Toward the Next Generation of Educational Technologies: A Survey of Internet of Things (IoT) in Education

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Abstract
Internet of things (IoT) means that physical objects (e.g., device) will be connected to the Internet and be able to interact themselves to other objects. The Internet of things has competitive advantages such as content delivery, automation processing, location independence, security assurance and time reduction thus IoT applications have received extensive attention from both industry and academia in recent years. Due to the rapid development of educational technology, IoT is being increasingly used in education. Learners’ data can be automatically retrieved from device /sensors and maintained through using the cloud infrastructure. The main IoT companies such as Cisco, Microsoft start to use IoT in the learning environment; the connecting technologies are widely applied in the diverse educational application. In this paper, a survey of the different educational IoT applications is presented. This paper is a survey more specific to how ubiquitous connectedness can transform pedagogy.

Keywords: Internet of things (IoT), Educational Technology, pedagogy.
Introduction

Internet of Things (IoT) was considered as an innovation for the global communication. IoT is the framework in which the physical objects will be connected to the Internet and the other devices. The architecture of IoT consists of three layers: perception layer, network layer, and application layer. The bottom of architecture is the sensor layer where sensor devices are launched into the environment to detect events or changes in its environment and send the information to other electronics, frequently. On top of the sensor layer is the network layer. The network layer is responsible for communicating the sensor device in the network such as the Ethernet, Wi-Fi, and gateway. The application layer is the top of IoT architecture which is used to provide services and determine the protocols for message passing.

![The architecture of IoT](image)

- The application layer provided the data processing and data analytic. The application layer involves the big data maintenance, and data analytic.
- The network layer is responsible for processing the received data from the perception layer and transmitting data to the application layer.
- The perception Layer system aims to collect and process the data from the physical world.

Figure 1: The architecture of IoT

IoT has been widely used in smart cities, smart environment, smart water, and so on. Automation and communication are major advantages of IoT, and these features have potential to change the world in various industries. Growing popularity of IoT applications has attracted much attention in recent research. Applying the IoT
applications in the learning environment explicitly could be beneficial. The mobile devices are widely used in the learning environment. The connectivity of IoT can help make life easier for learners with special needs. IoT applications naturally fall to the learning environment to pioneer mobile innovation and enable pupils to broaden the learners’ learning experience. For instance, a visually impaired learner who is given a mobile device, the learning status can automatically upload to the cloud system, the teachers and parents timely receive the learner’s learning profile on the cloud system. The learning activity could be more efficient for the student, teacher, and parents.

**Literature Review**

Internet of Things (IoT) was considered as an innovation for the global communication. IoT is the framework in which the physical objects will be connected to the Internet and the other devices. IoT has been applying in the diverse field. Automation and communication are major advantages of IoT, the IoT solutions greatly aid in the accelerated development of pedagogical materials. IoT applications had been applied in collaborative learning (IoTSCl) and the Pervasive-interactive-Programming (PiP) paradigm to enhance students’ learning motivation in university (Plauska et al, 2014). The building, transportation, learning material in the campus can be constructed from IoT technologies. IoT solutions used in diverse research fields such as Science Technology Engineering and Math (STEM) and Computer Science, the educational IoT solution can also be used in a project oriented class. Students can use this platform as a building block to create their own application (Kimsey et al, 2015). Chin & Callaghan (2013) argue that the IoT provides not only a convenience platform for teaching computer science but also a motivating educational material to capture students' imaginations. Enabling the campus intelligent is one of the essential issues for educational IoT. Chin & Callaghan (2013) contend these approaches are proposed in various educational environments. The educational robots were utilized to facilitate learning, (Plauska & Damaševičius, 2014). Fernandez et al. (2015) demonstrated a web socket-supported system to allow reuse existing laboratories. The proposed system was allowing reuse HTTP previous architectures, hardware, and services, including a more advanced environment that uses web sockets as communications support (Fernandez et al., 2015). The development of an IoT educational mobile learning tool for primary school students in rural underprivileged areas of northern was presented in the learning environment (Pruet, Ang, Farzin, & Chaiwut, 2015). A large sets of data which are usually collected, processed and stored for educational usage, some studies proposes a data acquisition DAQ system, based on low-cost hardware, IoT principles and open source and freely available data mining tools, what enables its widespread usage in educational research (Vujović & Maksimović, 2015).
Table 1: Educational IoT research

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Researches</th>
<th>Fields of application</th>
</tr>
</thead>
</table>
| • The voice and visual sensors connectivity        | Warng, 2010; Xue & Wang, 2011; Gonzalez, Organero & Kloos, 2008; Plauska & Damaševičius, 2014; Cheng & Liao, 2012; Pruet, Ang, Farzin, & Chaiwut, 2015; Fernandez, Ruiz, Gil& Perez, 2015 | ▪ English education  
▪ General education  
▪ Creativity  
▪ Collaborative learning  
▪ Computer science  
▪ Science technology engineering and math (STEM)  
▪ Primary education  
▪ RGB led laboratory |
| • Interactive learning                             |                                                                           |                                                                 |
| • Ubiquitous learning                              |                                                                           |                                                                 |
| • Living Labs                                      | Chin & Callaghan, 2013; Kimsey, Jeffords, Moghaddam, & Rucinski, 2015     |                                                                 |
| • Intelligent Campus (iCampus)                     |                                                                           |                                                                 |
| • Data connectivity and analytics                  | Cheng & Liao, 2012; Vujović & Maksimović, 2015; Pruet, Ang, Farzin, & Chaiwut, 2015; Fernandez, Ruiz, Gil& Perez, 2015 |                                                                 |
| • Data acquisition                                 |                                                                           |                                                                 |
| • Web socknet                                      | Fernandez, Ruiz, Gil& Perez, 2015                                         |                                                                 |

Educational IoT solutions

Considering a student will soon be connected to Sensor or RFID scanning objects while getting personalized curricula delivered to their desks. IoT is when the networks expand to places such as education. For the top 10 IoT solution providers, 70% of providers have been used their solution used in the educational field (see Table 1).

![Figure 2: The IoT solution in education](image-url)
Table 2: Top ten IoT solutions in education

<table>
<thead>
<tr>
<th>Provider</th>
<th>Educational Solution</th>
<th>Items</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon Web Service (AWS)</td>
<td>v</td>
<td>Educational web services   Campus web security                         Open Universities Australia (OUA), University of Maryland</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Massive Open Online Couse (MOOC) platform</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data connectivity and cloud storage</td>
<td></td>
</tr>
<tr>
<td>Microsoft Azure</td>
<td>v</td>
<td>Data connectivity and cloud storage</td>
<td>Florida’s Seminole County Public School District</td>
</tr>
<tr>
<td>Thing Worx</td>
<td>v</td>
<td>Curriculum development</td>
<td>University of Massachusetts Amherst</td>
</tr>
<tr>
<td>IBM Watson IoT</td>
<td>v</td>
<td>Personalize Learning, data connectivity</td>
<td>Sesame Street Pearson</td>
</tr>
<tr>
<td>Cisco</td>
<td>v</td>
<td>Intelligent campus bus</td>
<td>Watkins Glen Central School District</td>
</tr>
<tr>
<td>Salesforce</td>
<td>v</td>
<td>Learning Management System (LMS)</td>
<td>College for America at Southern New Hampshire University</td>
</tr>
<tr>
<td>Carriots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oracle Integration Cloud Service</td>
<td>v</td>
<td>Learning Management System (LMS)</td>
<td></td>
</tr>
<tr>
<td>Predix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KAA</td>
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<td></td>
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</tbody>
</table>

- **Amazon Web Service (AWS)**
  AWS provided the web infrastructure and automation tools (e.g., AWS CloudFormation) for users to create their web environments on the AWS infrastructure. The launch of the AWS Asia-Pacific Region enabled the educational institute to retain student information onshore and access local AWS support resources as required. AWS also provided the information security service. In the OUA case, the Massive Open Online Couse (MOOC) platform was quickly settled on the AWS cloud services. The launch of the AWS Asia-Pacific region enabled the educational institute to retain student information and access local AWS support resources as required. The student information can be adequately protected by using the AWS security service. The education services provider launched the web application in the OUA platform based on the AWS infrastructure. OUA started migrating its back-end systems and websites to the AWS infrastructure. The agility and flexibility of the AWS infrastructure enabled the educational service providers to build OUA’s MOOCs in only 22 weeks and support 110,000 students a few months later. The AWS Cloud service was applied in the technical environment for the user in the University of Maryland, College Park. To ensuring the compliance of data, the University of Maryland was using AWS to migrate all of its data centers to the cloud.

- **Microsoft Azure**
  The massive amounts of data bring challenges to file management. For educational instance, faculty and staff spend a lot of time manage the pedagogical materials. To solve this problem Florida’s Seminole County Public School District used Microsoft
Azure to implement of file management and cloud storage. In the past few years, Microsoft Exchange Online and Microsoft Identity Manager have been applied in the district. Microsoft allows the user to standardize and on consolidate in Windows Server with Microsoft System Center and Configuration Manager. Azure cloud solution takes advantage of real-time file connectivity, high communication performance, and the complete cloud storage service. The Florida’s Seminole County Public School case, they use the Azure StorSimple, the Microsoft Azure hybrid cloud storage solution to save data. Azure StorSimple addresses massive data growth, empowering the user to take advantage of economical cloud storage for users’ or operational data. Therefore, the user didn’t have to create physical disk space while using Azure StorSimple. Utilizing Azure solution for institution infrastructure, network connectivity, and files retrievals can decrease the maintain cost and reduce backup times.

**PTC ThingWorx**

PTC working with 28,000 customers to deliver smart, connected products. ThingWorx is a complete development platform for IoT. On the purpose of reducing the cost, time, and risk, PTC ThingWorx is required to build innovative IoT application and Machine-to-Machine (M2M). For educational technology, PTC IoT academic program contributes to providing a powerful academic package on IoT which include curriculum and software so that educator can develop curriculum material and learners can implement their IoT project in the classroom. PTC IoT academic program provides the free annual license for students, faculty, and researchers. For instance, learners can use IoT tool to develop their project deploy on the program. Recently, PTC IoT academic program providing the online courses available worldwide through Udemy, an established provider of Massive Open Online Courses (MOOCs) and company start with launches IoT MOOCs associated with the IoT product development and business strategies.

**IBM Watson IoT**

IBM Watson IoT is dedicated to developing the intelligent educational technology. In a few years, IBM Watson has been designing a nurturing relationship with the Sesame Street and Pearson that starts with the personalized learning. Watson cognitive tutoring capabilities with Pearson's expertise in higher education help learners improve their learning performance and assist them in completing their course. For instance, when learners come to class prepared, and educators can offer the personalized learning materials. Watson cognitive tutoring provides a more impactful classroom experience can occur resulting in better and deeper understanding for students. In the Sesame Street and Pearson Case, learners had access to personalized Watson interactions designed to enrich the digital experience. The learner will be able to engage with Watson to improve their grasp of course concepts and lead to deeper learning and better performance in the learning activity. Watson has the ability to interact with the learners using to remediate confusion and help the student identify areas of weakness. Watson provided instructors with the insights by Watson, thus they could use to improve learners’ learning performance. Watson provides the personalized learning based on the individuals’ need instructors can make educational strategy based on the strengths and weaknesses of the individual. Pearson collaborates with Watson drive cognitive learning for college students. In Sesame Street case, IBM Watson IoT solution was applied in the personalized learning to kids around the world. Sesame Street has over 45 years of deep expertise gained through research and more than 1,000 studies on how young children learn best. The IBM Watson IoT solutions
analyze the large amounts of learning data and provide the personalized suggestion for learner and educator.

**Cisco**

With the repaid develop of information technology, students and faculty can access to resources around the world in any time. 14,253 school districts and educational institutions, 9,834 colleges and universities in 127 countries had been used cisco educational IoT solution. At Watkins Glen Central School District, Cisco IoT solution was to develop intelligent campus bus. In this case, School bus rides between home and school can take up to 40 minutes each way, the campus network and school bus communication is the challenge of campus transportation. The aim of Cisco solution is ensuring students could use the transportation time productively, securing campus networking, optimizing uptime management, and improving student safety and wellbeing. Therefore, school buses with wireless access using Cisco 829 industrial integrated services routers and secure campus networking with Cisco switching. The student who they live in the place may disadvantage in the campus transportation. This case demonstrate that educational IoT can help to ensure equal access to education for all, improve student safety and wellbeing, as well as make better use of time and learning opportunities.

**Salesforce**

There are many advantages of incorporating IoT into campus, which can help students, faculty, and society on a daily basis. Southern New Hampshire University’s Innovation Lab established College for America (CfA) redesign the college education model with working. CfA delivers an innovative solution to the most pressing problems of cost, access, and quality in higher education throughout the US. Salesforce with the advantage of fast, scalable solution, CfA adopted Salesforce to manage students’ learning profile and launch the program. In the network layer, CfA used Salesforce to connect recruiting, student, marketing, and IT departments. CfA provides the competency-based Learning Management System (LMS) on Salesforce App Cloud. This case demonstrated that Salesforce can quickly integrate with a variety of solutions, making all student data accessible from one tool. Though the educational IoT, the student can get the personalized learning service. For instance, each student is assigned projects which are managed in Salesforce Cloud, and then the reviewer can evaluate the student’s work and make notes directly on the student’s record. In addition, CfA used Salesforce to offer additional support to students according to individual’s need. The college uses Salesforce Knowledge articles to achieve the goal of self-learning. When the students face the difficulty of the learning activity, students can obtain the suggestion by chatting with the Salesforce Live Agent live. In Salesforce, knowledge base sourced from a variety of channels can be integrated to help solve issues quickly and effectively. CfA is determined to make education affordable for everyone, and this case is paving the way for working adults to learn the skills they need to advance their careers at the record pace. Salesforce IoT solution uses social, mobile, and cloud technologies to connect the information. For students, alumni, and parents, the communications with institutions to be effortless.

**Oracle Integration Cloud Service**

Oracle educational cloud solution can engage with educator prospects and students with targeted multi-channel communication. On the cloud platform, students can access the online knowledge base and FAQs at any time in any place. To meet the demands of the students, faculty, and staff by delivering social and collaborative experiences, identifying top talent, and increasing productivity across campus. In addition, Oracle provides integrated solution and management tool to address
pedagogical issues and to ensure the student can learn efficiently. Mobile device provide everyone a convenience way to communicate, Oracle has a complete educational solution for educator and learner to enable the educational environment intelligent.

By starting from the IoT solutions above, it pointed that IoT is included by campus security, learning activity, and personalized learning. These case received support from the top IoT solution providers in completing the project on time and within budget. These solutions with security and architecture best practices in education. Inspiring cases of how schools around the world are using IoT solution to create immersive teaching and learning experiences.

**People's perception of educational IoT**

To examine the importance and the using intention, the evaluation items rated on a five-point Likert scale; the items ranged from 1 “strongly disagree” to 5 “strongly agree.” The result showed that no significant difference was found in the self-perception toward educational IoT for professional and students (see Table 1-2). However, the undergraduate students had higher intention to use educational IoT (Mean$_p$=3.74 < Mean$_u$=3.86) than professional. Table 2 demonstrated that Educational IoT was received more attention for the ungraduated student. The preliminary research and solutions demonstrated that how the IoT impact education, the result show that both professional and students percept that IoT plays the critical role in education. For vocational education, the application layer of IoT starts to transforming education in the Cloud. One of the participants has been enrolled the vocational nursing program on the hospital information system (HIS).

**Table 3: The participants’ intentions to use educational IoT solution**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>3.74</td>
<td>0.98</td>
<td>85</td>
<td>0.592</td>
<td>0.44</td>
</tr>
<tr>
<td>Undergraduate Student</td>
<td>3.86</td>
<td>0.93</td>
<td>63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: The importance of educational IoT**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>3.72</td>
<td>0.85</td>
<td>85</td>
<td>3.096</td>
<td>0.08</td>
</tr>
<tr>
<td>Undergraduate Student</td>
<td>3.97</td>
<td>0.86</td>
<td>63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusion**

The advantage of the IoT is the high impact it will have on aspects of learning environment and behavior of learners. From the point of view of the learners, faculty, and staff the most obvious effects of the IoT introduction will be visible in working efficiency and learning performance. In this context, enhanced learning is only a few examples of possible application scenarios in which the new paradigm will play leading role in the near future. Similarly, from the perspective of the educational environment, the most apparent consequences will be equally visible in fields such as the intelligent classroom. Starting from the innovation of educational technology could drive wide-spread diffusion of knowledge that contributes invariably to educational development. The case studies demonstrated the educational IoT solutions can successfully migrate the websites and back-end systems to cloud infrastructure. There’s no doubt that IoT will make our lives easier with the advent of mobile devices, connected vending machines, and others.
Discussion

IoT will be successfully integrated into the education. In order to include the IoT in education, education must shift. However, the security of data connectivity is the possible threats. The complete IoT security solution will secure the educational data connectivity to avoid hacking a database. The development of IoT security solution can create the safe learning and pedagogical experiences.
References


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