The IoT: Uses and Applications

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The Internet of Things (IoT) is a pervasive web in which each object or machine has a unique identity and is be able to use the Internet to link with other machine or send data; also known as the industrial Internet(Laudon, 2019). IoT makes it easier for people to communicate, collaborate with each other, and access educational resources, creating a multitude of opportunities for consumers, educators, and business owners to transform their lives. The following report defines the Internet of Things, provides several examples of how IoT technology is currently used, and explains the potential applications of IoT in an educational setting. The Internet-enabled devices used with the Internet of Things are useful in preschools, elementary and secondary schools, and colleges and universities, as they increase efficiency, facilitate better interactions between students and educators, and give educators more time to deliver instructional content. The report concludes with an overview of the barriers that make it difficult to implement IoT technology.

Keywords: IoT, the internet of things, RFID, Wi-Fi, Bluetooth, cellular networks, Z-Wave, ZigBee, cloud services, smart homes, connected vehicles, smart factories, Brightwheel, STEM, telehealth

INTRODUCTION

Rapid technological development has been a boon for consumers and business owners alike, as many advancements in technology have made it easier to communicate, participate in financial transactions, exchange goods and services, and access information from a variety of sources. No discussion of today's technology—or what the future holds for Internet users—would be complete without mentioning the Internet of Things (IoT), which is often called the Industrial Internet. Previously, Internet users were tethered to their desktops or laptops; eventually, browsers, games, and other applications went mobile with the invention of smartphones. The Internet of Things refers to the integration of the Internet with electrical appliances, motor vehicles, medical devices, manufacturing equipment, utility systems, consumer electronics, and any other product that can be connected to the Internet.

The Internet of Things is an extension of older technologies, such as radiofrequency identification (RFID) tags, and its rapid development is possible due to the availability of low-cost sensors, declining data-storage prices, the introduction of analytics software capable of analyzing trillions of pieces of data, and the implementation of IPv6, a protocol that makes it possible to assign Internet addresses to a variety of non-computer devices. Devices associated with the Internet of Things do not necessarily have to be wireless, but most of them use wireless communications technology, such as Wi-Fi, Bluetooth, cellular networks, Z-Wave, and ZigBee, to connect to the Internet directly or via mobile application. These devices typically connect to cloud services, making it easy for the user to avoid data losses caused by device failure.

By making it possible to connect residential and industrial devices to the Internet, technology companies have completely revolutionized the way people live and work.

USES AND EXAMPLES

Due to the many advancements made in the technology sector, the Internet of Things affects almost every aspect of daily life. IoT technology now powers televisions, thermostats, vehicles, and "smart" devices such as the Apple Watch. Smart televisions are capable of connecting to the Internet and running a variety of applications, including Hulu, Sling TV, Netflix, and Amazon Video, making it easier than ever to access television shows, films, and other programming at an affordable price. Smart televisions are so popular that approximately 60% of all American households have at least one TV that connects directly to the Internet (NPD Group, 2017).

Smart Homes

IoT technology has also made it possible for consumers to turn their houses into "smart homes" by using Internet-enabled devices to control lighting, temperature, and other functions. The interest in smart homes has increased exponentially since Google purchased Nest Labs for $3.2 billion in 2014. Nest Labs manufactures smart thermostats, smoke alarms, carbon-monoxide detectors, and security systems; the company also developed Nest Weave, a protocol that enables appliances, door locks, thermostats, and other smart devices to communicate with each other and with other Nest products. The Weave protocol is available to third-party developers and manufacturers, making a greater variety of smart devices available to consumers.

Google has extended its smart-home strategy by introducing Google Home, a digital speaker that integrates with Google's intelligent digital voice assistant. Apple offers a similar smart-home platform called HomeKit, which is a framework and network protocol for controlling Internet-enabled home devices such as thermostats and lights. HomeKit is programmed directly into Apple's iOS software for iPads and iPhones, and it is also integrated with Siri, Apple's voice-activated personal assistant, which uses artificial intelligence to assist users with tasks such as making phone calls, performing Internet searches, and keeping track of appointments.

Many devices, including smart thermostats, smart deadbolts, a home sensor that takes environmental readings, and a switch that enables users to control their electronic devices, are designed to be used exclusively with HomeKit. Apple is also developing a smart speaker called HomePod, which will make it easier for users to control the temperature, air quality, and security of their homes. Although Google and Apple offer some of the most innovative devices, Comcast, Time Warner Cable, and AT&T have also capitalized on the popularity of the Internet of Things by offering Internet-enabled home systems that control appliances and lights. Overall, the global market for smart-home products is expected to grow from $47 billion in 2015 to nearly $140 billion by 2023 (PR Newswire, 2017).

Connected Vehicles

Many vehicles are also capable of connecting to the Internet, making it easy for drivers to access navigation assistance, emergency services, and entertainment options on the go. Google and Apple are also major players in this market, as both companies have introduced technology to turn regular vehicles into "smart" vehicles that can be controlled with high-tech applications. For example, Google entered this segment of the market by introducing Android Auto and Android Automotive. Android auto is a smartphone-based vehicle interface, while Android Automotive is a version of the Android operating system designed for motor vehicles. Apple introduced a software platform called CarPlay, which allows the user to sync his or her iPhone to the vehicle's information and entertainment system ("infotainment" system). Vehicles compatible with Android Auto and CarPlay were first introduced in 2015, and now they are widely available in the United States and other markets. It is likely that connected cars will be linked to smart-home devices in the future.

Several companies are also experimenting with autonomous vehicles, which are also called self-driving vehicles or driverless vehicles. These vehicles combine IoT technology with artificial intelligence, making it possible to operate a vehicle without having to shift, step on the brake, or perform typical driving functions. Tesla, Volvo, Ford, GM, and BMW are among the automotive manufacturers interested in the development of autonomous vehicles; companies such as Uber, Google, Intel, and Baidu—a Chinese search engine—are also exploring the opportunities available in the autonomous-vehicle market.

Widespread use of autonomous vehicles is expected to have several benefits, including less congestion, fewer parking problems, and a reduction in the number of vehicles per capita; in fact, each autonomous vehicle on the road is expected to produce anywhere from $2,000 to $4,750 per year in societal benefits (Fagnant & Kockelman, 2015). In spite of these benefit, the use of autonomous vehicles also has several potential drawbacks. One of the most significant barriers to market penetration is the high cost of purchasing an autonomous vehicle. Many people will be unable to afford these vehicles once they are on the market, making it difficult to make the switch from traditional vehicles to autonomous ones. Additionally, government officials and consumers have concerns related to privacy, security, and liability—if an accident occurs, it is not clear whether the manufacturer or owner of the vehicle would be held responsible. It is also unclear how the use of autonomous vehicles will affect other forms of transportation (Fagnant & Kockelman, 2015).

Manufacturing Equipment

Smart homes and smart vehicles are not the only advancements to arise from the development of the Internet of Things; smart factories are also a reality thanks to the introduction of machinery that connects to the Internet and makes it possible for manufacturers to collect, store, and analyze data. Using the data collected by these machines, executives and line managers have an opportunity to identify changing industry needs and adapt to the evolving demands of customers, suppliers, and investors (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). Burke et al. (2017) describe the equipment used in smart factories as a "convergence of the digital and physical worlds—including information technology (IT) and operations technology (OT)." IoT technology has completely transformed the supply chain by making it possible to create open systems in which manufacturers and suppliers are connected to each other by technology.

Manufacturers have relied on automation ever since the Industrial Revolution; when the Internet was first introduced, many companies took advantage of its capabilities to reduce waste and increase efficiency. However, automated equipment typically performs a single task or process, limiting its usefulness in the broader business context. Now that IoT technology is available, manufacturers have an opportunity to integrate artificial intelligence with wireless technology, making it possible for machines to make complex decisions instead of performing discrete processes (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017).

Using equipment built with IoT technology and artificial intelligence also allows manufacturers to integrate factory activities with the rest of the business. For example, managers can make better decisions on the factory floor to ensure that their supply chains are not adversely affected. In other words, IoT technology increases productivity, connects the supply chain with the rest of the enterprise, and enhances relationships with key stakeholders (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). For example, using IoT technology improves relationships between manufacturers and their suppliers by increasing transparency and making it easier for manufacturers to identify quality problems before they cause production delays.

Smart factories have several key features: connectivity, agility, optimization, proactivity, and transparency (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). Connectivity refers to the ability to access real-time data, collaborate across departments, and integrate traditional databases with databases developed with IoT technology (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). Agility makes it possible for manufacturers to easily reconfigure their equipment and factory layouts, implement product changes, and react quickly to schedule changes. Enhanced optimization makes it easier for manufacturers to predict their production capacity, develop production processes that require little human interaction,

minimize manufacturing costs, and increase efficiency (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017).

Proactivity gives managers the ability to identify supplier issues as soon as they occur, discover product defects before the items ship to end users, and monitor inventory levels without human intervention. Finally, transparency ensures that all stakeholders have the information they need; for example, managers have access to production metrics, making it easier to make staffing and scheduling decisions (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). Manufacturers in many industries rely on these features to increase efficiency, improve productivity, and maintain positive relationships with suppliers and customers. For example, a leading electronics manufacturer implemented a fully automated production system based on IoT technology, reducing production lead times, minimizing manufacturing costs, and improving production capacity by 25% (Burke, Mussomeli, Laaper, Hartigan & Sniderman, 2017). The electronics manufacturer also reported a reduction in the number of product defects identified during the manufacturing process.

EDUCATIONAL APPLICATIONS

When discussing the Internet of Things, many people focus on smart devices, automated manufacturing, and autonomous vehicles; although these applications are important, they are not the only uses for IoT technology. Smart devices have many potential applications in the educational sector, from improving the quality of education provided to students with disabilities to making it easier for educators to develop lesson plans and deliver them to their students. Smart devices are so valuable that they can be used at every level of the educational system, including preschools, elementary schools, secondary schools, and colleges and universities.

Preschool

The Internet of Things has made it much easier for parents to stay on top of what their toddlers are learning during preschool. Several apps are available for this purpose, but Brightwheel is one of the most successful. The Brightwheel app makes it easy for parents to check on their children throughout the day, find out about upcoming events, and communicate directly with preschool staff (CNBC, 2018). Parents who download the Brightwheel app have the option of receiving notifications that are customized to their circumstances; for example, the parents of a child who still wears diapers can elect to receive a notification every time a staff member changes the child's diaper. Teachers have the option of sharing photos and videos with parents, making it easy to preserve special moments and document each child's development (CNBC, 2018). Preschool educators can also use the Brightwheel app to send emergency notifications to parents and designated guardians, ensuring that parents always know what is happening with their children (CNBC, 2018). The success of Brightwheel demonstrates that there is a strong demand for apps and devices that use IoT technology to create connections between the school environment and the home environment.

Elementary and Secondary Education

IoT technology has dozens of potential applications in the elementary and secondary classroom. Many educators report that they lose a significant amount of instructional time due to the disruptions that occur when they have to stop teaching to perform administrative tasks or address behavioral issues (Warner, 2015). The Internet of Things has already been proven to increase efficiency, making it a valuable addition to the classroom. Implementing IoT technology in elementary and secondary schools could help educators eliminate or at least reduce interruptions, giving them more time to deliver educational content. Teachers could also use smart devices and other forms of IoT technology to free up time for differentiating instruction or helping students improve their reading skills (Warner, 2015).

Warner (2015) offers a glimpse of the future when he discusses the use of IoT technology in the classroom. One way educators could use this technology to improve efficiency is to use smart devices to take attendance rather than having to use instructional time to make sure every student is present. It is possible to automate attendance-taking activities by having students wear smart devices that record the

electrical activity in their hearts; the devices would then use these activity patterns to verify each student's identity (Warner, 2015). Educators who use these devices could start teaching as soon as school begins instead of having to spend time marking every student present or absent, increasing efficiency and giving students more opportunities to learn.

Warner (2015) argues that IoT technology may also be used to identify students who are having difficulties. Typically, teachers do not know a student is having trouble unless the student or parent speaks up and asks for help. However, not all students are willing to tell someone that they are struggling, leaving them unable to comprehend the material. By using neurosensors in the classroom, educators could do a better job determining which students are struggling to complete an exercise (Warner, 2015). These neurosensors track cognitive activity, making it easy to identify any student who is using a significant amount of cognitive energy on an assigned task. Thus, students would not have to gather the courage to speak up and ask for help; their teachers would be able to use data from the neurosensors to determine which students need assistance.

Selinger, Sepulveda, and Buchan (2013) believe that IoT technology has nearly unlimited potential to help students learn and make it easier for educators to manage their classrooms. One of the most exciting innovations is the use of IoT technology to eliminate the need for students and teachers to travel to physical classrooms. Using technology this way would give cash-strapped public school districts the opportunity to scale teachers and deliver high-quality instruction from anywhere in the world (Selinger, Sepulveda & Buchan, 2013). IoT technology is already used this way in higher education, as demonstrated by the recent increase in the number of schools offering online courses, but the technology is in its infancy in terms of disrupting business as usual in elementary and secondary classrooms.

IoT technology also has the potential to transform the way students learn, reduce the cost of educating students, and give teachers the information they need to make better decisions. Currently, many teachers use static content in their classrooms, giving them little control over the information transmitted to students. IoT technology is useful for delivering interactive content and allowing students to learn at their own pace, creating a dynamic educational environment rather than a static one (Selinger, Sepulveda & Buchan, 2013). One of the most significant problems in public school district is the cost of procuring educational resources for students; furthermore, these resources are distributed to students without regard for their different learning styles and cognitive abilities. The Internet of Things makes it possible for teachers to customize their lesson plans and access crowd-sourced content that is a better fit for students with unique learning needs (Selinger, Sepulveda & Buchan, 2013).

Special Education

Teachers in special-education classrooms face unique challenges, as they must deliver educational content while also managing students with a variety of physical and behavioral disabilities. In fact, special-education teachers may encounter the following disabilities in their classrooms: hearing loss, vision loss, learning disabilities, mental illnesses, intellectual disabilities, mobility issues, traumatic brain injuries, and chronic medical conditions (McRae, Ellis & Kent, 2018). Students with these disabilities have different learning needs, making a one-size-fits-all approach inappropriate for the special-education classroom. Fortunately, the Internet of Things makes it easier for educators to meet these challenges without excluding students from opportunities to learn and interact with others.

Due to developments in IoT technology, students with physical disabilities, mental illnesses, and intellectual impairments now have access to a variety of Internet-enabled devices that make it easier for them to participate in educational activities. These devices include screen readers, screen magnifiers, on-screen alerts, and on-screen keyboards. Screen readers help students with vision loss by reading text out loud, while screen magnifiers allow students to enlarge content that is presented on a computer screen (McRae, Ellis & Kent, 2018). On-screen keyboards are useful for students with mobility issues, as they make it possible for students to type by using a pointing device to choose the right letters and words. On-screen alerts display visual messages on a screen, making it easier for deaf and hard-of-hearing students to participate in classroom activities (McRae, Ellis & Kent, 2018).

Due to the benefits of using IoT technology in a special-education environment, students with special needs are often early adopters, allowing them to benefit from IoT technology as soon as it enters the marketplace. For example, handheld computers and other digital assistants were identified as helpful to students with disabilities almost as soon as they were released. At first, educators viewed these devices as a support item rather than a necessary instruction tool; however, they quickly realized that handheld devices gave students with disabilities more autonomy and allowed some students to avoid revealing their disability status (McRae, Ellis & Kent, 2018). The fact that the handheld devices used by students with disabilities look much like the tablets and smartphones used by students without disabilities also makes students in special-education environments feel less isolated. For all their peers know, these students could be writing emails or sending text messages, not using a handheld device to overcome the challenges associated with having a physical or cognitive disability.

Colleges and Universities

IoT technology has already been implemented in college classrooms, but educators have only scratched the surface of what is possible. Over the years, technology has changed the way students and teachers interact with each other; a group of students learned from one professor and may have had a teaching assistant available to answer questions or provide assistance with class projects. Due to advancements in technology, college students now interact with a variety of learning agents on campus: professors, teaching assistants, tutors, counselors, and academic-support professionals (Melton, 2016). IoT technology facilitates these interactions and makes it easier for college students to locate the resources they need to complete assignments and finish their degree programs on time.

Melton (2016) reports on several innovations that are likely to occur within the next 30 years. One of these innovations is the use of smart devices to help learners customize their learning experiences. With IoT technology, it is possible for students to identify resources that meet their specific learning needs, increasing their chances of success in a college environment. For example, a student who learns by listening to lectures or watching videos could use a smart device to access these learning resources. The audio files and videos would not replace the professor's lectures, but they would complement the in-class materials and give the student a better chance of understanding and retaining the information.

While Melton (2016) focuses on future possibilities, other authors have examined the use of IoT technology in today's classrooms. One application currently used by educators throughout the United States is the use of clickers to facilitate more interaction between students and instructors in large classes. Upper-level classes are usually smaller, giving professors and teaching assistants more opportunities to interact with their students. However, introductory courses may have several hundred students, making it difficult for educators to get to know each person in their classes. To combat this problem, some instructors have incorporated personal-response systems (clickers) in their classrooms.

When an instructor asks a question, students use their clickers to choose an appropriate response. Their answers are displayed on a projector, giving everyone the opportunity to find out what their classmates are thinking (Mayer et al., 2009). Professors can also use clicker sessions to determine if students are struggling to understand the course material, creating opportunities to provide supplementary instruction or review anything that is not clear. Mayer et al. (2009) report that students scored significantly higher on their educational psychology exams when they used clickers to answer between two and four questions per class session. They even performed better than students who answered in-class questions without using clickers (Mayer et al., 2009). The success of clickers in college classrooms demonstrates that IoT technology has the potential to enhance education rather than distracting students.

IoT technology is especially promising for training students in the science, technology, engineering, and mathematics (STEM) fields. Demand for STEM degrees is predicted to increase significantly due to the need for graduates who have a strong foundation in science and mathematics. However, the United States currently lags behind China and other countries in terms of the number of students graduating with STEM degrees each year (Hook, 2015). By using IoT technology, college professors have an opportunity to enhance the delivery of content related to robotics, cybersecurity, data science, and engineering. Using IoT technology in the classroom also has the potential to make STEM programs more accessible to women

and minorities, which could create a more inclusive technology industry (Hook, 2015). He, Lo, Xie, and Lartigue (2016) agree that IoT technology has some promising applications in the field of STEM education. They developed a lab-development kit based on IoT technology, presented the modules to students in a software engineering course, and asked the students to provide honest feedback. The majority of the students responded positively to the IoT-based kit, and many of them enjoyed using the kit to develop a deeper understanding of STEM-related course concepts (He, Lo, Xie & Lartigue, 2016).

In addition to enhancing the delivery of educational content to college students, IoT technology has the potential to change the way colleges and universities operate, which could make them more efficient and effective. One major change linked to IoT technology is the development of the digital campus system, a place for educational institutions to post important announcements and allow students to complete tasks such as registering for courses, paying tuition bills, and setting up appointments with professors and teaching assistants. Digital campuses improve security, reduce operational costs, and make it easier for researchers to collaborate, making them an important addition to any higher-education environment (Aldowah, Ul Rehman, Ghazal & Umar, 2017). Colleges and universities can even use IoT technology to automate functions such as attendance tracking, energy monitoring, building access, and the use of information systems by students and employees (Aldowah, Ul Rehman, Ghazal & Umar, 2017).

Telehealth

The Health Resources Services Administration defines telehealth as "the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration" ("Telehealth Programs", 2020). Telehealth has recently become more popular during the Coronavirus pandemic, or more commonly referred to as COVID-19. Due to lockdown, social distancing, and lack of personal protective equipment; primary healthcare services have been disrupted causing a dire need for remote healthcare services. Telehealth has helped minimize the spread of the virus by allowing patients to communicate with their doctor remotely.

Applications of IoT within healthcare have enabled doctors to still provide medical services to patients during the COVID-19 pandemic. Medical devices with "smart" capabilities have allowed doctors to monitor patients' vital signs without in-person consultations. Video conferencing has enabled doctors to meet with patients and provide evaluations, diagnoses, and e-prescribe medication. Telehealth enables many routine appointments to be handled via phone or live video. If a patient in fact tests positive for COVID-19, live video conferencing enables them to meet with their physician while in quarantine, thus preventing the spread of the virus. Limiting exposure of the virus is key when a vaccine has not yet been developed. Telehealth has been an efficient solution during the COVID-19 pandemic in aiding patients and limiting the spread of the virus.

Telehealth technologies have many benefits and drivers aside from the need for telehealth imposed from the COVID-19 pandemic. The technologies developed to aid in the development of telehealth are not only smaller in size, but more efficient. Dinesen et al. (2016) noted an example of this efficiency by offices "offering office-based desktop computer consultation with providers through patient-specific devices, but now include education for patients and may even offer suggestions for change in disease-specific treatment" (pp. 26). Although converting regular face-to-face to an online setting presents challenges, there seem to be key issues driving the future of telehealth. Dinesen et al. (2016) explained eight key drivers:

(1) personalization of healthcare; (2) matching patients with appropriate technologies; (3) optimal use of healthcare data; including developing a secure interface between patient-generated data; (4) new education paradigms for patients and providers; (5) new communities of knowledge and practice; (6) new care and business models tailored to sustainability and scalability of telehealth initiatives; (7) transfer of scientific knowledge from research to implementation and practice; and (8) innovative research methodologies within telehealth. (Dinesen et al., 2016, pp. 26)

Because of these key drivers and subsequent benefits, telehealth was developed and advanced to the point where it was a viable, efficient solution during the COVID-19 pandemic.

BARRIERS TO IMPLEMENTATION

Although IoT technology clearly has many applications in an educational setting, there are still some significant barriers to implementation. One of those barriers is concerns related to interoperability. IoT advancements occur frequently, but there are still no national or global standards to control how this type of technology is developed and used. Several organizations are fighting to create such standards, but there is no guarantee that for-profit companies and educational organizations will adopt these standards any time soon. Google and Apple are among the most active companies in the IoT space, so it is only natural that they are competing to develop a set of source standards that will be adopted by all developers; however, neither company has managed to produce a set of accepted standards.

Adaptability is another major concern, especially for special-education teachers and their students. McRae, Ellis, and Kent (2018) interviewed students with physical disabilities, mental illnesses, and cognitive impairments to determine how they use IoT technology in an educational setting. They discovered that adaptability is one of the most important considerations, as students with disabilities often modify technology to suit their needs. For example, a student with muscle weakness may need to modify his mobility device if the muscle weakness worsens. If a device cannot be adapted to the student's unique needs, then it cannot be used to improve learning outcomes or help special-education teachers identify students in need of extra assistance.

Security and privacy are also major concerns for educators, students, parents, and school administrators. IoT technology makes it easy to connect devices via wireless technology or other protocols; although these connections have some benefits, they also make users vulnerable to security and privacy violations. The more devices there are on the same network, the easier it is to spread viruses and malware, making some educators wonder if IoT technology is harmful instead of helpful. When students sign up to use smart devices, they are also required to share some of their personal information. If someone gains unauthorized access to the network, the information could be used to commit identity theft or other forms of fraud, putting students and their families at risk. Before IoT technology is adopted in every school, developers must take steps to protect the security and privacy of users.

CONCLUSION

The Internet of Things has many benefits for consumers, business owners, and educational professionals. Due to rapid advancements in technology, it is now possible to use Internet-enabled devices to control thermostats and door locks, improve efficiency and productivity in a manufacturing setting, and facilitate better relationships between educators and their students. IoT technology is especially valuable in the education sector, as it makes it easier for instructors to tailor their lessons to the different learning styles and abilities of each student. Classroom technology also makes it possible for special-education teachers to help their students manage the challenges associated with physical, mental, and cognitive disabilities. Although IoT technology has many benefits, educators should also be aware of the potential drawbacks. Some of the most significant barriers to implementation include concerns related to system compatibility, problems adapting smart devices for students with disabilities, and concerns related to security and privacy.

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