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Internet of Things in education: A review

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Abstract

With almost 20 billion devices connected to the internet in 2020 and reaching 78 billion by 2025 IoT is already being used in various areas of our daily life and due to the ubiquity of its devices and applications, nowadays schools and academic institutions are trying to integrate IoT in their educational activities as well as in their educational programs. With the increased use of IoT technology in the education field, our main target is to study the benefits of utilizing this technology in education, at the same time will try to discover the place of IoT in it. Although there have been a lot of contributions regarding the integration of IoT in educational structures, there seems to be a lack of a coherent study that examines the field at all three educational levels, which was also our motivation to fill the knowledge gap.

Keywords: Internet of Things, IoT, primary, secondary, higher education, review, smart objects.

Introduction

In the modern era, the wealth of information and the exponential progress in the "development" of new knowledge pose challenges for educational institutions to rethink about the teaching and learning methods in a globalized society. In addition, the adequate preparation of students in the conditions of increased competition prevailing in the labor market is considered imperative. To achieve these goals, technology can play a key role on how we can move from a one-dimensional educational model of imparting knowledge to a collaborative, interactive, inspirational model that will help students to expand their knowledge and develop their skills. Research has shown that students learn faster by actively participating in original and interest-related activities, in combination with technology which can make it increasingly possible. Students are using software applications that enable them to create or interact with content that previously they could only watch without any other capability. Classrooms are now becoming more 'open', as collaboration can be achieved through speech, video as well as written word, moreover teachers have at their disposal a wider range of teaching methods in order to improve, an Internet-like structure" (Han, 2011; Uzelac, Gligoric, & Krco, 2015). According to Asghari P. et al. (2018) the Internet of Things is a network of "smart" objects that communicate with each other by exchanging useful information about themselves and their environment. This network of "smart" objects or "things" are embedded with sensors, software and/or other technologies, allow them to connect and exchange data with other devices and systems over the net. Garcia C. (2017) comes to answer the question what is the smart object? it is a physical element that can be recognized, can interact and be in touch through the Internet with its environment and other objects, also it has an embedded operating system and can usually be an actuator, a sensor, or both. Each smart object that connected to the IoT network is uniquely identified and can operate both autonomously and in conjunction with the rest of the network infrastructure. Figure 1 depicts the growth rate of IoT-based connected smart devices over time.

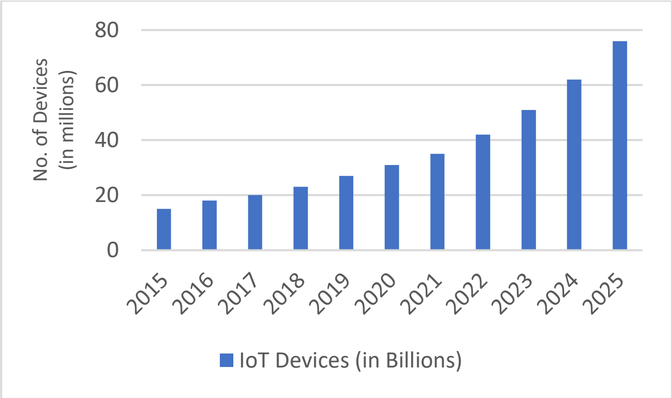

Figure 1. Objects connected to the internet or IoT-based devices (Khanna & Kaur, 2019)

IoT Architecture

The Internet of Things allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service (figure 2). This implies addressing elements such as Convergence, Content, Collections (Repositories), Computing, Communication, and Connectivity in the context where there is seamless interconnection between people and things and/or be-tween things and things. The Inter-net of Things implies a symbiotic interaction among the real/physical, the digital/virtual worlds: physical entities have digital counterparts and virtual representation; things be-come context aware and they can sense, communicate, interact, exchange data, in-formation and knowledge. Through the use of intelligent decision-making algorithms in software applications, appropriate rapid responses can be given to physical phenomena, based on the very latest information collected about physical entities and consideration of patterns in the historical data, either for the same entity or for similar entities. In the IoT architecture, intelligent middle-ware will allow the creation of a dynamic map of the real/physical world within the digital/virtual space by using a high temporal and spatial resolution and combining the characteristics of ubiquitous sensor networks and other identifiable "things" (Sundmaeker, H. et al. 2010).

Figure 2. Anything, Anyone, Everywhere P. F. Harald Sundmaeker et. al. (2010)

According to Zhang, Y. and Jing Yu, J., (2013), architecture of IoT is broadly classified into 4 layers (figure 3).

(a) The sensing layer: is the first layer of the IoT architecture and is responsible for gathering data from different sources. This layer includes sensors and actuators placed in the environment to collect information about temperature, humidity, light, sound and other physical parameters. These devices are connected at the network layer through wired or wireless communication protocols.

(b) The network layer: responsible for providing communication and connectivity between devices in the IoT system. It includes protocols and technologies that allow devices to connect and communicate both with each other and with the wider Internet. In addition, the network layer may include gateways and routers that act as intermediaries between devices and the wider Internet and may also include security features such as encryption and authentication to protect against unauthorized access.

(c) The management layer: acts as an interface between the network layer and the application layer. in two-way mode. It is responsible for device management and information management and extracting relevant information from stored data as well as real-time data and,

(d) The upper layer: provides the user interface for access to different applications and by different users. Applications can be used in various sectors such as transportation, healthcare, agriculture, supply chain, retail, etc.

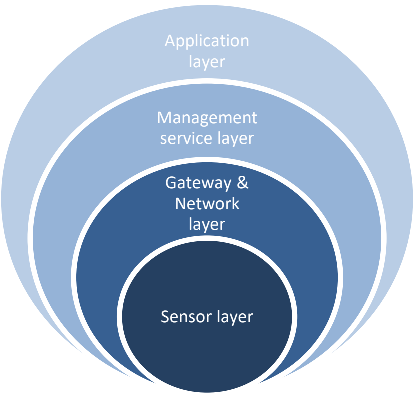

Figure 3. IoT Architecture

Sectors of IoT utilization

IoT applications are already being exploited in various fields such as medical services, smart retail, customer service, smart homes, environmental monitoring and industrial internet. Smart Home: home automation components and energy management devices make up the vision of the "smart home", offering more security and energy efficiency (figure 4).

In Health: wearable health monitoring devices and medical devices connected to the network. Smart health sensors collect comprehensive physiological information, use portals and the cloud to analyze and store it, then wirelessly send the analyzed data to caregivers for further analysis and review.

In Industry: optimization of industrial processes with less maintenance downtime, fewer interruptions and greatly reduced energy consumption.

Environment Monitoring of environmental data such as waste, to protect people and the environment and to reduce or avoid natural disasters.

Service: intelligent traffic systems, sensors embedded in roads and bridges bringing the concept of "smart cities" closer

Education: Now, due to its ubiquity, schools and academic institutions are trying to integrate IoT into educational activities for the benefit of students, instructors and the entire education system.

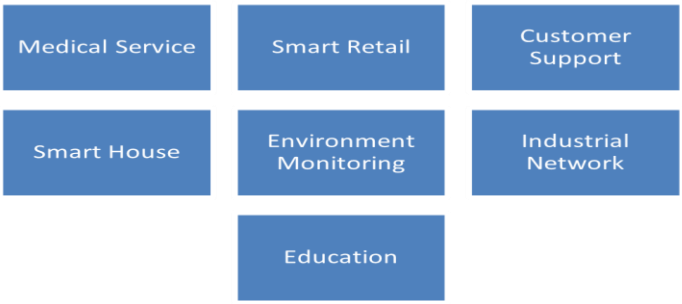

Figure 4. IoT fields

With the increased popularity of IoT in the field of education, it is very important to study how this technology with its special features, such as sensing and intelligence, can support and challenge the pedagogical processes for all the interrelated factors (teachers, students and staff) and assets (eg libraries, classrooms and laboratories). With our research, through a literature review will try to investigate the benefits of using IoT in education processes and the challenges of using it in three educational levels (primary, secondary, higher).

IoT in education

According to O'Reilly, (2015), the development of the IoT will indirectly change the knowledge transfer model in education into an independent, active, collaborative model. The impact of technology on the world of education has made many institutions reorganize the existing teaching and learning processes. Learning methods have shifted from traditional to digital as a result of advances in information and communication technology (Al-Emran et al., 2020), and the emergent technologies such as the IoT at present are rapidly developing in the digital world and transforming traditional education system into a scalable, adaptable with rapid dynamic changes, flexible and more efficient E-learning with a topology where the huge number of physical and virtual interacting objects are involved in the process of learning (Abbasy & Quesada, 2017).

The IoT infrastructure allows students to use data from sensors for learning purposes. With the innovation of the IoT in education, it helps the teaching and learning process be carried out remotely. For example, using IoT and cloud systems, special networks or extranets can be created (Lestari, 2018).

The advances in sensors, nanoelectronics, smart objects, cloud computing, Big Data, and communication on wide scale will make innovation continuous in IoT, and it will clout a great number of domains. The education domain is not an exception. Although IoT in education is a new conceptual paradigm and it is still in its starting phase, the hope is that researchers will use these data to corroborate their own research and to motivate follow-up research studies (Kassab et al. 2020).

Benefits of using IoT in education

The cognitive objects in which the IoT can be exploited or integrated neither limited to any particular, nor its application limited to a specific level of study. Having in mind Kassab's (2020) systematic study, 49% of the surveys are not limited to any level of education, while 35% concern undergraduate education and 34% graduate education. The majority of studies are not limited to any educational or cognitive subject. Some are related to cognitive subjects such as computer, electrical and electronic engineering while smaller number of studies focus on natural science issues, while even fewer are related to educational sciences.

The groups that interact educationally with IoT technologies are the teaching and special educational staff, as well as the students.

The teacher with the utilization of the IT can be helped regarding the management and monitoring of a class as well as the availability of the required teaching equipment/devices per student. Moreover, teachers can be informed about the activities of the students during school hours using RFID systems (about their visits to the study room, library, canteen, etc.). He can manage lessons and communicate with the students remotely, while receiving feedback on their interest in the course.

On the one the technology can help students with an easy way about their learning or other types of needs (Alotaibi, 2015; Borges et. al. 2011; Jiang, 2016; Gul et al., 2017), from the other hand are facilitated in direct communication with their instructor, with their classmates, discussing, exchanging opinions, practices, methodologies proposing solutions regardless of time, location, distance and so on (Yin et al., 2012, Kane et al., 2013. Fernandez et al., 2015).

IoT according to Ambrose et al. (2010), has a positive impact on the seven principles underlying effective learning, (a) Prior Knowledge, (b) Learning Organization, (c) Motivation, (d) Skills, (e) Practice & Feedback, (f) Self-Directed Learning and (g) Lesson Climate, while the use of technology gives us the possibility of choosing an educational approach for the transmission of Knowledge, combining the three modes: (a) Face to Face, (b) Distance and (c) Hybrid.

IoT in Primary Education

Building knowledge, learning activities through independent play. Lee & Kim (2019) demonstrated that children's logical math performance improved significantly after playing with S-Blocks (traditional bricks) with IoT technologies embedded. Moreover, in Arnott et al.'s (2019) study, it was observed that despite the advanced technologies used, children became experts in using games combined with IoT while adults lagged behind in the ability to help children in their play.

Miglino et al. (2014) compared children who learned foreign words in the traditional way with others who used the Wanbot IoT device. The first group found the lesson boring in the contrary, the second group found it interesting and fun.

Sigarchian (2018) observed that children using an e-textbook performed better in grammar and spelling than others who learned in the traditional way. The ability of IoT to connect the physical and digital world, encourage young children to explore the interaction between the two worlds using technology-embedded games and educational aids.

In the systematic review by Ling et al. (2022), it is found that digital devices can provide to young children opportunities in order to discover and explore the interconnectedness of the digital and physical worlds, while helping them to build knowledge, increasing their interest and excitement, encouraging their autonomous learning. in general, through the interconnection of the two worlds the knowledge facilitated in an attractive way, triggering the interest of young children and turn them into more independent and autonomous learners.

It is remarkable that no negative effect on the educational process has been recorded in the research, however, a condition for the use of new technology by young children is to take into account their sensitive age and the necessity of careful use to minimize the risks (Livingstone & Stoilova, 2021). Therefore according to Sumsion (1977), parameters such as level of cognitive development, pedagogical needs and the IoT devices could be accessible to them should be taken into account.

What are the research aspects in primary education which the studies on the application of IoT consider? They focus on summarizing the data's on how IoT devices have been used, the benefits that IoT devices can bring, moreover the reflection and the concerns regarding the use of these devices. In addition, the context (e.g. activities, spaces and participants) of the use of IoT devices mentioned in the studies, what are the IoT devices and what are the advantages of the use and development of IoT in primary education and finally examined the concerns arising from the integration of these devices into the educational process.

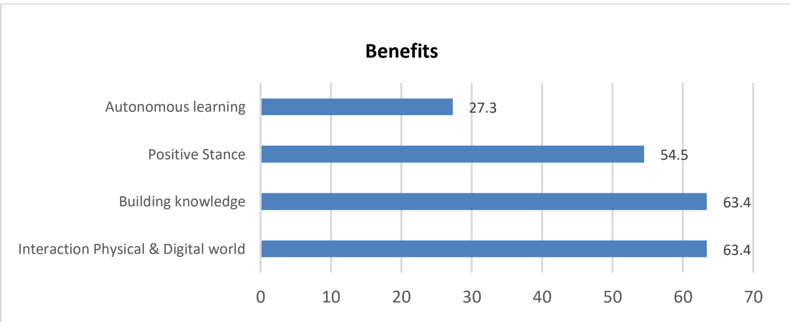

Figure 5. Benefits, Ling et al. (2022)

Taking into account the usefulness and functionality of the devices we can say that they fall into two main categories. The IoT devices that function as toys and the IoT devices that are used in gaming activities. Thus according to the findings presented in fig. 6, 81.8% made use of IoT games, while the remaining 18.2% used the devices in gaming activities. However, these results according to Holmes (2020), are not surprising considering the importance of play in the development of young children.

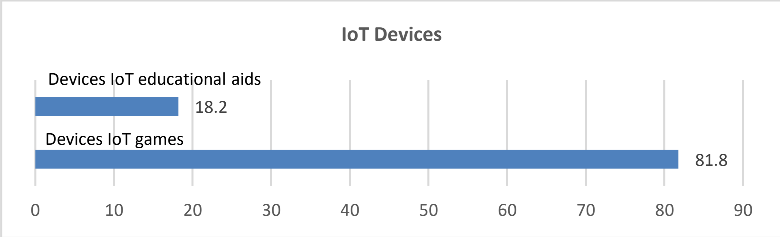

Figure 6. IoT Devices

According to the systematic review by Ling et al. (2022), IoT devices were mainly used in play and learning activities. As shown in figure 7, the 54.5% of IoT devices integrated into play processes, the 27.3% use the IoT devices to facilitate game-based learning and the 18.2% focused on using IoT devices in order to support learning. Meanwhile, these IoT-enhanced activities usually took place in homes or at school, while it appears that the IoT devices are typically used in unstructured play activities. On the other hand the majority of activities that involved the use of IoT at school tend to be more structured, including learning and play-based learning activities.

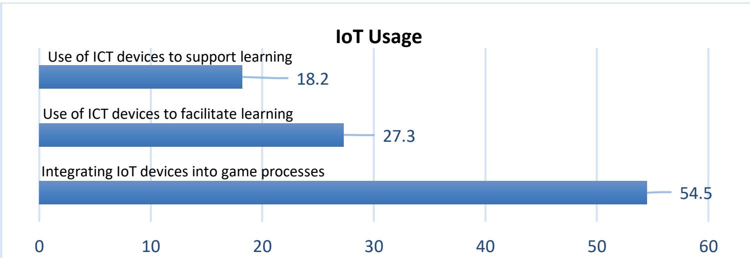

Figure 7. IoT Usage

IoT in Secondary Education

Considering the opinion of Council et al. (2007), IoT in Secondary Education is used to serve and guide the design of new educational activities that help students to gain knowledge through data collection by engaging in discovery and play activities. The use of advanced technological devices and software, based on IoT technologies enrich the learning process in secondary education and contribute to the creation of smart learning environments.

But what are the research aspects that the studies on the application of IoT in primary education consider?

Secondary education students use technology applications to become active members of a team, working together to monitor environmental ecosystems at the local level or to decide on environmental issues. Educational scenarios are a starting point for school communities to design and implement specific activities related to their own local conditions, provide added value to their members, and a meaningful motivation for their educational practices (Tziortzioti et al., 2019). The ultimate purpose of Tziortzioti's research is to pave the way for design educational activities that lead students to acquire experience by participating in coastal field exercises and collecting data using water sensors, Arduino microcontroller and

IoT platform, with the aim to engage experiences that speak to their interests in an active learning concept.

At Glaroudi's et al. research (2018), examined how the use of IoT technologies can be well accepted by secondary education students both as educational means and learning outcomes. During a mobile computing and Internet of Things, Summer School investigated the students' stance on further attending IoT-related activities, properly organized in STEM educational scenarios. The analysis focuses on the students' satisfaction and engagement in relation with students' potential to follow the activities, the perceived, by the students, easiness, enjoyment and usefulness while setting as parameters the student gender and age

On the other hand, beyond the common finding about the integration of new technologies and the learning benefits, at Mavroudi's et al. (2018) research examined the impact when the students at secondary school asked to take on the role of the educational context design process. The purpose of the intervention was to familiarise students with the basic IoT concepts and help them ideate and design IoT applications, with special focus on smart cities it took place in school classroom and comprised three main phases: (1) an introductory presentation, (2) the Tiles inventor toolkit, and (3) a student assessment

The research methodologies followed in the studies, is about the use of educational structures in order to construct, or programming or integrate different types of sensors or actuators. For example, were used educational methods for teaching students how to build, program and test different types of sensors that used to monitor the quality of water, air or soil. After collecting a set of data, students had to examined it, analyzed it and compared it, based on specific qualitative characteristics and finally to decide on the resulting findings, while they are also asked to explain phenomena related to the parameters which they had monitor. According to R. N. Caine and G. Caine, (1991), learning is most effective when students are involved in complex experiences and given the opportunity to actively process what they learn, so the students in order to carry out the experiments and finalized the study on the field had to design the appropriate software platform that is required for the combination with the hardware platforms, as well as sensors, hand-made constructions and so on.

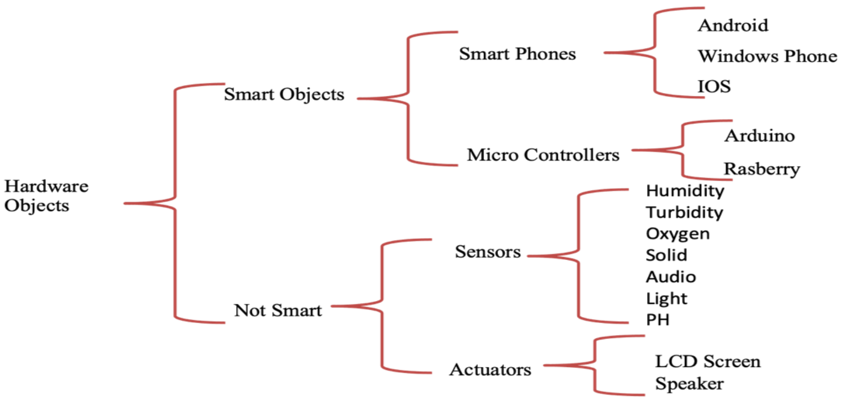

Figure 8. Objects Categories that used in projects

Through researches, the benefits that came of importing of IoT technology in education, according to Tziortzioti et al., (2019), gives to students the ability to design and to implement specific activities related to their local conditions and needs, providing added value to their effort and meaningful motivation for their educational practices, while learning becomes more effective when engaging students in complex experiences giving them the opportunity to actively process what they learn. On the other hand, through design as has been suggested by a lot of researchers, the teaching approach is used as a vehicle in order to generate and import concepts into secondary education (S. G. Puente et al., 2013).

IoT in Higher Education

Higher education is one of the sectors that has begun to use IoT to improve learning, training, management, experimentation, and so on. Many higher education institutions across the globe have used IoT to produce significant improvements in their performance (teaching, learning, management, training, buildings, etc.). IoT encompasses a wide range of fields, including computer and information science, engineering, and social and mathematical sciences (Tianbo, 2012). In addition, the development of IoT has three potential applications in higher education: students' progressive assessment, integration of existing teaching platforms, and the creation of educational middleware. This modification improves student convenience while also making the teaching process more successful for both instructors and professors. (Zhiqiang & Junming, 2011).

The basic axes underpinning the organization of lessons in higher education based in IoT are the following:

- From theory to practice. Where learning begins with theory and is followed by practical participation, where usually a variety key of concepts is gradually introduced to students in themed lectures, followed by weekly pre-set exercises. G. de Haan (2015), F. Ali (2015), E. Osipov and L. Riliskis (2013).
- Easy-to-start courses that start with hands-on experimentation. Here, the learning objectives are defined in part by a default material and sometimes an easy-to-use programming environment. V. Callaghan (2012), G. de Haan (2015), L. Kehinde et al. Al. (2016).
- Problem-based lessons. IoT devices are purpose-built with few limitations focused on solving the problem H. Maenpaa et al. (2015).

The main research aspects that examined in the literature review are (a) how to organize a prototype lesson based on IoT, (b) the evaluation of learning outcomes, as well as (c) the practices that can be adopted by teachers (H. Maenpaa et al. 2017).

In addition, emphasis is placed on the potential of IoT in higher education, maximizing the benefits and reducing the risks associated with it, while further efforts are needed to unleash the full potential of IoT systems and technologies, and therefore examined the impact of IoT on higher education (H. Aldowah et al. 2017).

The methodology for investigating research aspects, conclusions, and benefits stem from papers that study action research through the collection of empirical data, using questionnaires, interviews etc. as well as from the Systematic bibliographic review of Soegoto (2022) where he used the Funnel diagram (figure 9) in his research for the extraction, evaluation, composition of the works, investigation of research aspects, and gleaning of results.

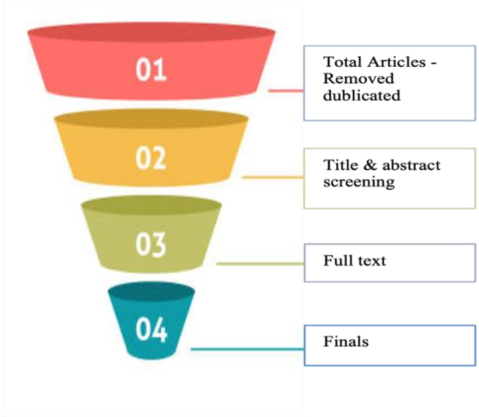

Figure 9. Funnel Diagram

The benefits as derived from the studies are on the one hand that universities could become leaders in technological development and innovation models, as well as can create future experts in IoT. In addition, the development of IoT is applied in higher education for the progressive assessment of students, the integration of existing teaching platforms and the creation of educational middleware, contributing to a more successful teaching process for both professors and students due to the abundance of connected devices and technology so that students and teachers can focus on real learning which is more beneficial than doing repetitive projects (Zhiqiang & Junming, 2011), (Tianbo, 2012). In addition, through IoT technology, teaching staff can collect data on students' performance in order to determine who needs more care and attention, on the other hand helping them in changing plans and methods for future classes based on these special needs (H. Aldowah et al., 2017).

Students can take advantage of learning resources, manage assignments, and work collaboratively on them, the professors also, use some of these applications to teach highly specialized concepts such as physical sciences, technology, scientific simulations, and social issues. With great interest we observe through the research of Essiane & Essama (2021), the development of a pedagogical IoT micro weather station aimed at teaching physical concepts to university students in Central Africa. Interestingly, students in non-prosperous societies and countries have the opportunity purchase and use smart economic devices to be taught about weather stations, weather phenomena and forecasting

The technological evolution of IoT not only contributes to the improvement of the educational process as described but also has an essential role in the security of university campuses, access to information and applications at any time and from anywhere (J. Gubbi et al., 2013), as many universities use the cloud architecture for hosting IoT applications, providing seamless connectivity and information storage, with a future challenge to be concerned about the speed of data exchange as well as the size of information to be stored.

The increasing use of management systems of education data such as e-class, progress, Moodle should manage a huge amount of data such as audio and video content. Online classrooms equipped with lecture management systems provide the opportunity for students to access on-demand educational content at any time.

Higher education is taking advantage of the use of IoT technologies, with the availability of big data where even smaller universities can increase their interdisciplinary research footprint and store big data and analytics on high-performance computing platforms. STEM education through IoT will evolve using high technology sensors, unmanned aerial vehicles (UAVs) and microcontrollers, in addition Engineering labs use audio, video technics, UAV's, Raspberry Pi and open-source systems (OSS) technologies that drive innovation and enhance learning processes.

Challenges are also imported to maintain the quality of teaching and assessment of student work. The Educational IoT applications need tools and technologies that will be used by the educators and the scientific community in general, in order to improve the quality of research and address ethical issues in higher education.

Challenges

Talking about the functionality and the use of IoT in the educational process attention is often focused on concerns and challenges, such as appropriateness of purpose, big data usage and interoperability.

The European Committee on Ethics in Science and New Technologies argues that the IoT will bring about a radical change in the control people have over their environment, by enabling interconnected autonomous objects to communicate with each other and take actions that affect the lives of individuals without those individuals being involved in the process (Freeman and Peace, 2005). The large increase in personal information that will become available, the potential loss of control over information and the types of actions that IoT can autonomously initiate raises important ethical issues related to the autonomy of things and people, privacy, security, safety, freedom, liberty, equality, equity, fairness, integrity, access, discrimination and others.

The challenges considering the literature review are focused on three axes:

Security: Safety requirements have always been a critical aspect of training. It is becoming increasingly clear that educational systems are vulnerable to cyber-attacks and the number of attacks is predicted to increase. Both students and their schools can easily become victims of such attacks (Georgescu & Popescu, 2015). Many of the devices used in a specialized IoT collect various data and the questions are, why this data collected? Who do they belong to? Where are they headed? These questions need to be answered by the legislature, government agencies, and educational institutions.

Scalability: With the integration of sensors in the work fields as well as the use of terminal devices based on IoT, rich real-time data collection is achieved and from this scalability, education and its relationship with technology are not excluded. Resulting in the creation of a large amount of data, there arises the need to analyze and process content, collect information and evaluate the resulting trends Lamri et al. (2014), Jagtap, et al. (2016), Mehmood et al. (2017).

Humanization: The success of the IoT will depend less on how far the devices are connected but the more on how human-friendly those devices are. According to Gubbi, Buyya, Marusic & Palaniswami, (2013), the IoT technology from one hand will reduce people's autonomy driving them into certain habits, on the other hand will give the power to companies to focus only on profit. For the educational system, this essentially means that the controlling actors will be the organizations that control the academic activities which will no longer be controlled by the educational system itself.

Funding: Education needs to come up with new ideas for financing an Information Technology infrastructure and services, since most educational institutions do not have a strategy for cost sharing and determining the total cost of ownership of an IoT infrastructure (H. Aldowah et al. 2017).

Conclusion

IoT devices have been used primarily as toys but also as training aids in early childhood education while the benefits promising a hopeful future for parents and teachers after the integration of these devices into pedagogical processes. IoT, in general, could create a connected digital and physical world for exploring, facilitating the acquisition of knowledge in an engaging way, engaging young children and turning them into autonomous learners.

However, the use of IoT causes concerns which focused on the cost and fragility of the devices and less but not insignificant, on data security. The hypothesis behind the researches is that the development of IoT in real-world focusing on education could drive to better understanding of our environment through the promotion of sustainable activities, starting at the school level.

The inexpensive and easily available infrastructure of smart devices which used for measuring, or/and visualizing combining data's, contributed to meaningful understanding of our natural sciences while at the same time the science is supported (Tziortzioti, C. et al., 2019). IoT provides a thematic umbrella that on the one hand helps educators to combine various aspects of science in order to address everyday life problems, on the other hand, the size of the group of learners combined with the pluralistic background of knowledge creating a particular educational challenge (H. Maenpaa et al., 2017).

In addition, universities can solve many challenges such as: tracking resources, developing access to information, designing safer campuses, adding value to higher education by engaging and motivating students and faculty as well as increasing the speed of knowledge transfer (H. Aldowah et al., 2017).

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