cloud computing platform of the Riga Technical University. This was to provide a persistent, reliable, and "unlimited" storage for the advanced computing power of the IoT technologies. The system is composed of a virtual platform with a 2.39 GHz central processing speed and 1 GB random access memory to support the database and webservers (Pinka et al., 2017). The storage and processing power of the virtual machine area also vital for the aggregation and transmission of the sensor data to a Smart TV. The initial version of the IoT solution was composed of a Apache web-server based on a Hypertext Preprocessor (PHP) server-side scripting and a MySQL relational database. The technical team also designed JavaScript Script Notation as the default data format for the transmission between IoT-enabled devices connected using USB cables and sensor devices over Wi-Fi networks. Figure 5 shows the architecture of IoT solution that was deployed for Riga Technical University.

On-site installation of the hardware boards was performed at the University premises with internet connectivity and powered using USB cables connected to power banks. Arduino microcontrollers coded in C programming language were installed to allow data transmission from the carbon monoxide sensors to dust sensors. Additionally, a Samsung Smart TV was installed to perform functions such as data visualization and other interactive functions in the IoT data integration system. Real-time sensors have been used to receive data updates from the cloud-based control nodes and analysis of the changes in data values. Small sized sensors were used for optimal power consumption and long-range data transmission. Moreover devices such as MQ-7 carbon monoxide sensors and optical air quality sensors were installed to automate student health and safety precautions in the laboratories. The developers wrote a Smart TV program in JavaScript to perform a range of learning and administrative functionalities to achieve optimal outcomes. Data security concerns of the IoT solution were addressed by automating threat detection and mitigation processes, implementing physical security measures such as biometric identification systems and CCTV surveillance, and access control and multi-step authentication procedures for the web-based programs.

In the development stage, the implementation team developed a training program for the staff, teachers, and students, to use the new system. In a case of access control and other usability issues, workforce training is an effective intervention for the efficient access of online libraries and virtual laboratories. Additionally, students and other users were trained on how to navigate the complex systems for minimized cybersecurity threats. The installation of wearable monitoring devices was considered a key resource for the education business model of the IoT solution.

In enhancing ecosystem management and energy on the RTU systems, sensors were installed in labs and libraries important to improve students' learning environments. Some of the devices include the smart Grid an IoT technology device that manage energy. Through energy management devices, the institution can balance power generation and power energy usage, which is an issue in most organizations. In efforts to reduce climate change impacts, Riga Technical University installed IoT sensors to control organizations' carbon emissions, temperatures, and monitor energy consumption. Students were required to acquire various wearable devices to monitor temperature and other variables. They then connect them to mobile devices for easier monitoring.

System Pilot Testing

Pilot testing was conducted to assess the performance and ensure that the functionality of various components is aligned to the needs of Riga Technical University. This is a critical quality control measure. The testing process evaluated whether the proposed system design meets the goals and objectives of the institution. The testing process was conducted repetitively to determine errors and interoperability. The pilot testing was performed comprehensively to enable students, staff, and other users certify reliability and accuracy of the IoT solution. Different user categories were involved in the testing process and asked to provide feedback on whether the system fits the institution's needs and improve performance in designed areas. After pilot testing, the project team verified and validated the implementation system.

In-house System Evaluation and Revision by the technical Teams

The IoT project team members evaluated and reviewed the systems to ensure they are working. The evaluation focused on assessing whether the IoT solution would be able to perform automated functions such as student health monitoring effectively and provide decision-making insights based on the students' medical history. The impact of IoT technology on academic performance of the students was evaluated by comparing the individual student scores before and after implementation of the systems. For example, a student who took weeks to complete a research using the physical library at the University takes a shorter time querying a range of online databases, which provide limitless access to credible, scientific information hence improving the overall student performance. Access control technology was evaluated to determine how effectively it helps to restrict the access to server rooms and restricted offices such, especially in the finance department by unauthorized persons. Additional systems that were reviewed for functionality and performance included the institution's Cisco physical access control, messaging systems, tags, sensors, and mobile applications to monitor and automated resource allocation systems used in the library and laboratories.

Outsourced System Implementation from external teams

System implementation phase involved actualization of the IoT solution the actual integration or installation of the IoT technology system. At this stage, the IoT analysts generated validation reports for the system installation and assessed for operation and maintenance processes, which involved simulating the challenges and developing relevant policies and strategies to improve system security. Technical teams from the Riga Technical University were also involved in the implementation of pre-designed security protocols that can assist secure the systems from security issues such as the use of firewalls and complex Wi-Fi.

Lessons Learned

IoT integration into academic institutions is a resource intensive process, which requires comprehensive feasibility studies and needs assessment. However, successful completion of the project contributes to the management efficiency and improved student performance significantly. The key challenges mainly arise in the selection of the appropriate vendors for software and hardware components and aligning the new systems to the physical learning environment at the institution. However, proper training of the technical teams provide a feasible solution to these issues. If the project had to be re-done, RTU would have selected a selected a advanced systems for interoperability with the future hardware and software components that the institution may need to integrate in the future.

Follow up Plan?

Ongoing assessment of the impacts of IoT in academic institutions is imperative for successful integration. A feedback monitoring team is tasked with the role of assessing for usability issues and providing practical solutions to the students and staff. Additionally, an automated cybersecurity management program is implemented to detect and fix privacy and confidentiality issues that are likely to arise during various data processing operations.

Replication possibility?

This study is replicable to higher learning institutions where students possess the basic knowledge and skills for the use of IoT technologies. However, the implementation constraints vary with the existing systems and the IT environment in which the learning programs are implemented.

System Live and Challenges

Deployment of IoT technologies was one of the most complex and resource intensive projects undertaken by Riga Technical University. The major problems that were encountered in the implementation process included protecting the data integrity and availability, resource planning, and the acquisition of genuine software and hardware components. Operating within the scope and schedule of the project was a major challenge, especially in the pilot testing and the continuous integration testing process. The process of selecting the appropriate security measures and cloud-service providers was also challenging due to the cost constraints and the quality concerns for the entire project.

Conclusion

Integration of the IoT in an educational institution is a critical decision and may be challenging, especially when appropriate knowledge and experience are applied. To avoid challenges and future security issues, the educational institution should think about what the institution must do with the system, but not what the institution can do. Weighing the systems' gains over the investment is important, which can be done through a cost and reward estimation. Additionally, the institution should select professionals and experts as part of the project team. The institution can consider asking and finding out about their experience and its impact on their current responsibilities and duties. Assigning tasks in the first stages of the project is important to prevent challenges, such as onboarding. On the other hand, to avoid a change plan, the project team needs to conduct a thorough evaluation of the system's security risks, vulnerabilities, and threats to avoid security issues. Also, in the development stage, the institution needs to train users, such as students and staff, on data security, frequently update passwords, and detect malware in different software and operating systems.

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Table 1: Number (1000K) of Academic Institution Apps by Level, Source: Level

Institution Level	**2016 (1000K)**	**2017 (1000K)**	**2018 (1000K)**	**2019 (1000K)**	**Source**
Library	1.2	1.5	1.9	2.4	Level
Post -Secondary (High School)	0.4	0.5	0.85	1.5	Level
Secondary (High School)	0.2	0.6	0.75	1.3	Level
Pre-Secondary (High School)	0.1	0.6	0.87	1.5	Level
Other	1.3	1.86	1.98	2.56	Level

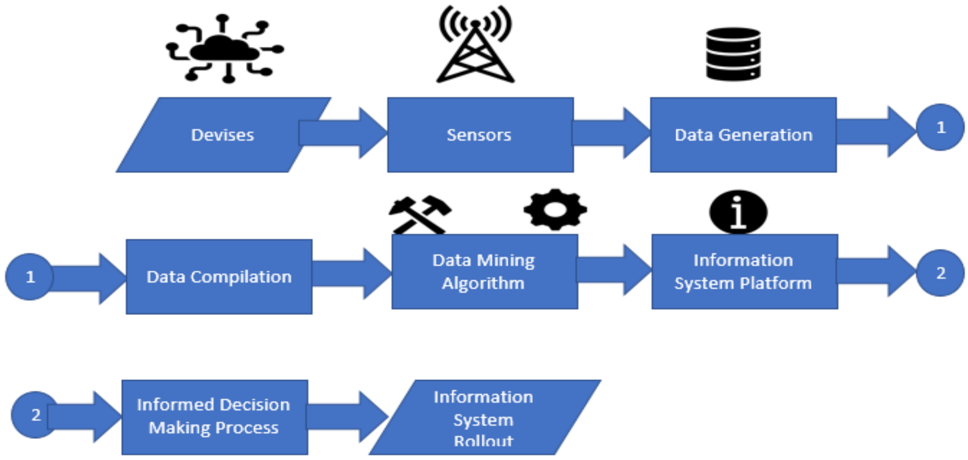

Figure 1: Internet of Things (IoT) Ecosystem (Source: Author)

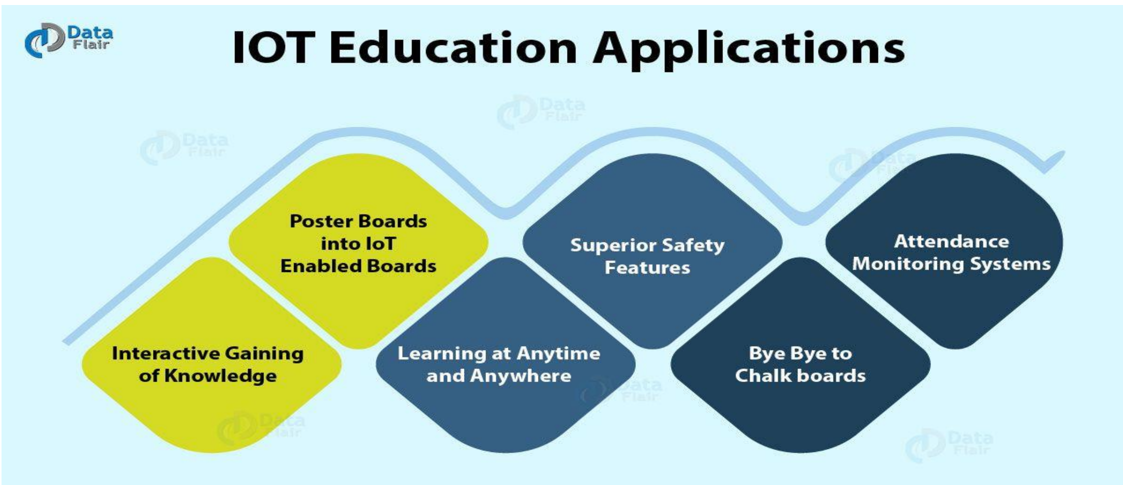

Figure 2: Applications of IoT in academics www.data-flair.training.com

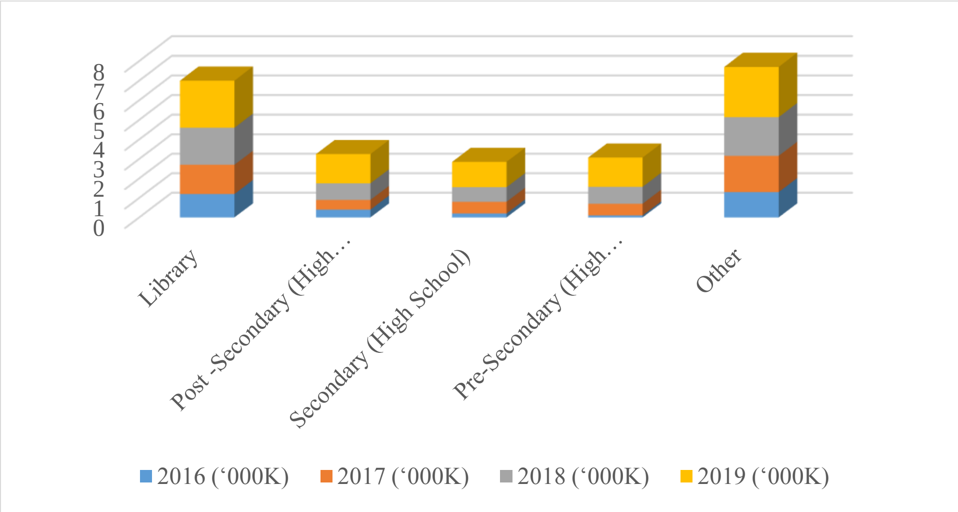

Figure 3a: Number (100K) of IoT Apps in Academic Institutions by Level (Graph Source: Author, 2019).

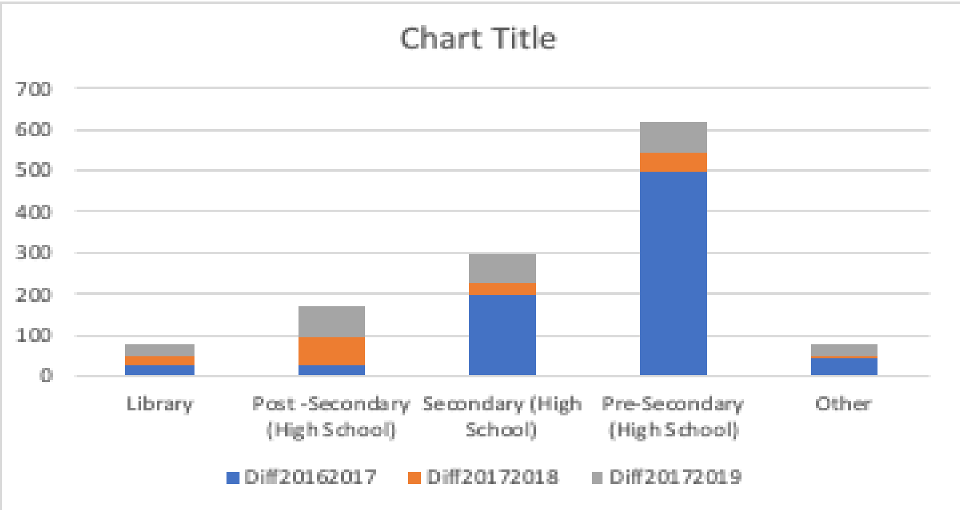

Figure 3b: Annual Percentage Differentials by Institution Levels 2016-2019 (Source: Author, 2019)

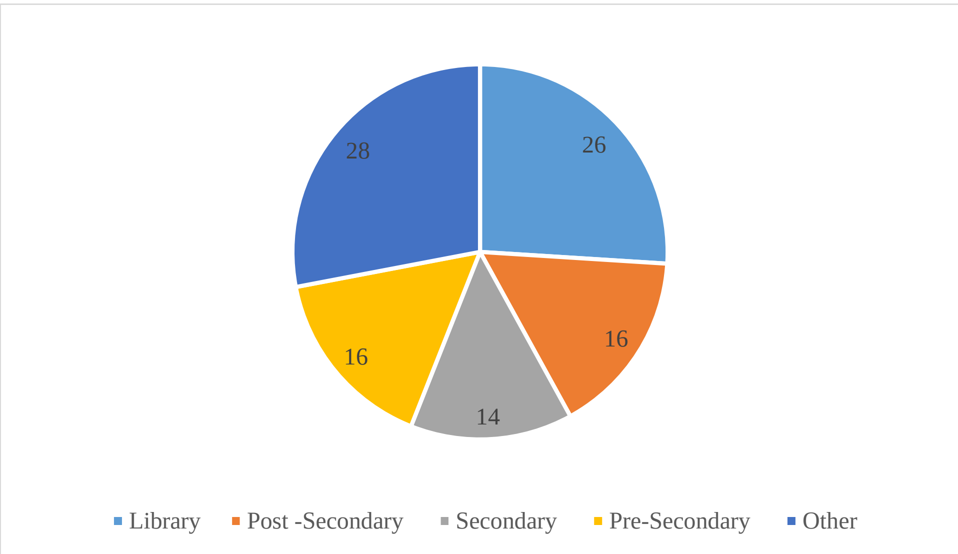

Figure 3C: Percentage Proliferation of IoT apps by Academic Institutions: Source: Author (2019).

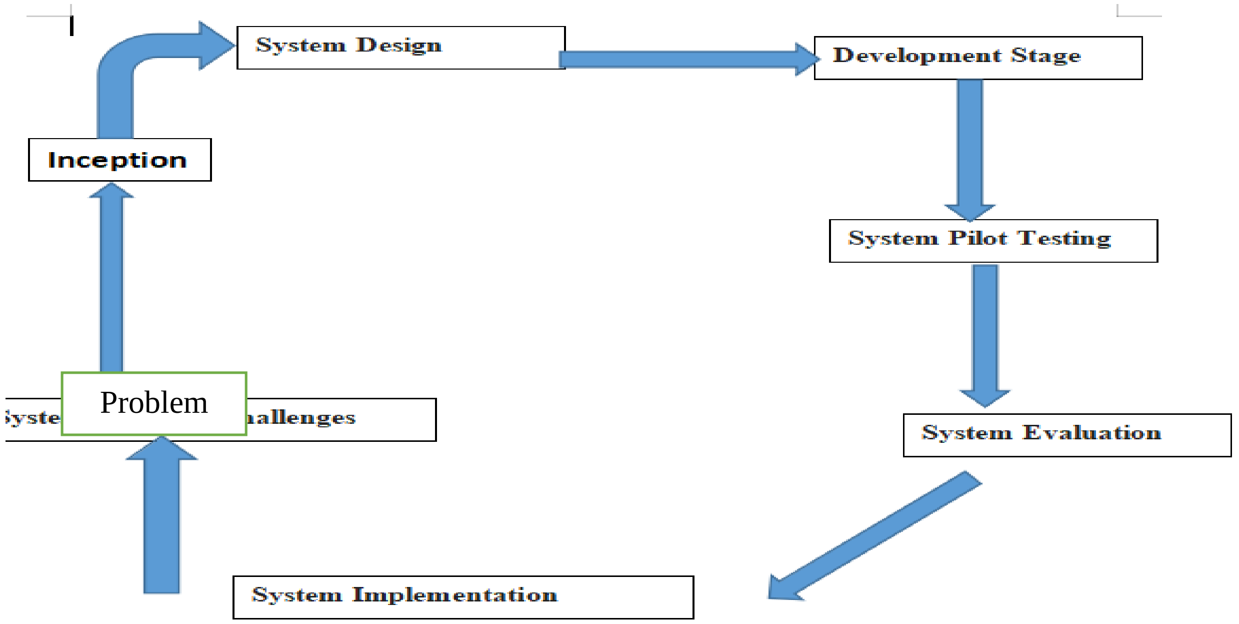

Figure 4: The development process

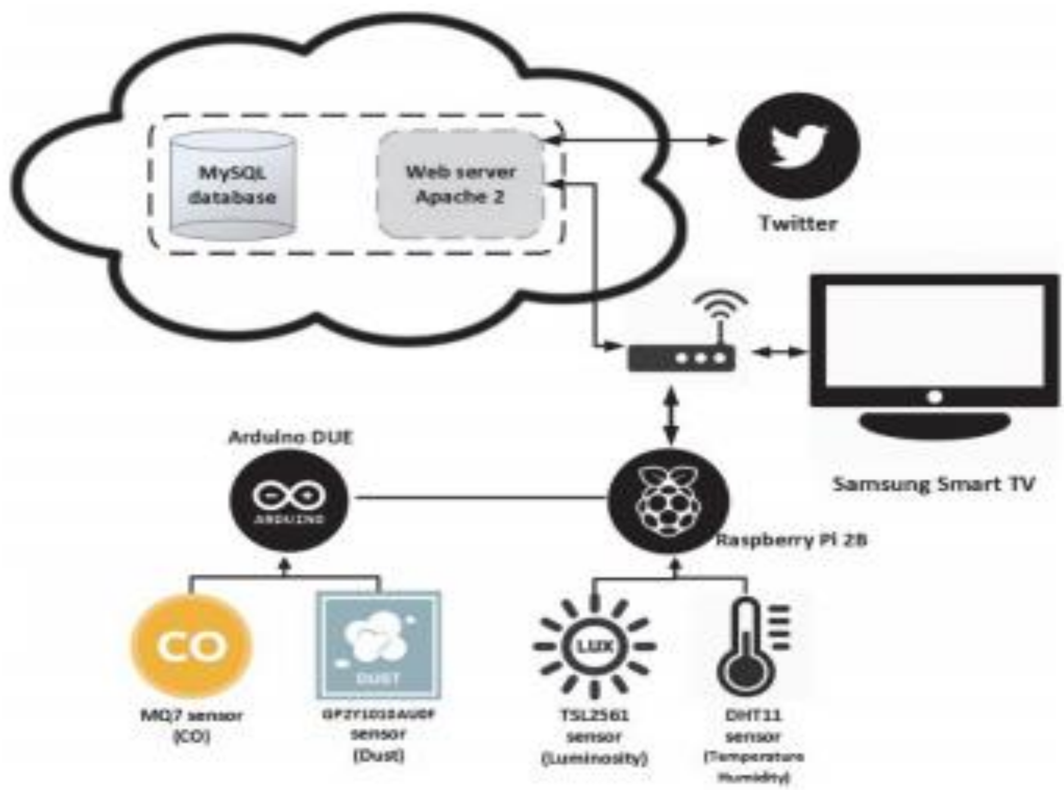

Figure 5: The IoT Architecture for Riga Technical University. Source:

https://www.researchgate.net/publication/312558235_Case_Study_IoT_Data_Integration_for_Higher_Education_InstitutionMy