Internet of Things for Education: Facilitating Personalised Education from a University's Perspective

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Abstract

Personalised education has been a developmental goal across all levels of the UK education sector for many years. In particular, the Higher Education sector has struggled the most due to a lack of personalisation, as student numbers in lecture theatres have grown significantly, occasionally exceeding three hundred. As a consequence, educators are constantly challenged to gather and understand individual student needs, let alone address them. At the same time, technology has advanced in the recent years, particularly in the areas of Internet of Things (IoT) and big data. IoT technology has emerged as a great means to collect data from lecture theatres and labs, while big data technologies enable the processing of these data. Consequently, IoT offers potential solutions to some of the key issues facing the future of personalised education. In this paper, an IoT system is being proposed, which would enable the personalisation of education for large groups of students in lecture theatres and labs. The proposal is derived from a case study based on work which has taken place in a mid-sized UK university.

Keywords: IoT; Education; Systems; Personalised education; SysML

1.0 Introduction

This paper discusses the integration of IoT in Higher Education in an attempt to address the need for developing further personalised education as it becomes more popular. To do so, a case study will be used to showcase the introduction of an IoT System at Bournemouth University (BU), England.

IoT technologies have grown significantly over the past few years. According to an article released early in 2018, "The number of internet connected "things" already exceeded our population back in 2008. By 2020 this number is expected to reach 50 billion. A whopping $19 trillion is anticipated as cost-savings and profits from this investment." [1]. The growth of interconnected 'objects' is permeating every aspect of modern life, including all levels of education, where there is a growing expectation to take advantage of the perceived benefits of ubiquitous connectivity between devices. It is becoming evident that by incorporating a variety of technological enhancements into teaching, educators are able to place personalised education at the centre of a student-centred teaching approach. In doing so, students can customise their learning activities, taking into account their personal circumstances, and their own learning style. Evidence of such advancements have been noted as part of several projects that have taken place globally in recent years for smart education [2].

At Bournemouth University, as it is the case in other institutions, it has been suggested that IoT technology, and more general technological innovations in general, could address the issues of personalised education for the benefit of both educators and students. Teaching in large lecture theatres, but also performing complex administrative tasks which require the use of multiple and often disjointed IT systems, are a few of the problems that educators face. Students often note that they are adversely affected by the lack of personalised learning and feedback. They feel their individual learning needs are diluted and often lost in large student crowds, leading to low student satisfaction that reflects directly on their learning achievements. Although there is funding allocated to support the enhancement of the provision of personalised education through technology, thus addressing some of the issues stated earlier, careful planning and appropriate research are required in order to propose a viable technological education system.

As part of an attempt to conduct such research, this paper attempts to define the requirements and propose a design solution for a specific case study which focuses on the personalisation of education through technology. The SysML modelling language has been chosen both for requirements and system description purposes. SysML was chosen as a standard formalism for systems engineering and the inherent benefits of model-based design techniques such as code generation, and identification of problems early in the product design and development cycle.

Subsequently, an IoT system is then proposed displaying it using SysML Block diagrams. The diagram is then evaluated against the requirements that have been identified,

The rest of the paper is organised as follows: in section 2, a background study of IoT systems in higher-education in general is detailed. Section 3 describes the case study of personalised education and IoT. Section 4 contains a short description on the requirements modelling process. Section 5 proposes a system relating to the case study and from the data collection viewpoint, through the use of block diagrams. Section 6 offers an evaluation of the proposed solution and open issues. Finally, section 7 offers conclusions gathered from undertaking this paper, and suggestions for future research.

2.0 Background study: IoT systems in Higher-Education Institutions

IoT is a recently devised term but its use and practical application has been growing in many organisations. “The Internet of Things (IoT) is a growing market. Estimates show that by 2020 we could have over 50 billion smart connected devices, a.k.a. things, on the internet.” [3].

IoT systems are used in several areas in Higher Education such as: attendance monitoring, personalisation through feedback, personalisation through learning analytics, physical access security, environmental conditions monitoring, and others.

2.1 Attendance monitoring

There are several cases of IoT systems which have been implemented for the education sector. Examples include the use of RFID tags to monitor student attendance, and the incorporation of attendance monitoring data into a wider university system. “As students walk into the classroom, attendance could be logged automatically using a device such as the Nymi, a wearable “smartband” that uses the wearer’s ECG pattern to authenticate identity. When the students take their seats, a beacon might push a warm-up exercise directly to their smart surfaces.” [4]. The benefits of such an approach relate directly to the extensive evidence which shows that attendance monitoring leads to higher student attainment.

2.2 Personalisation through learning analytics

A recent and innovative example of IoT technology that has been proposed for personalised education is the Muse headband. “Muse, a headband that reports brain activity to a mobile app, could help academics monitor student engagement and track learning styles” [5]. The device contains sensors in the headband positioned on the user’s forehead and behind their ears that tracks the activity of the brain. A lecturer can then access the application to determine students’ individual learning styles which could lead to a more personalised curriculum being delivered to them. For example, if the headband detected that the student learns more by performing certain activities, then this could be created for the student.

Another example are the ECG sensors [6] for monitoring how well students are assimilating and comprehending what is being taught. This is certainly an interesting development, which may lead to a more efficient classroom environment where academics have greater control of the teaching environment. For example, EEG sensors could be used during teaching to monitor the students' cognitive activities.

Personalisation through feedback acquisition is another area that IoT has shaped. Studies examining the use of mobile technologies to acquire real-time feedback in large lecture theatres have emerged in recent years. In these studies, a mobile app called *socrative* was employed to provide real-time feedback from large numbers of students [7, 8].

Lastly, social media technologies such as *Facebook and Twitter* can be used to collect valuable data for learning analytics as their is an inevitable fact in modern higher-education institutions [9].

Therefore, through the use of IoT technology, academics can collect data about students' performance and engagement, and then determine which students would benefit from additional support. This type of technology has been shown to support academics to adapt their teaching plans and methods for future classes [10].

2.3 University physical security

This is another example that showcases the potential value of IoT. In this case an example of IoT technology can be found in the use of RFID (Radio Frequency Identification) and NFC (Near Field Communication) to simplify and improve physical access and campus security. Student physical access can be monitored whilst on campus via RFID chips embedded on student ID cards. The system would record access when students enter a room via physical devices placed around campus. An example of such technology in use has been implemented in the Sookmyung Women's University (SWU) [11]. As part of the same infrastructure at SWU, student attendance can be monitored, as students move in different buildings, using a mobile app. Unsurprisingly, there are several other universities which have invested in this type of student attendance monitoring technology.

2.4 "Green" universities

Finally, an example of existing IoT technologies in use in this context is the Smart Classroom System. This type of system works in real-time to determine if the physical environment is optimised for student learning, by taking into account parameters such as temperature, noise, CO_2 and other environmental factors.

Taking this one step further, the monitoring of classroom environmental conditions through IoT could lead to a "Green campus environment" [12]. Eco-system monitoring is implemented through the use of physical devices, similar to the case study of this paper, to gather energy consumption information.

3.0 Case study: Personalised education and IoT

Bournemouth University is a typical example of a medium size higher education institution in the UK. Like many other universities, BU has been looking at ways of enhancing the learning and teaching experience of its students by further developing the personalised education they receive. One of the initiatives being pursued, relates to investing in IoT technologies to support the development of innovative learning and teaching methods used for delivering teaching in large lecture theatres and computing laboratories.

The basis for the new IoT development revolves around the idea of building an IoT system which will be deployed in large lecture theatres and computing laboratories (IoT in this case refers to the combination of physical devices such as sensors and computing systems to process information generated locally but also existing as part of other interconnected IT systems). The introduction of this technology is expected to lead to the customisation and enhancement of the students' learning experience, by allowing the optimisation of teaching materials, and their different forms of delivery. It is also expected to enable educators to focus on individual student learning needs and methods of learning. Additionally, there is a reasonable expectation of reducing both direct and staff costs by automating common tasks which are not directly related to the actual educating of students, i.e., tasks which require academic expertise, as stated in [13].

Unlike industry which generally invests heavily in new technologies, academic institutions tend to lack similar investment levels. This is mainly due to inflexible funding mechanisms and a general lack of appreciation of the business value that IoT and data analytic technologies can provide. "An educational system may be one of the most important reasons why countries do not grow" [14].

Yet, these technologies offer the means to managing costs, improve the quality of the educational provision, professional development, and improvements across a number of areas such as:

- Student response, performance, and behaviour
- Academic response, performance, and behaviour
- Facility monitoring and maintenance
- Data from other facilities

To achieve improvements in these areas, collecting data and processing them effectively (big data analytics) has been identified as a necessity. "Using big data enables managers to decide based on evidence rather than intuition. For that reason, it has the potential to revolutionize" [15]. Relevant data can help inform ineffective strategies and actions, whether they relate to teaching and educational efforts, or the effective management of facilities supporting education.

IoT has been characterised as a plausible solution to many of the aforementioned issues and has been described as "dawn of a new era" [16]. Apart from providing insightful information which supports decision making, it can also become an information enabling tool through the use of low cost and low-power small devices, which offer high performance.

In many ways, the drive for utilising technological innovations is fuelled by the increasing demands for academics to deliver high quality personalised education. The demands to succeed in this area are supported by higher student expectations for more effective learning and teaching. As academics are called to meet these higher expectations it becomes inevitable to look at efficiency gains in terms of reducing the administrative burden and management duties, which detract from focusing on the core academic mission of providing excellence in teaching. Invariably, the automation of manual and clerical tasks becomes a necessity. The application of technology is seen as an invaluable improvement in working practices, enabling academics to devise better supported learning and teaching strategies, rather than simply relying on old or ineffective methods of teaching activities.

Beyond the benefits of the technology itself, and the academic drivers for innovation, there is an emerging student perspective, which views the customisation of education as the gateway to achieving higher learning goals that are based on contemporary learning styles. Key qualities such as "responsibility, self-management, independence, confidence, resilience, creativity and entrepreneurial" [17] can be realised only when students control their learning experience and participate in the development of their highly personalised learning and teaching.

4.0 Requirements modelling for Case study

4.1 High-level diagram – Data Viewpoint

The diagram in Figure 1 shows the overall requirements of the IoT system that has been proposed as part of this project. Note that the notation used was SysML Requirements diagrams which give a structural view of the requirements.

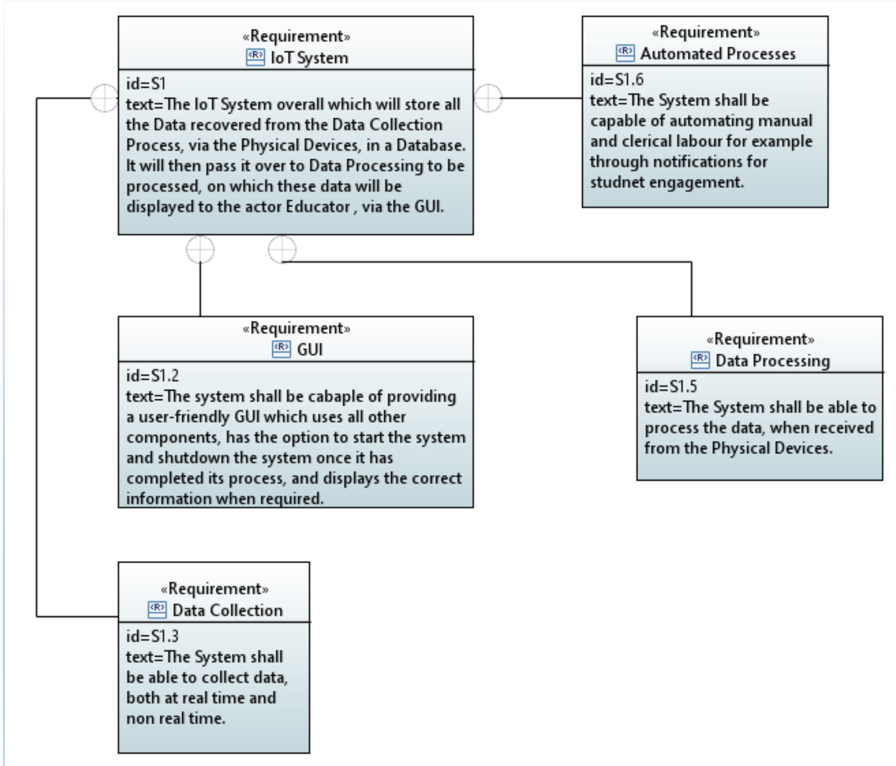

Figure 1: SysML Requirements Diagram – Overall System View

This diagram is a high-level description of the overall IoT system. It consists of four main parts: Graphical User Interface (GUI), Automated Processes, Data Collection and Data Processing.

Specifically, the GUI is the interface for academics/students to the IoT system and has all the functionality required to handle system operations; the Automated Processes refer to all tasks that will be automated as a result of information/data collected through the IoT system (such as notifications to educators for student engagement and performance); the Data Collection (monitoring) is the requirements that will be implemented mainly through physical devices and statistics/programs in VLE environments; the Data Processing (adaptation) is the requirement for processing appropriately all data collected to provide meaningful and useful adaptation suggestions.

4.2 Low-level diagrams – Data Collection Viewpoint

Figure 2 presents a SysML Requirements diagram at a lower-level of abstraction. At this lower-level, implementation decisions are being initiated according to the requirements diagram, enabling the traceability of requirements. Specifically, the diagram shows the implementation related blocks that <<*satisfy*>> specific requirements such as *Physical Devices* for *Real Time Data Collection*, *Portal* for *Non Real Time* and *Real Time Data Collection*.

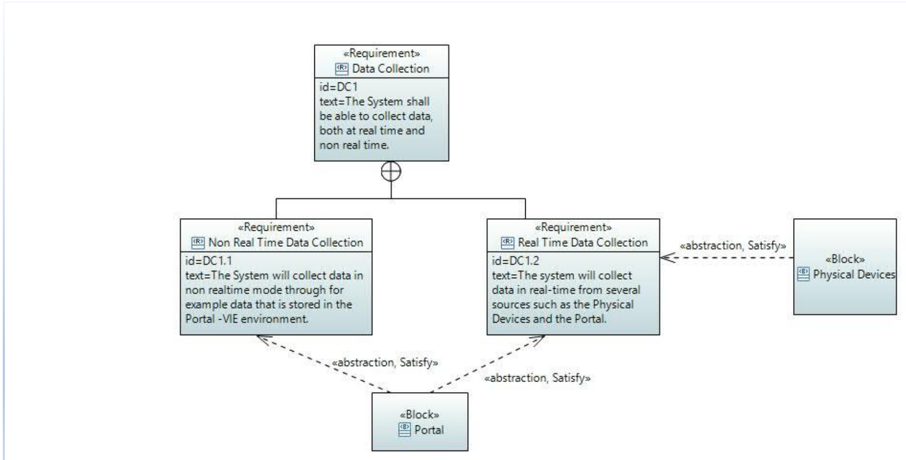

Figure 2: SysML Requirements Diagram – Data Collection

This is the aspect of the system which will rely on the use of *Physical Devices* and the *Portal* to gather data at real time and non-real time modes. For non-real time data collection, information from the *Portal* regarding student attendance and engagement is gathered and processed through learning analytics technologies. For real time data collection, both the *Portal* information and input from the *Physical Devices* are collected and processed at real time. Note that the term real time in this context refers to collection and processing of the information.

Figure 3 presents a SysML Requirements diagram at even lower-level of abstraction. Specifically, the diagram shows the implementation related blocks that <<*satisfy*>> specific requirements such as *GPS Tracker* for location monitoring, *Portal* interface for students/educators and *Key Fob* for implementing sensors.

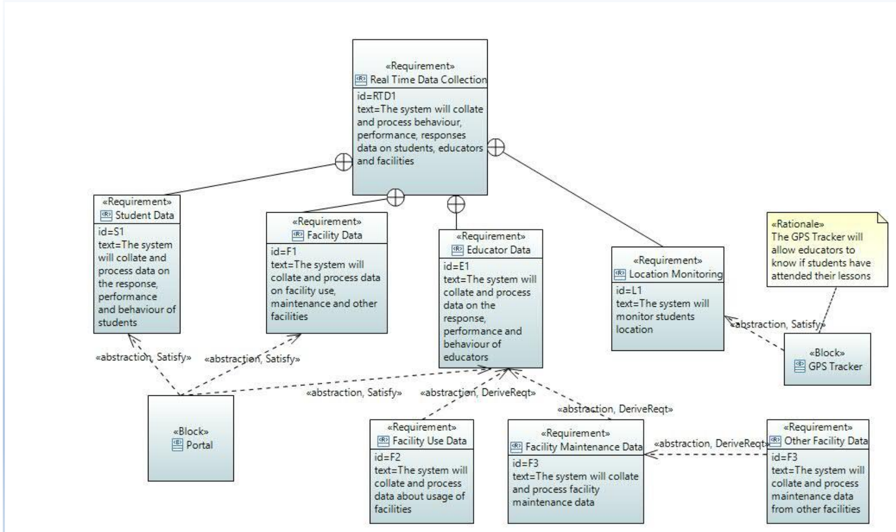

Figure 3: SysML Requirements Diagram – Real Time Data Collection Viewpoint

Additionally, the *Real Time Data Collection* is shown as consisting of *Student Data*, *Facility Data* and *Educator Data* which are collected through the *Portal*. The *Portal* is itself a VLE system, tailored to the interfaced IoT system, ensuring that they work in tandem. *The Portal* can be based on an existing VLE platform, such as Moodle, Blackboard, or Brightspace, customised accordingly, or it could be developed from scratch, tailored to the requirements of this case study. A *GPS Tracker* is used for location identification for attendance monitoring purposes, as well as energy efficiency. Finally, a *Key Fob* utilising a simple user interface, and containing sensors, will be directly tied to the IoT system.

5.0 Proposed System Design/implementation – Data Collection Viewpoint

The common element in all relevant IoT in education systems that is evident from the background study in Section 2, is the use of IoT for data collection. Therefore, this proposed system is constructed around the Data Collection Viewpoint and is presented in Figure 4.

Overall, the IoT system comprises three main aspects: *Database*, *Portal Interface*, and *Key Fob*. These aspects in turn consist of many key elements, parts, values and operations. As the same time, the IoT system is both used and interacted with by three main Actors: *Students*, *Instructors* and the *Institute's IT Department*. The solution has been designed around their requirements and the university's strategy to support the advancement of personalisation of education.

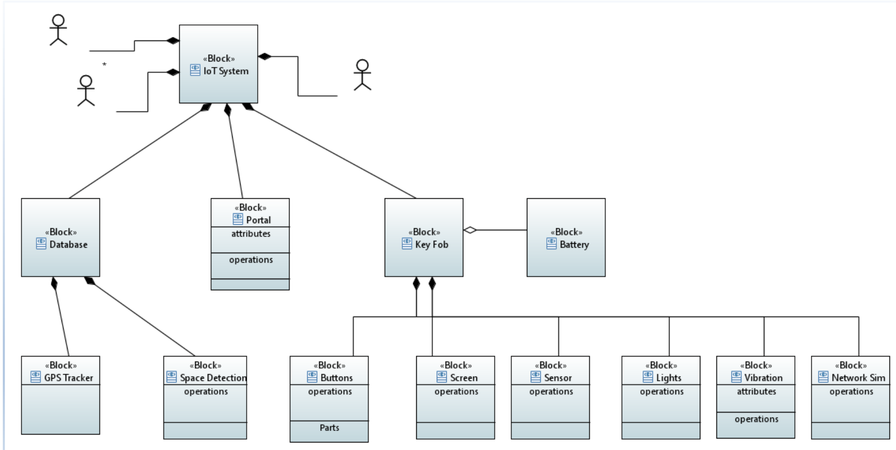

Figure 4: SysML Block Diagram – Data Collection Viewpoint

The proposed system will offer 24/7 operation and will be available throughout all the large lecture theatres and computing laboratories, connected though the existing local network infrastructure. It will allow for real time data collection and processing. The system will also ensure teaching room layouts are detected to process appropriate data according to where the students or instructors are physically situated. Furthermore, the system will deliver data on the behaviour of users occupying any physical space which is being monitored, enabling energy efficiency monitoring. This will include academics, students, and any facilities they use.

The *Key Fob* will be distributed to every student and academic enabling the monitoring of usage behaviour of the facilities available within a given space. The fob will operate autonomously but could also be activated via a button located on the device, enabling manual use. Three main buttons will be present on the device; the first button will turn the device on and off; second will manually enable location monitoring, and the third managing system alert. It will be able to automatically recall the room the student or academics are in using built-in sensors. The *Key Fob* will also allow for alerts and response receiving, with an LED screen being present along with two LED lights that will flash when an alert is received, or an issue arises with the device. The device will vibrate to add another type of notification. Finally, the Key Fob will have a built-in wireless that will provide the one-to-one connection with the local network. This will be run at all time as stated above.

The IoT system, integrates two main databases: *GPS* and *Space Detection*. The *GPS* database will manage the location data which will be location will be logged and stored for future reference. The *Space Detection* database will provide the basis for measurements and pre-set configurations of devices to be available. When signals are detected in a room, relevant configuration data will be retrieved on demand.

Finally, the system will contain a *Portal Interface*. This interface will be the main visual interaction means between the users and the system, providing users with log details, and the ability to view personalised data. This would enable academics to review and respond to issues raised throughout the student lessons. As such, the *Portal* will enhance communication throughout its user base, providing a better service and more engaged users.

6.0 Evaluation of the proposed solution and open issues

The benefits of the proposed solution can be seen in various ways. The fact that rich data will be collected and analysed in relevant ways, will enable informed decisions which support the enhancement of the student experience. It is important to acknowledge, however, that the proposed systems require a significant upfront investment, will incur development and maintenance costs, and require the acquisition and integration of new equipment.

The design and evaluation of the proposed solution was based on literature review in IoT systems in general and IoT systems designed for educational enhancements. The next logical step in moving this proposal forward would be to incrementally prototype different aspects of the system in order to test its effectiveness, but also offer the means of comparison with other similar options.

However, there are several issues which need to be addressed at the design/architecture level before moving to the prototyping phase, namely security, accessibility and ethical considerations.

While the implementation of IoT technologies can offer significant advantages, it is not without risk. One such risk which needs to be considered relates to data security considerations. "IoT has already turned into a serious security concern that has drawn the attention of prominent tech firms and government agencies across the world. The hacking of baby monitors, smart fridges, thermostats, drug infusion pumps, cameras and even the radio in your car are signifying a security nightmare being caused by the future of IoT." [18]. As important as implementing a system like this would be, extreme levels of security must be maintained, especially due to the type of data that would be gathered, most of which would contain personal information.

Apart from security concerns, there are several ethical considerations which should be taken into account. One issue that occurs throughout the use of IoT systems, relates to "Who is the owner of the data retrieved by the sensors of the objects connected to the Internet of Things?" [19]. This is in addition to the issues relating to data security and confidentiality of personal data. Implicitly, when students accepting a place at university, they provide permission for their personal information to be used in different ways, including statistical analysis, videos/audio participation, among other things. However, the proposed solution creates a new set of sensitive personal data which goes beyond the existing information gathered through conventional means, such as logging onto a computer system or accessing the library systems. Careful ethical consideration should be applied to all new forms of data collection methods, and processing of such data.

A further consideration relates to the reliability of the data, as the outputs of any system can only be as accurate as the data which it uses. Inaccurate or incomplete data gathered by IoT devices can lead to producing erroneous results, which in turn can negatively affect the improvements being sought.

Despite the drawbacks, there is a strong argument to be made about the benefits IoT systems can offer. "The Internet of Things itself is only an intermediate stage: In the future, data, people, machines and processes will be linked in the Internet of Everything". [20]. With the costs of the IoT systems becoming lower all the time, their potential benefits to improve personalised education is becoming a strong possibility. As demonstrated, the proposed IoT system can be cost effective and beneficial solution to the personalised education aspirations of Bournemouth University, and consequently other Higher Education institutions.

7.0 Conclusions and Future work

This paper has presented a well thought out solution for the application of the IoT, in a university setting, illustrated by a case study which relates to Bournemouth University. For modelling the proposed system, a combination of SysML modelling diagrams, such as Requirements diagrams, and Block Definition Diagrams were used. The solution provided was specifically created as a response to the current trend seen in UK Higher Education, whereby university students are requesting a more personalised education as part of their learning and teaching environment. This technologically driven need for customisation in conjunction with advances in IoT technologies, makes the IoT enabled solutions for education a viable future development.

8.0 References

1. 1. Jain, Y. (2018). 13 IoT Statistics Defining the Future of Internet of Things. [online] Newgenapps.com. Available at: https://www.newgenapps.com/blog/iot-statistics-internet-of-things-future-research-data [Accessed 9 Feb. 2018].
2. Zhu, ZT., Yu, MH. & Riezebos, P. Smart Learn. Environ. (2016) 3: 4. https://doi.org/10.1186/s40561-016-0026-2.
3. Wasserman, S. (2016). Benefits and Challenges of the IoT for Engineering Businesses. [online] Engineering. Retrieved 7th December 2017 from: https://www.engineering.com/IOT/ArticleID/11772/Benefits-and-Challenges-of-the-IoT-for-Engineering-Businesses.aspx.
4. Government 2020. (2014). Can the Internet of Things make education more student-focused? - Government 2020. [online] Retrived 7th February 2017

from: http://government-2020.dupress.com/can-internet-things-make-education-student-focused/.
5. Brown, J. (2017). How Will the Internet of Things Impact Education? Retrieved 2nd January 2018, from EdTech.: https://edtechmagazine.com/k12/article/2017/03/how-will-internet-things-impact-education.
6. Z. Cheng, L. Shu, J. Xie and C. L. P. Chen, A novel ECG-based real-time detection method of negative emotions in wearable applications, 2017 International Conference on Security, Pattern Analysis, and Cybernetics (SPAC), Shenzhen, China, 2017, pp. 296-301, URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8304293&isnumber=8304236.
7. Meacham, S. and Ross, M., Using a Multi-choice Approach to Enhance Learning Activities, proceedings of BCS SQM/Inspire 2015, pp.137-148, Loughborough.
8. Dervan, P (2014). Increasing in-class student engagement using Socrative (an online Student Response System). AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education, [S.l.], v. 6, n. 3.
9. June Ahn, What can we learn from Facebook activity?: using social learning analytics to observe new media literacy skills. In Proceedings of the Third International Conference on Learning Analytics and Knowledge (LAK '13) 2013, pp135-144, ACM, New York, NY, USA.
10. Hanan Aldowah et al, Internet of Things in Higher Education: A Study on Future Learning, J. Phys.: Conf. Ser. 892 012017, 2017.
11. M. Bagheri and S. H. Movahed, The Effect of the Internet of Things (IoT) on Education Business Model, 12th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS) 2016, pp. 435-441, Naples, 2016.
12. Movahed, H. (2016). The Effect of the Internet of Things (IoT) on Education Business Model. [eBook] Bagheri, Maryam and Haghighi Movahed, Siavosh. Retrived 3rd of December from: http://shura.shu.ac.uk/14405/1/SITIS2016-MB%26SHM.pdf.
13. Taylor, J. (2002). Automating e-Learning: The Higher Education Revolution. [ebook] Toowoomba, Queensland, 4350, Australia: University of Southern Queensland, p.68. Retrieved 15th February 2018 from: https://pdfs.semanticscholar.org/1a83/ebdebfed9966f4051c93351953907d99aac7.pdf.
14. Memon, G. R. (2007) Education in Pakistan: The Key Issues, Problems and the New Challenges, Journal of Management and Social Sciences, 3, 1, 47–55.
15. Brynjolfsson, E. and McAfee, A. (2012). Big Data: The Management Revolution. [ebook] p.5. Retrieved 15th February 2018 from: http://tarjomefa.com/wp-content/uploads/2017/04/6539-English-TarjomeFa-1.pdf .
16. Xia, F., Yang, L., Wang, L. and Vinel, A. (2012). Internet of Things. [ebook] School of Software, Dalian University of Technology, China, p.1. Retrieved 15th February 2018 from:

https://pdfs.semanticscholar.org/930c/4981e87584afa7e6f1f4977323e365aae097.pdf.

17. Pykett, J. (2010). Personalised governing through behaviour change and re-educationi. [ebook] Edinburgh: Institute of Geography and Earth Sciences, Aberystwyth University, pp.6-7. Retrieved 15th February 2018 from: https://www.researchgate.net/profile/Jessica_Pykett/publication/228479272_Personalised_governing_through_behaviour_change_and_re-education_i/links/0a85e53ac0067bffd4000000.pdf.
18. Banafa, A. (2017). Three Major Challenges Facing IoT - IEEE Internet of Things. [online] Iot.ieee.org. Retrieved 7th December 2017 from: https://iot.ieee.org/newsletter/march-2017/three-major-challenges-facing-iot.
19. Popescul, D. and Georgescu, M. (2013). Internet of things – some ethical issues. [ebook] Iaşi: Alexandru Ioan Cuza University of Iaşi, Romania, p.Google Scholar. Retrived 15th February 2018 from: http://seap.usv.ro/annals/ojs/index.php/annals/article/viewFile/628/599.
20. GmbH, T. (2017). Internet of Things: Connected machines present new opportunities for growth. [online] T-systems.com. Retrived 7th December 2017 from: https://www.t-systems.com/gb/en/solutions/digitization/digitization-topics/internet-of-things/machine-to-machine-communication-319936.