

## A CRITICAL OVERVIEW OF INTERNET OF THINGS IN EDUCATION

### EĞİTİMDE NESNELERİN İNTERNETİNE KRİTİK BİR BAKIŞ

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**Abstract:** As a relatively new concept, Internet of things (IoT) is known to offer some potentials for learning and teaching. Although this catchy term is becoming more and more popular in educational contexts, there is still need for clearing up the minds of teachers and students with respect to the nature of it and how it could be used for teaching and learning purposes. In this sense, this study aims to locate IoT in instruction and to provide a critical overview of it. It also makes a distinction between the use of IoT at the management and instructional levels in educational contexts. Today, educators seem to support the use of IoT in education but they mostly put forward ideas that seem to represent the use of IoT from an administrative perspective, leaving little space for discussions centering on direct instructional potentials of IoT. Therefore, this study highlights those benefits and discusses problematic issues, particularly with respect to access to digital devices and the Internet. It also attempts to provide a modest summary of recent studies focusing on the practical applications of IoT in educational settings.

**Keywords:** *Internet of things (IoT); education, management, teaching and learning*

**Abstract:** Oldukça yeni bir kavram olan nesnelerin internetinin öğrenme ve öğretmeye yönelik bazı imkanlar sunduğu bilinmektedir. Bu dikkat çekici terimin eğitim ortamlarında popülerliğinin artmasına rağmen, öğretmenlerin ve öğrencilerin, nesnelerin internetinin doğası hakkında ve öğretme/öğrenme açısından bu kavramın nasıl kullanılabileceğine dair aydınlanmaya ihtiyaçları vardır. Bu bakımdan bu çalışma, nesnelerin internetinin eğitimdeki yerini tartışmakta ve eleştirel bir bakış açısı ile konuyu ele almaktadır. Bunun yanında nesnelerin internetinin eğitim ortamlarında yönetsel ve öğretimsel kullanımı arasında bir ayrım yapmaktadır. Günümüzde eğitimciler nesnelerin internetinin eğitimde kullanımını desteklemekle birlikte, genellikle yönetsel bir bakış açısına karşılık gelen fikirler öne sürmektedirler. Bu da nesnelerin internetinin doğrudan öğretimsel potansiyelleri üzerine yoğunlaşan tartışmalara çok az yer bırakmaktadır. Bu nedenle bu çalışma, nesnelerin internetinin olası faydalarını vurgulamakta ve özellikle dijital cihazlara ve internete erişim başta olmak üzere problemleri konuları ele almaktadır. Ayrıca son zamanlarda nesnelerin internetinin eğitim ortamlarındaki uygulamaları üzerinde duran çalışmaların kısa bir özetini sunmaktadır.

**Keywords:** *Nesnelerin interneti, eğitim, yönetim, öğretme ve öğrenme*

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## Introduction

Major developments in the world of computers and microchips have deluged our lives in the last two decades, making ICT an internal and inevitable part of daily and educational environments. Developments in digital technology have arrived in stages beginning with the wave characterized by one computer for multiple people. Then came the waves of one computer for one person and multiple computers (or digital devices) for one person. Paving the way for the fourth wave, Kevin Ashton introduced the term “Internet of things” in 1999 (Asseo, Johnson, Nilsson, Neti, & Costello, 2016). Online Oxford Dictionary (n.d.) defines IoT as “the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data” (Online). In other words, it refers to the ability of tools and appliances around us to interact with each other through the Internet and cloud computing (Morpus, 2017). The wave of IoT, which we are experiencing now is characterized by connection of everyday objects to the Internet and by communication not only between humans and computers but also between objects and computers and among objects.

It is clear that a conspicuous feature of Internet of things is connection and communication. IoT involves a huge number of diverse devices that are taken for granted by most of us as they are embedded in everyday objects, such as mobile phones, tablet computers, scanners RFID (radio frequency identification), wearable devices or any other smart device with embedded microprocessors and Internet connection. These devices, according to Benson (2016), compute, connect to other devices and interact with them to collect data and to control the environment. Internet of things differs from traditional information technologies as it involves a huge number of different digital devices, and these devices, with their complicated hardware and software components, defy an easy description and classification. With connectivity and communication as its guiding principle, IoT changes the way everyday activities are carried out. It basically makes our world smarter and much more interconnected, leading to drastic changes not only in lifestyles but also in ways of working and learning (Lee, 2016).

Today, Internet of things is widely applicable in a variety of public domains. The changes that IoT causes in our lives are made with the help of smart devices, which come with Internet connection and could be monitored via the Internet (Morpus, 2017). Such opportunities for connection, Kurzweil and Baker (2017) believe, have the potential to improve teaching and

learning as well. However, although the term itself was used almost two decades ago for the first time, its use in education is so new that education was not mentioned as a field with practical applications of IoT in Atzori, Iera and Morabito’s (2010) comprehensive paper on the nature of IoT and its applications in different domains. However, as technological innovations deeply affect different domains in a parallel fashion, developments in other domains are obviously felt in education. Due to this accelerating trend and the increase in the number of such devices that schools use, the educational landscape is likely to be shaped by IoT in the near future (Ralhan, 2017). However, according to Aston (2017), heavy use of IoT technologies “requires an education system which not only teaches the concept, but embraces it too” (Online, para. 3). Embracing this new technology could happen only if all stakeholders of education accept IoT and discuss its potential benefits and downsides to make most out of it in educational contexts.

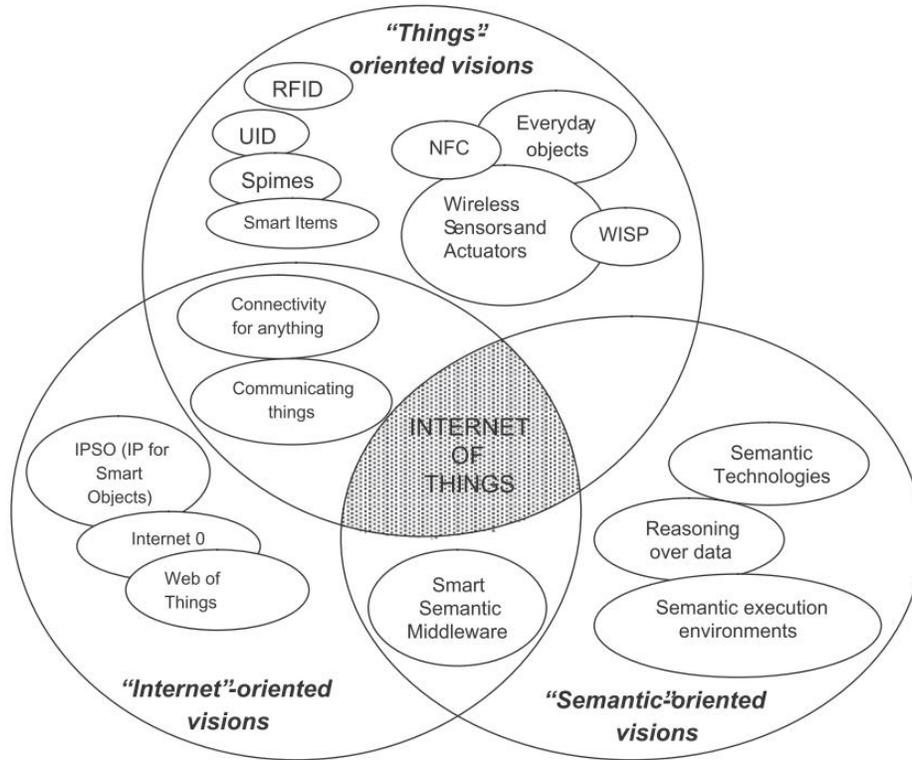


Figure 1.  
*Three perspectives coming together to form the Internet of Things paradigm (Adapted from Atzori et al., 2010, p. 2789)*

People with different perspectives define Internet of things from a different lens, which contributes to the fuzziness of the term (Atzori et al., 2010). Internet-oriented visions highlight

the importance of connectivity and communication in general, while the things-oriented vision focuses on the communication among everyday objects and their connection to the Internet to transfer data. Finally, semantic-oriented visions aim to make sense of the data and provides insight into how to compose, select and manage web services (Figure 1).

In the educational domain, researchers and educational technologists mostly elaborate on what we could call the management or campus improvement issues far as IoT is considered in educational environments. These issues include but not limited to improving student health and safety through the use of wearable devices, video monitoring and threat detection (Asseo et al., 2016; Gupta, 2017; Ralhan, 2017; Selinger, Sepulveda, & Buchan, 2013), energy efficiency and monitoring in the school environment (Asseo et al., 2016; Benson, 2016; Kashyap, 2016; Meola, 2016; Morpus, 2017), tracking student attendance (Asseo et al., 2016; Brown, 2017; Gupta, 2017; Mishra, 2017; Nilsson, 2015; Peters, 2016; Ralhan, 2017; Selinger et al., 2013) and improving access to data (Gupta, 2017). However, it's not clear how these improvements could directly translate into improved learning in schools. In this respect, this paper outlines the suggested uses of IoT in education and aims to discuss apparently unclear aspects of IoT and practical challenges that might make it difficult to implement IoT projects in educational contexts.

### **IoT in Learning Environments**

A learning model based on IoT is composed of four distinct layers that work in tandem to support students in mobile learning: (1) The perception layer is composed of sensors, RFID tags, 2D barcodes, wireless sensor networks, electronic product codes that are used to identify the elements in the physical world, collect information about the environment and automatically control it and connect it to the other network devices and servers. (2) The network layer is responsible for the transmission of information through the Internet. (3) Using a blended learning approach, application layer responds to application requests from the perception layer and delivers learning content. (4) Data management layer presents the data sources to learners, record various user data, such as test scores, interests, preferences, achievements and so forth (Shan, Wang, & Hao, 2016). Shan et al.'s conception is illustrated in Figure 2.

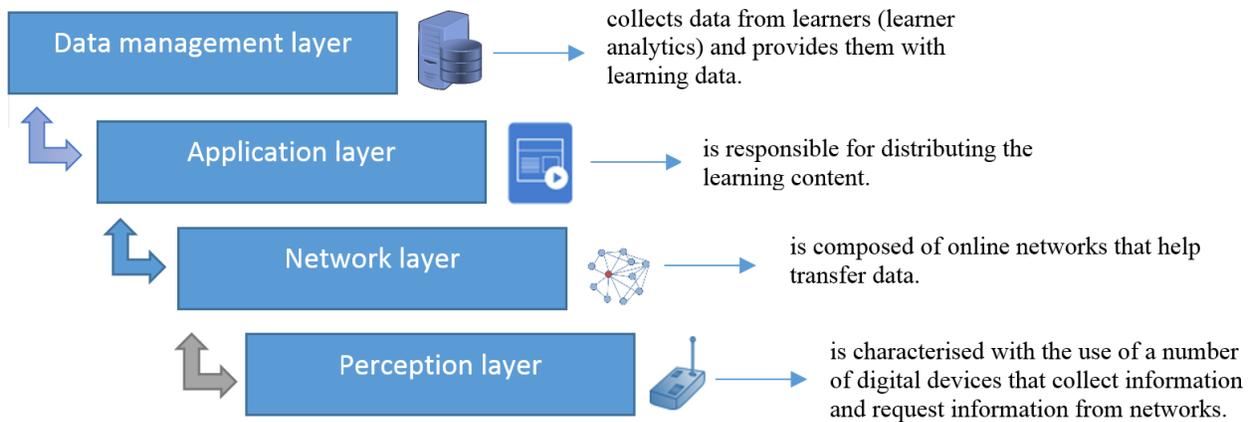


Figure 2.

*The four layers of IoT supporting mobile learning (based on Shan, Wang, & Hao, 2016)*

These layers work in tandem to implement IoT for learning purposes. Various ubiquitous devices and equipment play a significant role in the perception layer. For example, everyday objects communicate with humans and with each other by using communication technologies, tracking solutions, wired and wireless sensors, actuators, 2D barcode scanners, radio frequency identification (RFID) tags, mobile phones, digital scanners that transfer text to smart devices, smart watches (Apple Watch) and other wearable devices. Some of these sensors, which Shan et al., (2016) call “emotional sensors,” help collect data about the learners’ emotional state, their level of concentration, gestures, “while environmental sensors” (e.g., light sensors, cameras, and audio sensors) collect various data about the environment. Lee (2016) extends this list by adding smart clothes, fitness bands/activity trackers (e.g., Fitbit, Nike + FuelBand), head-mounted cameras (GoPro) and smart glasses (e.g., Google Glass and Microsoft HoloLens). With respect to economic dimension of Internet of things, the perception layer and the digital devices within it are fundamental because they constitute the background of the whole story. They interact with their environment by connecting to the Internet. In the network layer, devices transfer information mostly over the Internet, so high quality internet access is a prerequisite for successful implementation.

Taken together, wireless technologies and the Internet play a fundamental role in establishing connections between different devices; this is basically what Internet of things is about. The most important point is that current technology is able to equip numerous devices and even people with wireless sensor capabilities and although Wi-Fi is the leading method of connection, other

technologies such as Zigbee, NFC, RFID and Bluetooth are also utilized. Most of these devices aim to minimize energy consumption (Correll, 2015). Content delivery happens on the Internet in the third layer through the use of pedagogical models. Finally, in the data management layer, data from digital devices and those related with the use of pedagogical content existing in the third layer are stored and processed. Analytic data about learners and learning processes are an inherent part of the data management layer. In brief, these distinct layers are deeply interdependent. That is, lack of any of these layers or the components in them would induce a complete paralysis of the whole system.

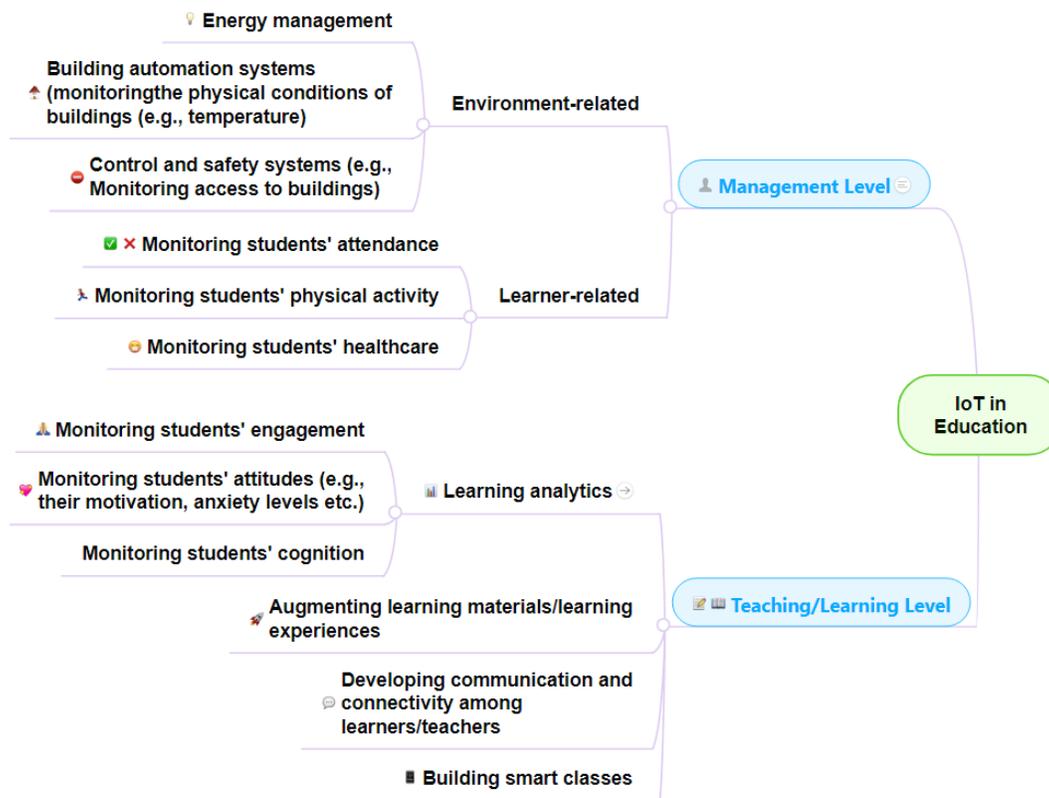


Figure 3.  
*Sample practical applications of IoT in education*

The upsurge of digital devices in educational contexts brought about new developments in the way teachers viewed education and how they carried out educational activities. Nowadays, IoT seems to alter education with respect to teaching and learning, school management, experimentation and training, school buildings and so forth (Tianbo, 2012). Practical applications

of Internet of things in educational environments basically fall into several categories. Some of these categories are exemplified in Figure 3. For example, data from Internet of things devices could be used to improve management practices and life at schools. IoT could also be utilized to increase the effectiveness of instruction/learning through learner analytics, better access to information and individualizing learning through the use of smart devices.

### **Management Level**

On the management side, IoT could be used to automate daily operations that the school management has to carry out to open up more time and space for learning activities. Although such uses of IoT may not be directly influential in learning, they could help make the school environment ready for learning activities and save some of the time that would otherwise be spent for doing day-to-day routines. For example, tracking equipment could be done using wearable devices to free teachers from the obligation of taking attendance and regularly reporting to the management office (Ralhan, 2017). In addition, IoT could support traditional building automation systems, help manage and conserve energy, regulate access to buildings, introduce environmental control and safety systems for students and school personnel (Benson, 2016). Similarly, IoT devices could help monitor temperatures across the school building; this in turn could positively affect learning as the temperature in the physical environment is known to be influential in students' cognition and attitudes (Mishra, 2017). In this respect, IoT increases the cost effectiveness in educational institutions.

In short, it is possible to use the collected data to develop strategies for better management at school with respect to such issues as energy, monitoring the school building and students (Asseo et al., 2016). IoT data could help make the school environment a more comfortable and safer place for students. However, there is limited research testing indirect the impact of IoT applications on learning. Instead, it is accepted that a more comfortable and safer learning environment could improve learning outcomes. This is the expected value of using IoT to improve school management issues. In addition, these applications are mostly expensive systems to establish, so most schools around the world will be unable to allocate enough funds to carry out such projects. (Asseo et al., 2016)

## **Instructional and Learning Level**

A great majority of the proposed applications of IoT at the instructional level are similarly related with management issues, yet at the individual level this time. These include the use of wearable devices and other student monitoring systems by means of IoT devices. For instance, de Arriba-Pérez, Caeiro-Rodríguez and Santos-Gago (2017) suggest using wrist wearables to collect data about learners' patterns of sleep and stress levels. Such data, as they claim, could be used to improve students' self-awareness of their sleep and stress patterns, so that they could know the best time for studying and resting and balance the two while preparing their schedule. Similarly, these data could be used by a learning management system to recommend activities to help students complete the tasks that they have to do. Teachers could also decide on the potential activities intended for different times of the class depending on student readiness, utilise data about the stress and sleep patterns to support teachers in instructional decision-making and planning. In addition, as Peters (2016) notes, advanced e-learning materials that are more accessible thanks to IoT devices enable students to progress at their own rates. Teachers could provide individualised learning opportunities and evaluate student progress seamlessly.

As seen above, applications of IoT seem to have a great impact on what educational technologists call "smart schools." However, most IoT projects focus on a particular aspect of the use of IoT for educational purposes. It is exceptionally rare to see large-scale applications of IoT within a single educational environment as described by various educators (Benson, 2016; Mishra, 2017; Morpus, 2017; Nilsson, 2015; Ralhan, 2017) (e.g., automatic tracking of attendance, monitoring student progress in reading and understanding, wider use of digitally administrated tests, monitoring student well-being in sports activities, tracking student buses using Google maps and smart phones, optimizing airflow, weather conditions and the use of flat screen monitors to see data from teachers and students and so forth).

## **Practical Applications of IoT**

In addition to discussing the issue from a theoretical perspective at the management and instructional level, the present study provides a brief overview of practical applications of IoT, such as the of QR codes, AR codes and augmented reality, enriched analogue and digital textbooks. The use of QR codes, for example, in printed materials could help connect the

analogue to the digital, thereby enriching the traditional textbook. Using them to deliver reading passages to students seems quite innovative. It is a method of delivery which current generation of students are accustomed to; appealing to students' habits and styles could make a difference. Similarly, according to Shan et al., (2016), mobile phones equipped with a RFID reader could help individualize learning plans and contents in a smart library, museum, zoo, classroom or botanical garden and so forth, thereby making learners more autonomous. More and more studies are being carried out to investigate how IoT could be operationalized in educational settings. Some of these studies and their results are summarised in Table 1.

Table 1.

*A summary of research on the IoT in educational settings in general*

Study	Purpose	Method/Data Collection and Participants	Results
Gómez, Heute, Hoyos, Perez and Grigori (2013)	To pilot a model in which the everyday objects are augmented using visual tags NFC and QR codes	An experimental study in which 50 learners in two groups (traditional and IoT) learned about computer parts in a computer course. The IoT group studied using the proposed system, which included tags attached to computer parts.	Internet of Objects as a tool to assist instruction improved students academic performance. The authors also concluded that the system promoted meaningful learning because it linked knowledge to real contexts.
Bagheri and Movahed (2016)	To investigate the impact of IoT on education business model in higher education by comparing traditional and business model	Literature review	IoT is able to transform educational environment by (a) saving time and money, (b) increasing safety (c) personalising learning and boosting learner collaboration and engagement.
Küçük, Çelik and Bayılmış (2018)	To develop a smart bus system that monitors school buses and students in real time	HM-11 Bluetooth low energy module beacon devices, Firebase cloud platform and MIT App Inventor Android mobile application were used to develop the system.	The smart bus system allows parents to monitor their children in realtime by using a mobile application.
Uludağ and Uçar (2018)	To develop a smart class and student monitoring system	The authors designed a system that checked and recorded student attendance automatically and controlled classroom door and lighting. The system came with communication and included some of the features of IoT.	The authors developed a fully working system which is at <a href="http://www.firatots.com">www.firatots.com</a>

## Quick Response Codes

Quick response (QR) codes are tools that are easy to construct and use. Researchers consider them as a tool for tagging objects, so that they can connect to the Internet and function as a component of IoT. For example, Coetzee and Eksteen (2011) note that RFID tags and QR codes are tools that can be scanned using digital devices like RFID scanners or smart phones to establish a connection between the physical world and cyberspace to expand the Internet into what people now call “Internet of Things” (p. 2). This is because, according to Miorandi, Sicari, Pellegrini and Chlamtac (2012), identification and sensing are considered as two key features for everyday objects to be able to be a part of IoT, and using QR codes (and RFID scanners) is one of the methods of identifying objects (p. 1502). This is firmly supported by a number of other researchers who note that QR codes are one of the basic tools for putting IoT into practice (along with a number of components, including but not limited to Wi-Fi, bluetooth, artificial intelligence, and wireless sensor networks) (e.g., Adorni, Coccoli, & Torre, 2012; Dlodlo, Foko, Mvelase, & Mathaba, 2012; Jinghua & Jie, 2010; Madakam, Ramaswamy, & Tripathi, 2015; Ralhan, 2015; Want, Schilit, & Jenson, 2015). In brief, QR codes are seen as one of the practical applications or enablers of IoT.

Although they have been around for nearly two decades, their educational use does not go that far in the past. However, they have been readily accepted by those who are aware of their potentials (So, 2011) and the ease at which one could construct and use them. Like many other mobile applications, QR code readers could help transfer mobile phones to pedagogical agents by connecting the analogue world to the digital one, provided that there are enough devices and reliable internet connection. In this sense, QR codes could function as a “gateway” to the digital world (Baik, 2012), and they function as a quick solution for the problem of manually entering lengthy web addresses into the address bar (Thorne, 2016). As they allow quick and effortless access to digital materials, some researchers suggested using them to enrich printed materials with online content (Uluyol & Agca, 2012). In various research projects QR codes were found to be motivating and introduced variety into classroom (e.g., Baruffi, 2015; Huah & Jarrett, 2014; Rikala & Kankaanranta, 2014) by probably arousing students’ interest due to the mystery involved in accessing unknown information embedded in the code (Thorne, 2016).

Typical uses of these versatile tools include but not limited to enriching printed materials by introducing additional written or audio-visual information in the links provided in them, sharing materials with colleagues and students with ease, augmenting traditional bulletin boards with additional information (or creating QR-only bulletin boards), to hide answers in a quiz sheet, to carry out class polls and so on. Considering the user-friendliness of the QR code software (Robertson & Green, 2012), they could be produced not only by teachers but also by students. For example, Baruffi (2015) study used QR codes to provide definitions of grammar terms and audio version of a book and asked the students to create their own QR codes for movie trailer to be used in a poster and requested them to create a QR code for their famous historical figure and share it with friends. Similarly, in Jeon's (2015) study, the students used QR codes to write sentences and describe pictures and embedded the sentences and descriptions in QR codes. In most of these practices, regardless of their creator, QR codes are often used to extend or augment the information provided.

### **Smart and Wearable Devices**

More and more smart devices (mobile phones and wearables) are being used in our daily lives. According to Shin (2012), smart devices are cordless and mobile agents with the capability of internet-browsing, audio-visual (voice and video) communication, geo-location and the ability to operate autonomously at least partially (p. 563). Equipped with one or more of these features, wearable devices refer to smart devices in which built-in sensors along with other components are used to track human activity (Lu, Zhang, Zhang, Xiao and Yu, 2017; Sandall, 2016; Swathi & Lanka, 2015). More clearly, wearable devices could be defined as "wearable computers with a mobile Internet connection that are worn like dresses and personal adornments to display information for users intelligently and efficiently, such as wearable glasses and wearable watches " (Liu and Guo, 2017, p. 43). Their being worn by its user differentiates it from other mobil devices that people carry. These devices interact not only with human beings but also with other devices around (Labus, Milutinovic, Stepanic, Stevanovic, & Milinovic, 2015). The famous examples of these devices include but not are limited to digital watches (e.g., Pebble, Fitbit, The Apple Watch, Samsung Gear S, Sony SmartWatch 3 and so forth), Google Glass, Google Cardboard, Spectacles, fitness trackers, wireless bluetooth headset sunglasses (e.g., Elinka), smart shoes and so on. They are mostly used to transfer physiological data about a person to a data hub

where they are analysed later, and the resulting data are used for various purposes, including providing feedback to learners without disturbing them. According to Ezenwoke and Ezenwoke (2016), huge amounts of data from wearable devices are collected and analysed in real time. This helps teachers get useful information about learners and use it to shape learning.

According to de Arriba-Pérez et al., (2017), the data about students collected using wearable devices could support learners in time management and learning strategies that they can use along with improved knowledge about themselves. Such data could inform teachers about the best timetable for certain activities for students depending on their motivation and emotional load; they could also guide teachers in forming groups for team work depending on learners' stress levels and sleep profiles and in identifying motivational profiles of learners (p. 326). There have been similar studies with positive results. Most of these studies were small scale ones carried out with limited number of participants or qualitative-only (Table 2).

Table 2.

*A summary of research on the use of wearable devices in education*

Study	Purpose	Method/Data Collection and Participants	Results
Nakasugi and Yamauchi (2002)	To evaluate a system that enabled learners' to develop a sense of history and help them see historical events in real places to combine past and present data	Qualitative – Interview with 10 participants who used the system. Historical information was over	The system enabled the participants (4 out of 10 participants) to acquire new view points and feel history as a reality. The authors also claimed that the system boosted the participants' motivation as well.
Wu, Dameff and Tully (2014)	To investigate how Google glass fits simulation-based training	Qualitative – the analysis of video recordings from Google Glass and the participants' (42 emergency medicine residents and 9 medical students) perspectives	Wearable technologies can be integrated into simulation-based training without distracting learners and the data from videos can successfully be utilised for self-reflection.
Coffman and Klinger (2015)	To investigate if Google Glass can be incorporated into the lessons “educational psychology” and “organizational behaviour”	Qualitative – the teachers and learners were asked to use Google Glass during classes	This tool could easily be integrated into the lessons, as it could help teachers take pictures of learners' work, video-record in-class practices, use the Internet and poll the learners

de la Guía et al. (2016)	To investigate the benefits of wearables and IoT technologies in helping learners create effective realistic task-based language learning scenarios	The participants (15 young learners) were requested to prepare recipes in IoT/wearable assisted tasks. They carried out survey and classroom observations.	The IoT/wearable assisted task-based teaching boosted the learners intrinsic motivation and arouse their interest. The system helped the students be aware of the steps involved in the tasks and made it possible for the teacher to track student participation.
Engen, Giæver and Mifsud (2017)	To investigate if the use of student data from wearable devices in a physical education class could concretize and contextualise abstract numbers and figures and motivate students to learn maths and social science.	In a two-week period, teachers designed learning activities in which smart watches (The FitBit Surge) were used. 21 students participated in the study. The study involved data from the watches, class observations and an interview with the class teacher.	Wearables were found to be pedagogically valuable in all three subjects. However, privacy issues emerged both prior to giving the pupils the watches as well as during the study.
Lew and Tang (2017)	To measure EFL learners' anxiety levels by monitoring galvanic skin response (through heart rate and skin temperature) (in study 2)	Qualitative (case study) – They carried out two case studies. They used the use of Microsoft Band 2 to collect physiological data.	Although the authors were able to identify stressed moments thanks to the data about heart rates, they were not able to find a reliable link between physiological data and anxiety levels. Nevertheless, they they claimed that such data could help boost academic success of learners. They recommend further research to investigate this.

From the perspective of the learners, wearable devices deliver multimodal information (in the form of text, audio, video and possibly other forms) quickly. Moreover, such devices could be of help to handicapped students who could be supported additional (and larger) visual and audio as needed (Labus et al., 2015). In short, data from wearable devices and dynamic QR codes could be used to analyse learner profiles and behaviour and emerging data could be used to guide learning and teaching. However, cost, battery quality, overheating and the need for a smartphone are commonly voiced downsides with wearable devices (Attallah & Ilagure, 2018). Moreover, the issue is not that straight as other potential problems related with data security, privacy and learners' reactions to being monitored are to be considered carefully.

### **Learner Analytics**

Learning analytics basically refers to collection and analysis of learner data for instructional purposes. It is perhaps one of the most significant instructional benefits of IoT practices in learning environments, so it deserves a special attention. Based on an IoT perspective, data from

everyday digital devices at school could be used to plan instruction. Data from everyday digital devices could be used to collect data about learners and their involvement in the lesson. As the data from such digital devices are collected continuously and transferred to a hub, teachers are able to use these data to monitor engagement levels of the class and adapt his teaching practices accordingly. However, access to such digital devices in mainstream schools does not seem feasible for the time being. Future developments in technology and innovation could help reduce the costs. Only then could we have the opportunity to utilise them in our classes.

Nilsson (2015) claims that ever increased amounts of school-related and instructional data could help educators build personalised learning environments and studying how more successful students learn could help improve learning. Some IoT projects, with such aims in mind, have already made their way into the classroom. For example, Alt Schools in New York City and San Francisco used it to individualise the instruction based on student performance (Rosales, 2017). Moreover, recent studies on IoT-based learning analytics come with some positive results. Commonly used IoT technologies in such research studies include but not limited to eye trackers, various sensors, RFID readers and QR codes (Table 1).

Table 3.

*A summary of research on IoT-based learning analytics*

Study	Purpose	Method and Participants	Results
Pirkl et al. (2016)	To monitor the participants' (two females and four males) learning progress	worked with a sensor-based online learning platform used a eye trackers, sensor pens and exercise texts	As the paper probably reported preliminary findings, they do not report many results, yet they report that they were able to calculate the time needed for answering questions.
Lu et al. (2017)	To test if a framework they proposed (LEARNSense) can be used to monitor student engagement in the class.	Information about students' action collected using a wrist-worn device were used identify student engagement levels in the class. The data were collected from surveys and interviews in addition to data from digital devices.	LEARNSense was able to measure the students' level of engagement correctly by using the data about their physical actions.
Tan, Wu, Li and Xu (2018)	To design a system to monitor student attendance and behaviour and enable quick access to learning materials	A WiFi-based RFID reader was used in open-source hardware platforms to record data about students' attendance and behaviour. QR codes were also used to facilitate	Such an IoT system can (a) motivate learners, (b) improve their class attendance (c) make a positive impact on their learning process and (d) prevent off-task behaviour, such as playing with mobile phones.

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quick access to course materials and give real-time responses.

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The experience gained out of such projects seems invaluable, but we also need evidence-based practices based on empirical data. Furthermore, the idea of continuous and accurate analysis of engagement levels could appeal to most educators. However, what really counts is the action that the teacher is to take after detecting signs of boredom or disengagement in the class. Current use of wearable devices apparently fails to help teachers in this respect.

Although data from learner analytics could provide beneficial from a couple of aspects, it is not certain how students would react to being continuously monitored by the school management and their teachers. Being monitored might lead to distress in students as being under surveillance usually does not feel good for a great majority of people. Prospective studies could focus on the impact of being under surveillance on students' psychological status. In addition to taking into account cost-benefit balance, educators are to consider psychological dimension of the issue. In addition, continuous data collection should not lead to the mechanisation of teaching and learning processes.

Besides all these, some ethical issues come to the fore when it comes to the monitoring students by using technological devices and the Internet. It is certain that collecting data in this way puts privacy on the agenda as a critical item. Given the gigantic amounts of data collected through IoT devices, one could forespeak that some of these data are prone to be misused. In line with this, Kurzweil and Baker (2017) warn that data from sensors in the hands of wrong people could become a nightmare as they enable others to track a person's location and activities and send the related information to third parties. Therefore, schools, wider bodies of management and other stakeholders of education must find methods that could ensure data security to protect privacy of students. Moreover, educators have to ask themselves to what extent they will utilise the data IoT devices will provide and only collect the essential data rather than recording every step that students take. This is supported by Brown (2017), who rightly questions the detail at which we collect data about students.

### **Concluding Remarks**

A particular problem related with the introduction of IoT to schools lies with the digital divide between the rich and the poor. Augur (2015) notes that this divide “is not going to be an easy or happy discussion when it comes to IoT implementations” (Online, para. 10) and that “the dream of personalized, detailed instructions and seamlessly interactive technology will run head-to-head with the funding issues as well as current test-based accountability systems” (Online, para. 11). In other words, the equipment that play a vital role in the applications of IoT in learning environments could be difficult to afford, not only for individuals but also for schools and bodies of management. This obviously undermines the applicability of Internet of things at schools, at least in the current economic and educational landscape. In some areas of the world, let alone such expensive equipment, some schools are unable to afford fast broadband access to the Internet. This is a significant challenge because high quality Internet access is obviously a must for the implementation of IoT at schools. Unless necessary equipment is introduced to the market at affordable prices and broadband Internet access is ensured, IoT could not go beyond being a mere fantasy for most educational institutions, particularly in poorer areas around the world. Moreover, it may not mean much to have hi-tech equipment in the classroom without a proficient teacher who could use it efficiently for pedagogical purposes. This is supported by Augur (2015), who highlights that improvement in connectivity levels alone does not mean much. What we need is creative ways of using the Internet for learning purposes.

Improving school environment and making it a more liveable place is an essential part of the story, but this is mostly reserved for administrators. It seems that applications of Internet of things and educational environments are mostly related with campus life rather than learning. It is not certain whether or how improvements in campus life could improve learning (Correll, 2015). In-class practices are expected to focus on this grey area. Although educational technologists claim that IoT could lead to significant improvements in learning, they fail to elaborate on how this could be achieved. This is not to say that improvement in school management and campus life does not have a positive impact on student learning. However, such an impact would be indirect rather than obvious; what we need is teaching and learning practices based on IoT applications. It seems that more specific activities and projects will be on the way to classes in

the not-too-distant future. So far, we have not seen practical applications of and empirical research on the idea of individualised curriculum with the help of IoT.

IoT could help educators to introduce the real world into the classroom (Augur, 2015). In this respect, perhaps the greatest benefit of IoT is that it removes all the barriers as far as access to information is concerned (Mishra, 2017). However, only when access to high-speed Internet and digital devices is ensured, could IoT help eliminate barriers. Otherwise, IoT itself creates new barriers for those disadvantaged communities. Therefore, problem of access to high-speed Internet and IoT devices are to be solved to be able to put into practice IoT-supported activities in educational environments. In short, as Mishra (2017) readily admits, IoT still has a “tough and long road ahead” (Online, para. 17) to transform instructional environments. Economic problems make this road relatively challenging not only for individuals and schools but also for nations. However, it would be misleading to think that it will eventually fail because IoT is its infancy today and there seems to be some prospect for improvement. It is estimated that as of 2020, 50 billion devices will make their way to the Internet and people will shortly be using Internet of everything (IoE) instead of IoT (Cajide, 2015). In such a context, Lee (2016) anticipates that Internet of things and wearable devices will place interaction and learning experiences at the center of attention and will make electronic and mobile learning in its current form a thing of the past.

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## Uzun Özet

### Giriş

Son zamanlarda sıklıkla gündeme gelen Nesnelerin İnterneti ticari ve sosyal hayatta olduğu kadar eğitim alanında çeşitli imkanlar sunmaktadır. Nesnelerin İnternetinin eğitim alanında popülerliğinin gittikçe artmasına rağmen, bu dikkat çekici kavramın doğası ve öğretme/öğrenme açısından bu kavramın nasıl uygulamaya konulacağına dair tartışmalara ihtiyaç vardır. Bu bakımdan bu çalışma, Nesnelerin İnternetinin eğitimdeki yeri üzerinde durmakta ve konuyu eleştirel bir bakış açısıyla ele almaktadır. Günümüzde eğitimciler Nesnelerin İnternetinin eğitimde kullanımını desteklemekle birlikte, genellikle Nesnelerin İnternetinin yönetsel bir bakış açısıyla kullanımına karşılık gelen fikirleri öne sürmektedirler. Diğer yandan Nesnelerin İnterneti kavramını öğretim ortamı ile bütünleştirmeye yönelik çalışmalara ihtiyaç vardır. Bu bakımdan, Nesnelerin İnterneti kavramının kuramsal boyutta ele alınması ve daha sonra kuramsal tartışmalardan elde edilen fikirlerin uygulamaya konulması ve bu konuda uygulamaya dönük çalışmaların yapılması gerekmektedir. Nesnelerin İnterneti oldukça yeni bir kavram olduğundan ve farklı kimseler tarafından farklı şekillerde tanımlandığından bu çalışma konuya açıklık getirmekte ve konunun kuramsal boyutunu ele almaktadır. Ayrıca yer yer şimdiye kadar yapılmış olan çalışmalara ve bunların sonuçlarına değinmekte ve Nesnelerin İnternetinin yönetsel ve öğretimsel bağlamda nasıl kullanılabileceğini tartışmaktadır. Yapılmış örnek uygulamaları ele almakta ve Nesnelerin İnternetini eğitim ortamlarında uygulamanın zorluklarını gündeme getirmektedir. Aynı zamanda nesnelerin internetinin eğitim ortamlarındaki uygulamaları üzerinde duran çalışmaların kısa bir özetini sunmaktadır.

### Nesnelerin İnterneti

Yaklaşık 20 yıl önce ortaya atılan Nesnelerin İnterneti kavramı mikroşlemcilerle donatılmış olan gündelik eşyaların birbirleriyle ve insanlarla etkileşimi anlamına gelmektedir. Teknolojinin, 20. yüzyılın ikinci yarısında “bir gruba bir bilgisayar” ile başlayan ve 2000’li yıllarda “bir kişiye birden fazla bilgisayar” (veya dijital cihaz) ile devam eden seyahati günümüzde cihazların birbirleriyle ve insanlarla iletişimini sağladığı bir noktaya erişmiştir. Zaten Nesnelerin İnterneti de bu fikirden hareketle ortaya çıkmıştır. Nesnelerin İnternetinin temelini cep telefonu, tablet bilgisayarlar, RFID tarayıcılar, giyilebilir cihazlar veya içine mikroşlemci entegre edilmiş ve internete bağlanabilen diğer cihazlar oluşturmaktadır. Bu anlamda en belirgin özellikleri iletişim

ve bağlantı olan Nesnelerin İnternetinin temelini doğru olarak kablosuz teknolojiler ve internet oluşturmaktadır. Bu cihazlar içinde buldukları çevre ve bu çevrede yaşayan insanlar hakkında veri toplamakta ve bu verileri aktarma noktaları sayesinde ilgililere ulaştırmaktadır. Bu yönüyle insanların yaşamlarını doğrudan etkilemektedir. Nesnelerin İnterneti; algılama (çevreye dair bilgi toplamaya yarayan karekodlar, sensörler, RFID etiketleri, kablosuz algılama ağları), ağ (verilerin kablosuz cihazlar vasıtasıyla internet üzerinden transferi), uygulama (bilgilerin kullanılması) ve veri yönetimi (verilerin öğrencilere sunulması ve onlar hakkında bilgi toplanması) gibi bileşenlerden oluşmaktadır. Bu bileşenler bir bütün oluşturmakta ve birbirleriyle etkileşim halinde işlevlerini yerine getirmektedir.

### **Eğitim Alanındaki Uygulamalar**

Nesnelerin İnternetinin eğitim ortamlarındaki kullanımı oldukça yeni olmasına rağmen bu konuda hızlı gelişmeler kaydedilmektedir. Nesnelerin İnterneti bir yandan eğitim ortamlarını kontrol altına almayı ve bu yerleri daha rahat ve güvenli hale getirmeyi hedeflemektedir. Örneğin Nesnelerin İnterneti sayesinde okul ortamında ısı ve nem takip edilerek enerji verimliliğinin sağlanması, okul çevresinin güvenliğinin artırılması, okula giriş-çıkışların takibi vb. işlerin otomatik ve hatasız olarak yapılması veya öğrenci ve personelin sağlığının ve devam durumunun izlenmesi mümkün olmuştur. Bu tür uygulamalar günlük rutinleri daha kısa sürede otomatik olarak yapıp öğrenme ve öğretme üzerine daha fazla odaklanmayı mümkün kılabilir.

Diğer taraftan Nesnelerin İnterneti; öğrenen analizi, bilgiye kolay erişim ve akıllı cihazların kullanımıyla öğrenmeyi bireyselleştirmek suretiyle eğitimin niteliğini artırmayı hedeflemektedir. Ancak günümüzde öğretime yönelik Nesnelerin İnterneti uygulamaları geniş çaplı olmaktan uzak olup bireysel araştırmacıların çabalarından ibarettir. Ayrıca daha çok eğitim ortamlarının fiziksel olarak iyileştirilmesi ve güvenliğinin artırılmasına yönelik uygulamalar mevcuttur. Çünkü öğrenmeyi bireyselleştirme hedefi daha fazla maliyet ve donanımlı personel gerektirmektedir. Giyilebilir cihazlar sayesinde öğrenciler hakkında toplanan algı, stress ve motivasyon düzeyi ve uyku düzenine dair bilgiler, onlar için en iyi öğrenme ve etkinlik zamanını belirlemede yardımcı olabilir ve öğrencilerin öz farkındalığını artırmaya yarayabilir. Bu tür uygulamalar öğrenmenin bireyselleştirilmesine katkıda bulunabilir. Çeşitli dijital cihazlar vasıtasıyla toplanan veriler öğrencilerin derse ne derece katıldıkları ve ne derece motive oldukları hakkında faydalı bilgiler sağlayabilir. Karekodlar ve RFID tarayıcılar sayesinde analog ve dijital dünya kolaylıkla birbirine

bağlanabilir ve öğrenme materyalleri zenginleştirilebilir. Giyilebilir cihazlar vasıtasıyla öğrenciler hakkında toplanan veriler geribildirim verme başta olmak üzere çeşitli amaçlar için kullanılabilir.

### **Uygulamadaki Güçlükler**

Bütün bu potansiyel kullanım biçimleri bağlamında Nesnelerin İnternetinin eğitim sektörüne entegre edilmesi söz konusu olduğunda üzerinde dikkatle durulması gereken bazı noktalar vardır: (a) Nesnelerin interneti hızlı internet bağlantısı gerektirir. (b) Hem cihazların hem de internet bağlantısının ciddi maliyetleri olacaktır. Bu nedenle fayda–maliyet hesabının yapılması gerekir. (c) Veri güvenliği önemli bir sorundur. Kimin hakkında ne kadar veri toplanacağı üzerinde ciddiyetle durulmalı ve gereğinden fazla veri toplanmamalıdır. (d) Sürekli izlenmek öğrencilerde strese sebep olabilir.

### **Sonuç**

Nesnelerin İnterneti hem sosyal ve ticari hayat için hem de eğitim alanı için bazı imkanlar sunmaktadır. Ancak uygulamaların yaygınlaşması ve fayda sağlaması için ortaya çıkacak problemlerin çözülmesi gerekir. Bu problemlerin çözümü ölçüsünde Nesnelerin İnterneti hayatımızda yer edinecek ve eğitim ortamlarında da kendinden daha fazla söz ettirecektir. İnternete bağlanan cihazların sayısının her yıl katlanarak artıyor olması göz önünde bulundurulursa, eğitim ortamlarının Nesnelerin İnterneti tarafından şekillendirilmesi ve günümüz sınıflarının tarihe karışması mümkündür.