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THE INTERNET OF THINGS IN EDUCATION. TECHNOLOGY, PEDAGOGY AND LEARNING

INTERNET DAS COISAS NA EDUCAÇÃO. TECNOLOGIA, PEDAGOGIA E APRENDIZAGEM

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Abstract Our society, driven by technological innovations, has become increasingly digital and interconnected, making operating tasks easier and faster.

The Internet of Things is based (IoT) on a set of technologies that allows intelligent devices, such as sensors, to connect objects to the Internet and collect data that will be stored for later analysis and control. According to the Hype Cycle, it is one of the emerging technologies in which we recognize added value for all sectors of society, Education included.

In this context, school should take advantage of the possibilities offered by this technology, since it makes the classroom an "open space" where physical limitations are not relevant to the interpretation of the surrounding environment. It supports an active Case-Based Learning (CBL) by exploring issues that meet the interests and the context of students and their community. For this, the object under study will be monitored and students will act on it, after analysing the data, and control the variables, in real time and with constant updating.

Therefore, this article aims to carry out a bibliographical review of data obtained from three databases: B-ON, IEEE Xplore and Google Scholar, between 2014 and 2018, years in which IoT is at Gartner's inflated peak.

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The obtained data will be subject to content analysis, in order to investigate the added value of IoT in Education, especially with regard to the CBL methodology, and investigate the technology associated with it.

Keywords Internet of Things, Technology, Education, Learning

Resumo A nossa sociedade, impulsionada pelas inovações tecnológicas, é cada vez mais digital e interligada, tornando as tarefas operacionais mais fáceis e rápidas.

A Internet das Coisas (IoT) é baseada num conjunto de tecnologias que permitem que dispositivos inteligentes, como sensores, liguem objetos à Internet e recolham dados que serão armazenados para posterior análise e controle. Segundo o Hype Cycle, esta é uma das tecnologias emergentes em que reconhecemos valor acrescentado para todos os setores da sociedade, incluindo a Educação.

Neste contexto, a escola deve aproveitar as possibilidades oferecidas por esta tecnologia, uma vez que faz da sala de aula um "espaço aberto", onde as limitações físicas não são relevantes para a interpretação do ambiente envolvente. Apoia uma aprendizagem ativa baseada em casos (Case-Based Learning, CBL), explorando questões que vão ao encontro dos interesses e do contexto dos alunos e da sua comunidade. Para isso, o objeto em estudo será monitorizado e, após análise dos dados, os alunos atuarão sobre ele e controlarão as variáveis, em tempo real e com atualização constante.

Este artigo tem como objetivo realizar uma revisão bibliográfica de dados obtidos de três bases de dados: B-ON, IEEE Xplore e Google Scholar, entre 2014 e 2018, anos em que a IoT está no pico inflacionado do Gartner. Os dados obtidos serão sujeitos a análise de conteúdo, de forma a investigar o valor acrescentado da IoT na Educação, especialmente no que diz respeito à metodologia Case-Based Learning (CBL), bem como a tecnologia a ela associada.

Palavras-chave Internet das Coisas, Tecnologia, Educação, Aprendizagem

1. Introduction

The Internet revolutionized society by making it more and more digital and connected. It evolved to the Web 4.0 or Ubiqua Web, represented by the Internet of Things (IoT), based on the connectivity and interactivity between people, information, processes and objects, through technologies that allows anyone to access the network, from any place, at any time, using devices as multifunctional equipment with intelligent sensors, such as household appliances, cars, clothes, among others, from applications that can be adapted to people's needs (Davis, 2008). In this last evolutionary stage of the Internet, objects become a source of information, since they are embedded with sensors, gaining the ability to communicate. This allows for more and more direct and rapid access to information and provides a closer relationship between people with a strong sharing component.

Today's students are the mirror of this technologically advanced society, based on research, interaction, and widespread access to information. Given that the predominant model of teaching still follows the production model, based on transmission and repetition, the 21st century school will have as challenge the establishment of a school based on participation, research, use of real data and, therefore, more inclusive, generating pedagogical practices that consider local and community contexts. In this sense, the IoT is an asset, because it is based on a set of technologies that allows connecting objects to the internet and collecting data for eventual automatic control and for storage, that allows for a posterior multidisciplinary analysis.

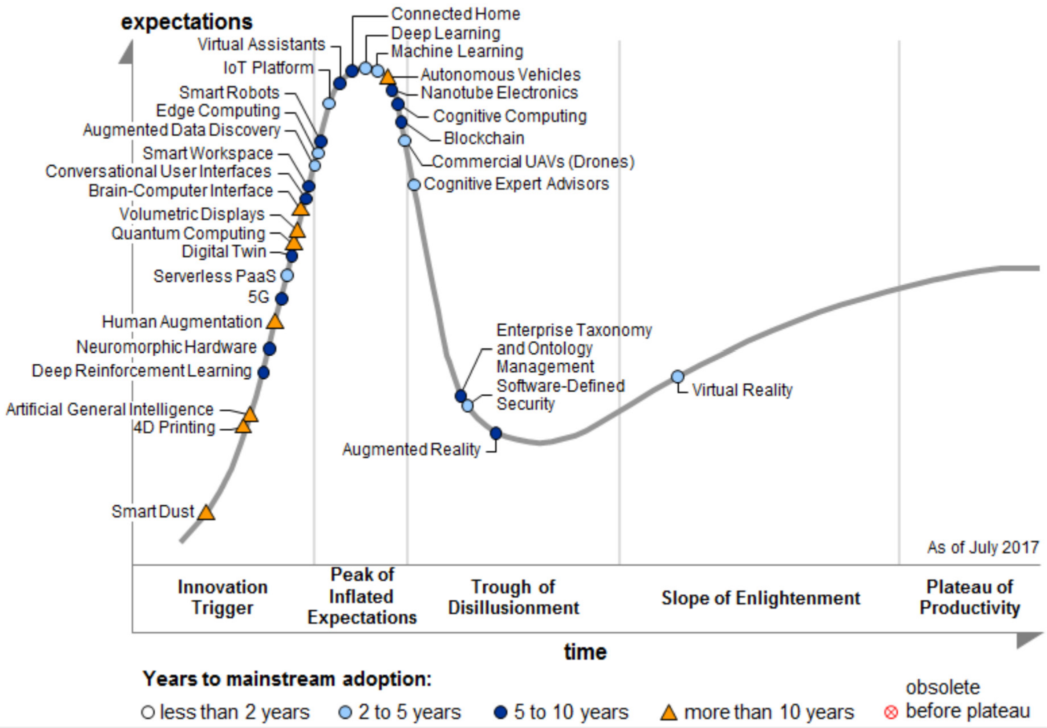
Given this innovation reality, this article makes a scooping review of the literature based on data obtained from the following databases: B-ON, IEEE Xplore and Google Scholar, between 2014 and 2018, years in which IoT is at Gartner's inflated peak.

2. Theoretical Contextualization

2.1. Internet of Things

The IoT has been considered by some authors as a technology so innovative that its impact on society will be equivalent to an Industrial Revolution (O'Brien, 2016), having reached the peak of the inflated phase of the Hype Cycle for technologies emerging from Gartner (2017).

Figure 1. Hype Cycle of Gartner 2017



This technology can still be considered with many new developments occurring in the integration of objects with sensors, in the Cloud-based Internet (Li et al., 2015).

According to Atzori et al. (2010), the IoT is on the crossing of three paradigms: orientation to the Internet (middleware), orientation to things (sensors) and semantic orientation (knowledge). Even assuming its interdisciplinary nature, the usefulness of the IoT can be triggered only in an application domain where the three paradigms intersect (Gubbi et al., 2013).

Sundmaeker et al. (2012, p.43) analysed the meaning of the word “things” under an Aristotelian philosophical prism, and considered that these are “real/physical or digital/virtual entities that exists, and moves in space and time, and that are able to be identified”, what led these authors to define IoT as:

> a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual

> personalities and use intelligent interfaces, and are seamlessly integrated into the information network (p .43).

This idea of interpreting the IoT not as a technology but as a global concept is corroborated in the 2016 report of the IERC – IoT European Research Cluster (Jamalipour et al., 2016).

Xia et al. (2012) refer to the IoT as a network interconnection of everyday objects, which are often equipped with ubiquitous intelligence. They also add that this technology will increase the ubiquity of the internet because it will integrate all objects into an embedded system, which will give rise to a strongly network full of objects communicating with humans or other objects.

According to Gubbi et al. (2013), IoT is considered as something more user-centered and not restricted to communication protocols. It is the

> Interconnection of detection and actuation devices, providing the ability to share information across platforms, through a unified structure, developing a common operational framework to enable innovative applications. This is achieved by ubiquitous detection, data analysis, and information representation with cloud computing as a unifying structure. (p. 1647)

O'Brien (2016) defines the IoT as a technology that allows, through sensors, to connect objects with the Internet in order to obtain information about the environment or activity that will be stored and provide feedback and control.

A more systemic definition is presented by Ray et al. (2016). For these authors, the IoT is an ecosystem that widely exploits and expands existing environments of embedded and connected devices. The scope of the IoT is the computing infrastructure that will allow an ecosystem in which there are more "things" connected to the Internet than the number of people (Ray et al., 2016). The basic idea is that behind this ubiquitous presence of objects / things, around individuals, they are able to measure, infer, understand and even modify and act in the environment in which they are inserted (Botta and Donato, 2016). Thus, between 2008 and 2009 the number of devices connected to the network exceeded the world population (Mukhopadhyay and Suryadevara, 2014).

The IoT presents itself as a technology with interest for application in Education, because with IoT students will be able to monitor their own surrounding environment and collect data in real time for further studies, with the data emitted by these interconnected environments (Johnson et al, 2015), allowing the exploration of subjects that meet the interests and context of the students and their community through active Case-Based Learning (CBL).

2.2. Case Based Learning

Case Based Learning is a methodology rooted in the constructivism of Jerome Bruner (Hartfield, 2010) and in the experientialism of John Dewey (1994). Both perspectives converge in the involvement of the students in the construction of significant knowledge and in the promotion of learning by discovery. Learning by discovery is a necessary condition for learning the variety of problem-solving techniques, of transferring information for best use (Bruner, 1961).

This methodology uses collaborative learning, favours learning integration, develops students intrinsic and extrinsic motivation to learn, encourages students self and critical reflection, enables scientific research, integrates knowledge and practice, and supports the development of a wide variety of learning skills (Williams, 2005), allows students to put theory into practice in a secure classroom environment, where they spend the same time in real and educational environments (Wood, 2003; Thistlethwaite et al., 2012). According to Lee (2012) this involves a guided inquiry and is based on constructivism, whereby students form new meanings interacting with their knowledge and environment.

According to Ridley and Byrom (2018), this methodology supports peer learning by developing collaborative work and communication skills, as shown in Table 1 from the Williams adaptation (Williams, 2005).

Table 1. Benefits of CBL, by Ridley and Byrom, adapted from Williams (2005)

Benefits	How	Impact
• Preparation for placement and practice • Collaborative and communication skills • Encourages active and motivated students • Improves research skills and critical thinking • Develop reflective practice	• Involving cases and "real life" scenarios in the classroom environment security. • Students who work in small teams and share their ideas through regular feedback sessions. • Mix of directed and self-directed study. • Through research and search clubs and shares current literature and evidence to support weekly feedback sessions. • Weekly brainstorming sessions exploring learning and personal development.	• Build trust to care for women and families. • Development of clinical and care skills. It closes the theory-practice gap. • Allows students to become effective members of a multidisciplinary team. • Helps develop self-employed people with lifelong learning skills. • Improved evidence-based practice. Greater confidence to access and criticize research and literature. • It develops self-awareness and guarantees the development of continuous practice.

Case-based learning has a strong history of successful implementation in medicine, law and administration colleges and is increasingly used in undergraduate education, particularly in pre-professional courses and sciences (Herreid, 1994). Since technology strongly influences education, it is fundamental to know the potentialities linked to the IoT in Education and the technology necessary for their implementation, to apply in real cases.

3. Methodology

According to Gil (1989), the research methodology describes the structure of a study by explaining the procedures, methods and techniques necessary for the development of the research, in order to obtain a secure knowledge and to determine the truthfulness of the facts.

Accordingly, it was considered that, depending on the type of data collected, the most appropriate methodology would be qualitative, since "qualitative methods emphasize the specificities of a phenomenon in terms of its origins and reason for being" (Haguette, 2005, p.63). It is "oriented towards the construction of comprehensive models of what is being studied" (González, 2005, p.80) and are based on information or primary data obtained directly from reality (1980, cit. by Vilelas, 2009, p.103).

This qualitative research was based on documentary analysis which is, according to Quivy and Campenhoudt (2008), especially appropriate when it aims to study social changes and historical development as is the case of the present work. The authors also add that it has the advantage of taking benefits of the richness of the documents available, specifically in electronic databases.

This scooping review is structured based on the proposal of Kitchenham et. al., (Kitchenham, B.; Brereton, P.; Budgen, D.; Turner, M.; Bailey, J.; Linkman, 2009) and aims to make an analysis of the use of IoT in education between 2014 and 2018, during the peak of inflated expectations when the technology is widely publicized and diffused. Considering the above and the published scientific production, we intend to know, for this period:

- What was the potential of the IoT in Education?
- What were the applications of the IoT in Education?
- What pedagogy was needed to implement the IoT in education?

In this context, this research began with the collection of documents, namely, scientific articles obtained from three databases: B-ON, IEEE Xplore and Google Scholar, between 2014 and 2018, the period at the peak of this technology, and having as search keywords "IoT", "Internet of Things", "Education", "Learning".

By reading the title, 74 articles were selected. Then, applying the inclusion criteria (the articles were within the time interval chosen for the analysis and approach the IoT in education), and by analyse the abstract, we obtained a sample of 31 articles.

Deleted articles are due to the exclusion criteria: they are not aimed at education, they only deal with the definition of the IoT and are postgraduate courses in IoT.

The Table 2 presents these articles, listing the title, author, year of publication and where it was published.

Table 2. Sample of articles under analysis

Title	Author	Year	Published
Teaching Management System with Applications of RFID and IoT Technology	Ping Tan, Han Wu, Peng Li, He Xu, 2018	2018	Education Sciences
Open Source Technologies in Teaching Internet of Things	Culic, I., Radovici, 2017	2017	The 13th International Scientific Conference – eLearning and Software for Education, Bucharest
How could Internet of Things change the E-Learning	Georgescu & Popescu, 2015	2015	The 11th International Scientific Conference – eLearning and Software for Education, Bucharest Environment
Developing IoT Enabled Applications for Augment Enginering Education	Popentiu-vladicescu & Madsen, 2017	2017	The 13th International Scientific Conference – eLearning and Software for Education, Bucharest
Internet of Things in Education: A Case Study for Learning Agriculture	Birsan & Stavarache, 2017	2017	The 13th International Scientific Conference – eLearning and Software for Education, Bucharest
How the Internet of Things Will Impact Schools	Pierce, 2016	2016	T H E Journal
The Internet of Things—A survey of topics and trends	Whitmore, A., A. Agarwal, 2015	2014	IEEE
Curriculum. Considerations for the Internet of Things	Voas & Laplante, 2017	2017	IEEE
Internet of Things and its applications in E-learning	Z. AjazMoharkan, T. Choudhury, 2017	2017	IEEE
Exploring the Internet of "Educational Things"(IoET) in rural underprivileged areas	Pruet, 2015b	2015	IEEE
Architecture for integrating real objects with Virtual Academic Communities	V. Jhorman, A. Villanueva, D. Marquez, 2015	2015	International Conference on e-Learning

Title	Author	Year	Published
IoT-DESIR. A case study on a cooperative learning experiment in Sardinia	Salis, C., Murgia, F., Wilson, 2015	2015	International Conference on Interactive Collaborative Learning
ICT and Internet of Things for Creating Smart Learning Environment for Students at Education Institutes in India	Rahman & Deep, 2016	2016	IEEE
Educating Internet of Things Professionals. The Ambient Intelligence Course	Corno, F., Russis, L., Bonino, 2016	2016	IEEE Computer Science
A Study on Enhanced Educational Platform with Adaptive Sensing Devices using IoT Features	Tew, Tang, & Lee, 2017	2017	Annual Summit and Conference 2017
IOT Based Information Dissemination System in the field of Education	Koshy, R., Shah, N., Dhodi, M., Desai, 2017	2017	International Conference for Convergence in Technology
Motivating students with Mobiles, Ubiquitous applications and the Internet of Things for STEM	Mavroudi et al., 2017	2017	Global Engineering Education Conference
The internet of things: a survey	Li, Xu, & Zhao, 2015	2014	Springer Science+Business Media, New York
Educational Robots for Internet-of-Things Supported Collaborative Learning	Plauska, I., Damaševičius, 2014	2014	Springer International Publishing Switzerland
Three questions about the Internet of things and children	Manches, Duncan, Plowman, & Sabeti, 2015	2015	Association for Educational Communications and Technology
Educating Creative Technology for the Internet of Things – Research and Practice-oriented Approaches Compared	Haan, 2015	2015	Wittenborg University of Applied Sciences Apeldoorn, the Netherlands

Title	Author	Year	Published
Internet of Things: A Survey on Enabling Technologies, Protocols and Applications	Al-fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015	2015	IEEE Communications Surveys & Tutorials
Internet of Things (IoT): An Overview	Kuyoro, Osisanwo, & Akinsowon, 2015	2015	3rd International Conference on Advances in Engineering Sciences & Applied Mathematics
Future Classroom with the Internet of Things. A Service-Oriented Framework	Chang, Chen, & Huang, 2015	20015	Journal of Information Hiding and Multimedia Signal Processing. Ubiquitous International
A Review on Internet ofThings (loT), Internet of Everything (IoE) and Internet ofNano Things (IoNT)	Miraz & Ali, n.d.	2015	Glyndwr University Wrexham, UK
Learning IoT without the "I" – Educational Internet of Things in a Developing Context	Pruet, 2015a	2015	DIYNetworking'15, Florence, Italy
IoT in Education: Integration of Objects with Virtual Academic Communities	Marquez, J., Villanueva, J., Solarte, Z., Garcia, 2016	2016	Universidad Autonoma de Occidente, Cali, Colombia
The Effect of the Internet of Things (IoT) on Education Business Model	Bagheri, 2016	2016	International Conference on Signal-Image Technology & Internet-Based Systems IEEE
Internet of Things for Smart Classrooms	Temkar, Gupte, & Kalgaonkar, 2016	2016	International Research Journal of Engineering and Technology (IRJET)
Experimental Evaluation of Internet of Things in the Educational Environment	Elsaadany & Soliman, n.d.	2017	Paper—Experimental Evaluation of Internet of Things in the Educational Environment
A Survey on Role of Internet of Things in Education	Gul et al., 2017		IJCSNS International Journal of Computer Science and Network Security, Vol. 17, No. 5, May 2017

The selected articles, besides meeting the inclusion criteria, were subject to the quality evaluation criteria proposed by Dyba and Dingsøyr (Dybå, T.; Dingsøyr, 2008). From this analysis, the selected articles presented a specific definition of the objectives of the research, an adequate description of the context, adequate planning for the research objectives, an adequate strategy for extracting the data for the research objectives, sufficient data analysis and an objective indication of the results.

Then, given that it was intended to know the potentialities and applications of the IoT in Education and the necessary technology for its implementation, we defined the domains of analysis: potentialities, applications and technology. Next, we proceeded to the content analysis of selected articles.

According to Vala (2007), content analysis is currently one of the most common techniques in the empirical research carried out by the different human and social sciences. Similarly, Quivy and Campenhoudt (2003) point out that the place occupied by content analysis in social research is increasing, since it allows methodical treatment of information and testimonies with a certain degree of depth and complexity.

A traditional content analysis, such as the one presented here, starts from a positivist logical-deductive framework where the theory retains full control of the research results (Guerra, 2006).

4. Results and discussion

In order to present the results of the answers to each research question, this section was structured into three topics: the potentialities of the IoT in Education; Applications of the IoT in Education; and technology needed in the implementation of IoT in Education.

4.1. The Potentialities of the IoT in Education

Table 3 presents a systematization of the number of times each of the subcategories in the articles analysed is referred, regarding the potentialities of the IoT in Education, in the sample of articles studied.

Table 3. The Potentialities of the IoT in Education

Dimension	Categories	Subcategories	Frequency
Potentialities	Education	Creation of new pedagogies and tools for teaching	10
		Shares information among students, teachers, and other schools	9
		Improve curriculum	5
		Provides meaningful learning spaces	5
		Prepares digital citizens for the proper use of technologies	3
		Allows quick access to information	2
		Improves teaching efficiency	2
		Decrease retention rate	2
		Provide technical support education and teaching management	1
		Saves resources	1
	Student	Positive impact on learning	10
		Collection and storage of data related to student activities	7
		Student-centred learning, anywhere	6
		Collaborative Learning	4
		More active learning, learn by doing	4
		Encourages student involvement / interest in learning	4
		Interdisciplinary learning	3
		Strengthens students' motivation for learning	3
		Helps reduce student difficulties	3
		Allows real-time interactive responses in the classroom	2
		Impact on student creativity	2
		Develop critical thinking	2
		Visual learning	1
		Improve attendance	1
		Important for students who cannot attend school (health reasons…)	1
		Reduce error	1
	Teacher	Monitoring student performance	4
		Allows real-time feedback	1
		Greater control of tasks	1

As can be seen from the results obtained, the IoT has the potential to make the teaching-learning experience more enriching, interesting and dynamic. Therefore, it presents itself as an added value for teachers, students and managers in sharing various types of data in an open way.

In this way, it is estimated that the IoT allows a greater democratization of access to information, leading to a greater production of knowledge.

Teachers and students will have the opportunity to collect and analyse data in order to promote the teaching-learning process, to enable research and resolution of real-world challenges. Therefore, it will awaken in students their creativity, the possibility to obtain information contextualized with their age, interests and geographical location. It enables the resolution of real and concrete challenges from the surrounding environment, facilitating the student to build their own knowledge in an interdisciplinary way.

In this context, the classroom will be an "open" space, where physical limitations will not be relevant to the interpretation of the environment, which can be monitored, analysed and studied in real time.

In this way, it is confirmed that the use of the IoT in the classroom has the potential to support a case-based methodology, since both provide an active learning, with an interactive, motivating, student-centred methodology in which the student will have to apply their knowledge to solve real-world problems. They are also shown as a significant learning environment, which develops analytical thinking and values different disciplines.

4.2. Applications of the IoT in education

Table 4 shows a systematization of the references to the applications of the IoT in the sample of articles studied.

Table 4. Applications of the IoT in Education

Dimension	Category	Sub-Categories
Applications	Education	iCampus, MIT, British Telekom, University of Essex: makes use of the spaces we inhabit (construction, rooms ...) as a laboratory infrastructure for computer education. It tests the operation of the delivery of digital services based on different network technologies.
		ENOLAR: is an international federation of about 300 live laboratories. Living Lab is a living environment that harbors people and technology in an environment that fosters innovation, development and symbiotic research.
		IoT is already present in most colleges, in the form of smartboards, security cameras, lights.
		At WASHINGTON Snoqualmie Valley Schools, Chief Operating Officer Bill Davis can monitor and control various building-related systems from a computer or smartphone, from heating and air conditioning to clocks and security cameras and locks on all doors.
		HVAC systems connected to the district IP network facilitate temperature control at each school, helping to save energy. Having remote access to security cameras and door locks, in turn, could help save lives.
		More common examples of IoT in schools are "smart building" systems that help administrators manage their facilities, such as those in the Snoqualmie Valley.
		A classroom that can measure students' level of interest by monitoring their behavior using cameras and microphones. The impact of different parameters in the physical environment, such as temperature, ambient noise and CO_2 level in student concentration was also analysed. An intelligent classroom system will determine in real-time whether the environment is optimized to maximize a student's ability to focus on a given moment.
Applications	Student	Creation of a cloud platform that allows students to program IoT systems from a web interface, making it more intuitive and friendly
		The Smart Urban Farming project at the University of Bucharest has proposed using the Internet of Things to remotely monitor sensors that detect soil moisture, temperature and light, and control irrigation equipment. Real-time data is displayed with the use of a web application and the user has the possibility to control functions such as opening / closing the roof of the stove, switching on / off the lights and irrigation or even setting the desired temperature with only one click. The system is a thumbnail; so it can be used for educational purposes: one can learn to grow plants or learn biology in a more interactive way.

Dimension	Category	Sub-Categories
		My Digital Life Course, Open University, UK: The course proposes an educational model focused on concrete experiences, creative experiences, active participation and collaborative learning. They create functional prototypes for applications that manifest themselves in the real world - for example, online weather stations, sound-controlled tea makers, even an application for paranormal activity.
		Sensitive Buildings Class New York University: Students create smart habitats for city dwellers, learn how sensor management systems work, and create their own prototypes.
		An example of IoT application used in education is the Glove Sensor, designed in Australia to help children learn Australian Sign Language. The student must wear a sensor glove while signing, transferring the signal to a computer and translating into written language.
		OBSY (Observe Octopus), a prototype developed in Thailand, designed for high school students. It is designed in the form of an octopus collecting sensors such as light, temperature, humidity, which acquire data from the environment. It also has a camera attached to a Raspberry Pi that sends real-time data to a web application. The goal of OBSY is to help children understand the process of growing a plant. They will have to observe this experience, learn and take notes, and finally draw conclusions.
Applications	Student	Scanmarker, which is already available in USA stores. It is a remarkable tool that allows the user to scan and copy text and transfer it to the application of the computer. It scans thirty times faster than a user.
		Institute of Technology in Mumbai, India, propose Beacon where the beacons generally seem air purifiers the size of a palm or stickers pasted on walls, shelves or product units. They send unique location identifiers to applications, which are programmed to respond differently based on received data. Through these low-power signals received by phone applications, beacons allow for attended and strategically targeted push notifications on virtually any smartphone when it enters a predetermined location. This is used in the classroom environment to send students notifications about the last task and deadline that they usually forget or have to go to the teachers.
		In the United Kingdom and Singapore, by the UK company ScienceScope, students are collecting and analysing environmental data using smart sensors
		Oral Roberts University in Tulsa, Oklahoma, asks students to purchase and use Fitbit fitness tracking technology to record their steps to a physics class with a goal of at least 10,000 steps per day. The Tustin Unified School District in California is among elementary and middle school districts that are studying how to use fitness sensors and other portable devices for learning.

Dimension	Category	Sub-Categories
Applications	Student	"Smart-Box" are small IoT environments that provide the ability to display the results of the developed programs.
		Participate Schools and NQuire, students engage in discovery-based learning with the help of mobile and Web technologies.
		The DISTANCE project is developing a co-created ecosystem that supports the collection of data from devices inside and outside the control of the individual
		Cordoba University has developed an educational project with the aim of contributing to improve teaching and learning through the Internet of Things. They found "evidence that the Internet of Objects, applied as a tool to support the teaching process, improves students' academic performance. In addition, they use real objects and associate them as a learning resource through the Internet of Objects facilitating meaningful learning as it allows to link the specific knowledge to a real context.
		University of Helsinki (Finland) during an experimental apprenticeship course on problems and projects on improving an urban rooftop greenhouse used the Internet of Things as a means of providing a learning experience tailored to the interests and personal competences of the student.
		Pad, a tablet for each student that automatically monitors their academic performance using test data provided by them. Each student must log in to the test server of the institute through the Exam Pad and conduct their weekly tests. As tests are evaluated, they can be analyzed to measure individual student performance
		KidFit1, is a bracelet fitness tracker capable of capturing and responding to children's physical activity.
		The hereO is a watch that can inform parents about the location of their children. Baby monitor screens that sprout and provide feedback on children's sleep patterns
		Teddy the Guardian, is a digital teddy bear that can capture and communicate important "health parameters like heart rate, oxygen saturation, body temperature and stress levels." The bear is intended for use in hospitals to communicate this information to health professionals, significantly reducing the anxiety of children, usually associated with traditional tests.
Applications	Teacher	The Tongda College of Nanjing University, China, proposes the implementation of a management system based on the attendance register

Dimension	Category	Sub-Categories
Applications	Teacher	The University of Kent Canterbury, United Kingdom, project required that students and teachers measure, share data and acquire more understanding about their environment in a pleasant way, but also directly related to the curriculum, with the ultimate goal of designing the next generation of schools. After the implementation, the project was found to offer "a new learning experience, which allows students and teachers to dive directly into the data generated, encourages open discussion and discovery, and transfers the time of installation to higher-level learning activities high in the classroom ".
		"Smart-Box" are small IoT environments that provide the ability to display the results of the developed programs.
		At Uttar Pradesh Noida, India, it helps teachers monitor each student through various applications, such as the weekly progress calculator application, where each student's weekly achievements can be loaded into the application, which measures student performance through various analyses and displays graphs for academic evaluation. This can help find out the students who need extra attention and, at the end of each week, the teacher will know to whom he needs to focus next week.

Regarding IoT applications in Education, it was clear from the results obtained that their approaches are taken from the perspective of optimization and management of their infrastructure and security.

This is also useful in a learning context, through the individual proactivity of the teacher who envisions added value for his students and subject.

Based on a maker philosophy, a series of projects that used IoT in a classroom context, allowed the map of pedagogies to be put into practice (Figueiredo, 2021) and activate the pedagogical metamorphosis of involvement, participation, autonomy and creation and community integration and interdisciplinary dialogue (Alves and Cabral, 2021).

The application of IoT in Education is of great interest, as it allows the creation of contexts situated in the student's reality, providing data to understand and, eventually, act on their object of study, using multidisciplinary skills. Therefore, IoT provides, through the adoption of maker pedagogy and project-based learning, the opening of the classroom to the real world.

4.3. Necessary technology in the implementation of IoT in Education

Table 5 presents a systematization of the references to the necessary technology in the implementation of the IoT in Education in the sample of articles studied.

Table 5. Necessary technology in the implementation of IoT in Education

Dimension	Categories	
Technologies	The main components of the IoT world include sensors / actuators, communication between servers or server platforms, middleware platforms, analytical data mechanisms and applications developed in mobile devices.	
	Arduino Raspberry PI Dragon Intel Joule Minnow	Development Boards
	Wyliodrin STUDIO	The platform allows students to easily connect to devices and deploy applications they write in an intuitive interface. Wyliodrin STUDIO searches the network for available devices and displays them to students, they can connect to any of them. After that, students can write applications in various programming languages, even visual ones, in a Web editor and, with a click of a button, the applications are projected on the board.
	FOG	It consists of devices, sensors, data and the cloud. Unlike a computer / laptop or tablet, IoT devices can access specific hardware such as lights, sensors, and motors.
	Sensors / Actuators	Sensors are devices that monitor environmental characteristics or other objects, such as temperature, humidity, movement, and quantity. When multiple sensors are used together and interact, they are called the Wireless Sensor Network (WSN). Wireless sensor networks contain the sensors themselves and may also contain gateways that collect sensor data and transmit them to a server. While the sensors "detect" the state of an environment or object, the actuators perform actions to affect the environment or the object in some way. Actuators can affect the environment by emitting sound, light, radio waves or even smells.

Dimension	Categories	
	Middleware Platforms	They are between IoT hardware and data and the applications that developers create to explore IoT. Thus, middleware helps bring together a large amount of devices and data in a way that allows developers to create and deploy new IoT services without having to write different codes for each type of device or data format.
	Smart Devices	It will be the connected 'things' that could respond to user events. These things can be devices like smartphone, computer or tablet. For simplicity, any object that belongs to the student and is connected to the system is a smart device.
	Ethernet Wi-Fi, Bluetooth or ZigBee	For things - objects - to communicate with each other and with the Internet, it is necessary to integrate a wireless communication system (Wi-Fi, Bluetooth or ZigBee) or wired (Ethernet). Communication technologies include radio frequency identification (RFID) used in the identification and tracking of objects; Bluetooth used in connection of two small devices to each other; ZigBee for automatic peer networking; RF links from Wi-Fi; and cellular networks.
Technologies	Virtual Academic Communities (VAC).	Objects pass from passive elements in educational environments to become more active objects and more involved in the teaching-learning process.
	Twine7 da Super Mechanical	It is a small box described as "the simplest way to connect things to the Internet" - it allows users to link almost any physical object to a local network. The wire integrates sensors with a cloud-based service, allowing easy configuration. Simply point the wire to a Wi-Fi network and the sensors are recognized immediately by the web application, which reflects what the sensors see in real time.
	ThingSpeak	It is a service offered by ThingSpeak that runs in the cloud to help build connected projects and launching products connected to the Internet of Things.
	Pachube, Nimbits, ThingSpeak, iDi, SensorCloud, Sen.Se, Exosite, EVRYTHNG, Paraimpu e Manybots	Specified for data management. Nimbits is a development platform and database server for processing and controlling sensors in a distributed cloud.

From the analysis of the results regarding the technology necessary to implement IoT in Education, we can perceive the technological evolution of society, driven by technological innovations, becoming more digital and interconnected and providing a greater quality of life. As different technologies have emerged, at low cost and in portable formats, they have become accessible to everyone, and therefore cannot be underestimated.

IoT is a technology driven by diverse technological forces, such as sensors and actuators, communication between servers or server platforms, middleware platforms, data analysis, and applications built on mobile devices.

In this context, students carry mobile devices that can collect and share interdisciplinary information contextualized with their age, interests and geographic location and allow them to solve real and concrete problems, facilitating them to construct their own knowledge. Therefore, IoT is a technology that is as promising as the challenges it poses in Education.

5. Conclusions

According to the data obtained, we found that, during this period, there were several applications of IoT in Education, both in terms of connected devices and in terms of access by various educational institutions. This is because it was recognized that it is useful for students to explore real-world situations to "build their own knowledge" (Costa, 2014, p. 116) through real-time data collection (Johnsonel et al., 2015).

Answering the research questions:

- What was the potential of the IoT in Education?

  We can see that IoT has great potential as a resource in the classroom, as it allowed students to develop social and emotional skills, identifying, experimenting and disseminating inspiring models to develop skills and express talents and generate useful knowledge for the transformation of society and future generations. In this way, it made the teaching-learning experience more enriching, interesting, dynamic and provided greater democratization of access to information, leading to greater knowledge production.
- What were the applications of the IoT in Education?

The results showed a large set of IoT applications in the classroom that allowed: solving real classroom problems, providing students with a broader and more abstract perspective of concepts for better understanding and acquisition of knowledge. It presented itself as a powerful tool for students' creativity and for transforming school grammar.

- What technology was needed to implement the IoT in education?
  The IoT, according to the data obtained, is based on a set of low-cost and affordable technologies. Useful resources, since they allow the open collection and sharing of data that can, and should, generate knowledge exchange. In this way, the school, open to the community, will be valued by all as a true learning community and promotes lifelong learning.

In this sense, since IoT provides active learning that includes perception, writing, problem solving, memory, image, processing and structuring of knowledge (Warin et al., 2011), it promotes understanding and develops insights (Loghmani et al, 2011) and allows the development of students' cognitive skills (Yilmaz, 2011), based on the Case-Based Learning methodology (Costa, 2014), which allows learning from a real case, using data analysis, action on the environment, research and debate, stimulates dynamic pedagogical, motivational, participatory and interdisciplinary work.

Some studies, for example, Gul et al. (2018), report that using IoT devices in the classroom may present some difficulties, such as network bandwidth, reliable Wi-Fi connection, web analytics, security, privacy, availability of student training devices and cost of equipment. However, according to Gul et al., the use of IoT in education has opened doors to new and innovative ideas to facilitate and improve the lives of students and teachers. It is expected that in the future new techniques can be introduced to solve all these problems.

In short, during this period, a large number of successful cases of IoT application emerged, which leads us to consider IoT as a technology with potential in education. This scooping review reveals several applications in this area, from the integration of connected devices in classrooms to the development of personalized learning platforms. Fast forward to the current reality, the technological and educational landscape has changed considerably, new technologies have emerged, such as Artificial Intelligence (AI). Students and teachers needs have also evolved.

Given this dynamic scenario, new research into IoT and AI in education is expected. From the fusion between these most revolutionary educational technologies comes the Artificial Intelligence of Things (AIoT).

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