IoT – Enhancing Data-driven Decision-making in Higher Education. Case Study of Ohio University

A dissertation presented to

the faculty of

The Patton College of Education of Ohio University

In partial fulfillment

of the requirements for the degree

Doctor of Philosophy

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May 2018

This dissertation titled

IoT – Enhancing Data-driven Decision-making in Higher Education. Case Study of Ohio University

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Abstract

OGALLO, GODFREY G., Ph.D., May 2018, Instructional Technology

IoT – Enhancing Data-driven Decision-making in Higher Education. Case Study of Ohio University

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The rapid advancement in information technology and the ubiquitous penetration of the Internet are heralding an experience in the world where every physical device is interconnect-able to other devices and the Internet. IoT forms the core of this new wave of ubiquitous technologies. This nascent technology is opening new and virtually inexhaustible sources of innovation in various sectors. As the education sector transitions to technologically augmented learning, IoT offers a great potential in the realm of higher education where some principles of IoT are already in use.

The purpose of this study was to explore how IoT can enhance data-driven decision-making (D3M) in the teaching and learning process in higher education. Six faculty, seven students, and four administrators participated in this study.

A qualitative case study was used to explore how IoT can be used to enhance D3M. Individual interviews and document analysis approach was used in data collection. Multiple techniques facilitated the data analysis. Provision coding was applied in the first cycle coding to organize the data into categories. Pattern coding was implemented in the second cycle coding to condense code summaries from first cycle coding into precise themes. Unified framework of construct validity was applied to enhance the credibility and dependability of the study.

Findings revealed that participants engaged with IoT to enhance the learning experience, improve collaboration on projects, augment student-centered teaching, support customized teaching, and learning, facilitate seamless learning, and parity for diverse learners. Participants had mixed concerns about the issue of individual privacy, data security and connectivity challenges. The constructs of UTAUT2 framework was used to explore the beliefs and perceptions that influence the adoption of IoT amongst the participants in higher education.

The conclusion drawn from this study elucidated that if correctly implemented, IoT can support the development of strategies that could be used to enhance the reaching and learning process.

Dedication

This dissertation is dedicated to Sheila, Zawadi and my extended family.

Acknowledgments

I would like to express appreciation to my committee chair Dr. Kessler, for his regular advice, keen interest and continuous encouragement towards my doctoral journey. Dr. Kessler, you always reminded your postgraduate students that every learning moment could contribute to their dissertation project. You consistently and convincingly conveyed an attitude of academic adventure concerning research.

I would like to submit my gratitude to Dr. Machtmes for her real guidance and helping me to develop the background in research. You were continually ready to listen to whatever point I had any inquiry identified with my doctoral undertaking.

My sincere thanks go to Dr. Wu for your regular encouragement and interest in my dissertation journey.

Dr. Kruse, through my graduate studies, you have remained inspirational to my academic life. I have admired your professional life, and hopefully, I will take the same professional path. I appreciate the opportunity of having you as part of my committee. This has given me the confidence to exude the lessons I learned from you at a previous level of my academic journey.

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Chapter One - Introduction

"From the vantage point of the digital age, we can approach the history of the information age in a new light" (Wright, 2007; p. 4) in that access to information is taking a different demeanor. The rapid advancement in computer and information technology, and ubiquitous penetration of the Internet is heralding an experience in the world where every physical device is interconnect-able to other devices and the Internet. The Internet of Things (IoT) forms the core of this new wave of ubiquitous technologies. IoT is a network paradigm where every day physical objects (things) can be embedded with sensor technologies with the capability to connect to one another, the Internet and other networks through uniquely identifiable Internet protocol (IP) addresses (Whitmore, Agarwal & Da Xu, 2015). In that, the IoT technology is designed to connect our physical and virtual worlds to enable data collection and transmission through embedded sensors, microcontrollers and software. These devices generate big data, which can be harnessed through context-aware computing to provide real-time insights with limited need for user input (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014).

Currently, the IoT technology is opening new and virtually inexhaustible sources of innovation. This nascent technology is transforming a variety of industries which includes the automotive (Zhou et al., 2016), healthcare (Gómez, Oviedo, & Zhuma, 2016), aviation (Chen, 2016), and logistics (Villanueva, Villa, Moya, Santofimia, & López, 2012). Given the broad scope of the application of IoT technology, these industries are leveraging IoT technology to control production processes, empower workforce efficiency, increase operational efficiency and enhance user engagement with consumer electronics through a personalized experience. Today, several appliances are embedded with IoT technology including intelligent cars, thermostats, lights, refrigerators, smart homes, wearables, and smart cities (Rathore, Ahmad, Paul, & Rho, 2016). Moreover, IoT is becoming part of our daily life as it is embedded in everyday devices in the areas of environmental monitoring, medical and healthcare management, energy management, infrastructural management, automation of building and constructions, and transport sector management to collect and transmit data unobtrusively.

According to Gartner (2015), IoT technology is poised to grow quantifiably from 6 billion devices in 2016 to approximately 20.8 billion by 2020. The Gartner IT Hype Cycle (as shown in Figure 1.0) has predicted that the emergence of IoT technology will offer a competitive advantage to the adopters within the next ten years. The IoT trend is dawning an era characterized by miniaturized, relatively inexpensive and inconspicuous technology (Mukhopadhyay & Postolache, 2014)

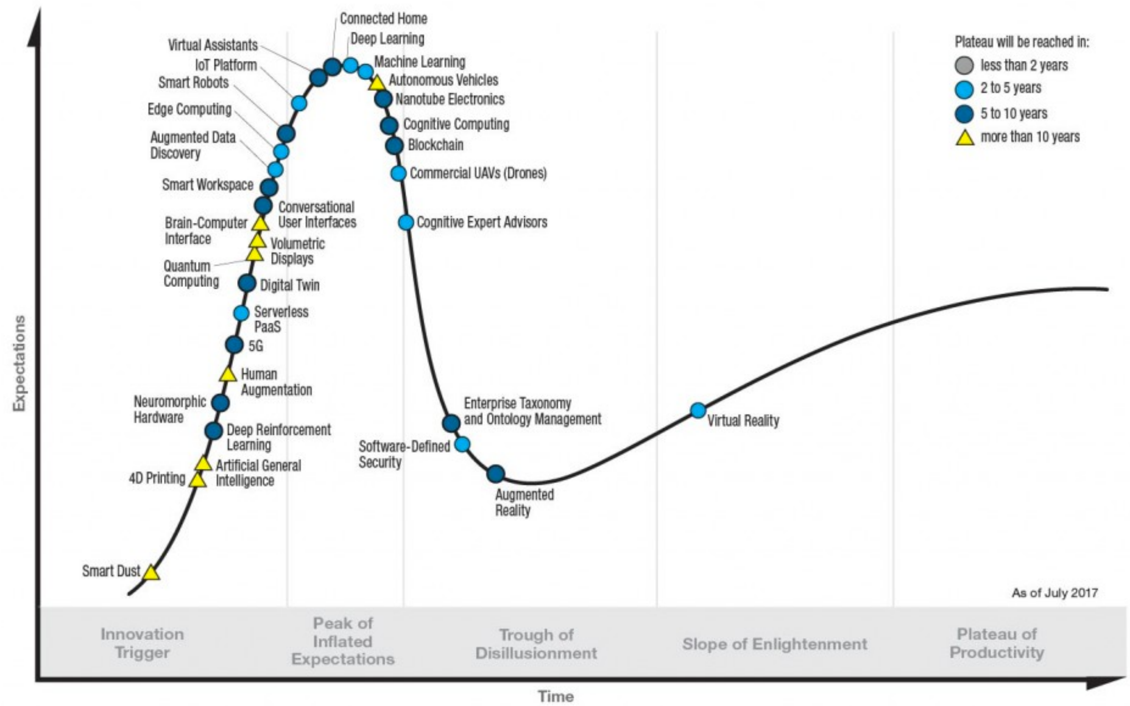

Figure 1. Hype Cycle for Emerging Technologies
Source: Gartner (2017)

The IoT platform is built based on the principle of pervasive computing also commonly known as ubiquitous computing - where one person uses many computers (Mukhopadhyay & Postolache, 2014). IoT devices are designed to be intuitive to control and manage through the web with the capabilities to provide real-time information (Gómez, Huete, Hoyos, Perez, & Grigori, 2013).

As this emerging trend in computer and information technology inundates our daily life to the extent of providing users with unlimited access to information, this is likely to be one of the many disruptive influences in education. The education sector is poised to experience an increased transition from the traditional factory model of education to a digital approach to teaching and learning (Melton, 2016). Amid the disruption, there are many opportunities that higher education can realize from integrating IoT technologies in the teaching and learning process (Marquez, Villanueva, Solarte, & Garcia, 2016). For instance, this nascent technology has the potential to support the capturing of unprecedented amounts of educational data. This data can be used to design strategies for improved teaching and learning process. Additionally, when IoT is used as learning tools, this technology does not only gives students the opportunity to interact with real-world objects but it also fosters an increased understanding of subject matter. Further, it supports learners to self-track their learning journey. Similarly, Cisco (2013) noted that in an IoT enabled education, the faculty has the opportunity to use student data to customize instructions that address individual students learning styles and needs. Relatedly, Zebra Technologies (2015), reported that IoT technology could be used to improve campus security through enhancing the tracking of the critical institutional asset by leveraging solutions such cloud computing and radio frequency identification (RFID) across an IoT platform (Zhang et al., 2006).

Today, more students are bringing to campus more than one smart device – such as laptops, tablets, smartphones and wearable devices to support their learning (Hwang, 2014). The increased access to campus networks from multiple devices is as a result of the increasing interest in the BYOD (Bring Your Own Device) policy (Flavin, 2016). This policy permits faculty, students, and administrators unrestricted access using their digital devices to campus network to promote and facilitate the free flow of information within higher education.

In congruence with the mantra of today's digital ecosystem, the culture of D3M is increasingly being embraced by the education sector (Trumble, Wake & Mills, 2017). This is decision-making backed up by empirical evidence. Therefore, as more smart devices are connected to the campus network, this is generating big data that can be harnessed to make D3M. According to Gubbi, Buyya, Marusic, and Palaniswami, (2013), "One of the most important outcomes of this emerging field is the creation of an unprecedented amount of data" (p. 1649). In this regard, the value of IoT in education can be realized by sifting through the incredibly rich trove of data generated by smart devices connected to the campus network.

Using predictive analytics, institutions of higher education can leverage the plethora of data generated from smart devices connected to campus network to make informed decisions about institutional strategy; address campus issues through predictive and collaborative engagements; improve student completion rates and reduce costs of education (Crow & Dabars, 2015; Afreen, 2014). Relatedly, García-Sánchez and Luján-García (2016) postulated that IoT applications are steadily transforming educational technologies from being static applications to more interactive tools of learning that promotes experiential learning.

Site of Case Study

In this explorative research, the case study site was selected purposefully because of the ease of accessibility and the likeliness that the chosen site will allow the research questions to be explored productively (Yin, 2009). The case study site is at Ohio University, one of the oldest institutions of higher learning in the U.S. Ohio University is a public university, with total enrollment exceeding 38,651 students as of the Spring semester of 2016.

A report from the Office of Institutional Research at Ohio University shows there has been progress in student enrollment. The Spring 2016 Enrollment Headcount showed 21.4% change in student enrollment from 2010-2016; Final Fall Enrollment Headcount of 2009-2015 reported 23.7% change in enrollment and the Final Summer Enrollment Headcount 2009-2015 noted a change of 37.7% student enrollment. The report of 2016-2017 showed the total number of faculty at 2181, administrators at 1855 and 1256 classified (to mean hourly employees).

The average full-time faculty compensation at Ohio University in 2016-2017 is $147,553 for professors, $116,936 for associate professors, $108,938 for assistant professors, and $124,216 for all ranks combined.

The main campus has 214 building with 26,481 rooms and approximately 8.2 million gross square feet of space. Including the main campus in Athens, the university has five regional schools. That is the Eastern campus (located outside of St. Clairsville in Belmont County), Chillicothe campus, Southern campus (located in Ironton in Lawrence County with a satellite operation in Proctorville and Hanging Rock), Lancaster campus (which has a satellite operation in Pickerington) and Zanesville.

Problem Statement

Different sectors have realized a multitude of opportunities due to integrating IoT technology to their operations. These industries include healthcare (Gómez, Oviedo, & Zhuma, 2016; Mano et al. 2016), supply chain management (Lee & Lee, 2015), aviation

(Chen, 2016) and military defense facilities (Zheng & Carter, 2015). IoT has enabled these sectors to enhance D3M from an evidence-informed perspective. Therefore, nowhere does IoT offer greater promise than in the realm of higher education, where isolated principles of IoT technologies are already in use. According to a report from Bradford Networks (2013), educational institutions are implementing the BYOD policy with up to 85% of schools allowing unrestricted access to the campus network from personal electronic devices. Considering that, IoT technology is already infiltrating campuses with an average of seven smart devices brought to school by each student (Hudson, 2016). These institutions can leverage the data generated from smart devices to enhance D3M in the teaching and learning process.

Despite the growing popularity in research on the IoT paradigm (Whitmore et al., 2015), there is still a paucity of research (Al-Momani, Mahmoud & Sharifuddin, 2016) focused on how this nascent technology can enhance D3M in higher education. Specifically, to improve the teaching-learning process, lower the cost of tuition and to improve operational efficiency in education administration. Therefore, the focus of this study was to explore how IoT technology can enhance D3M in the teaching and learning process.

Purpose of the Study

The primary purpose of this qualitative case study was to explore how IoT technology can enhance D3M in the teaching and learning process at Ohio University. Specifically, the study examined the potential opportunities and benefits of integrating IoT technology in higher education. The study investigated how the different stakeholders at

Ohio University have engaged with IoT to enhance D3M. This study also examined the perceived concerns regarding the adoption of IoT technologies among the stakeholders at Ohio University. Ultimately, this study explored the factors affecting the adoption of IoT technology in higher education. The UTAUT2 framework informed this research. This model predicts and explains peoples' technology acceptance behaviors for novel technologies.

Research Questions

The following research questions served as a guide to the interviews used to collect data for this study.

RQ1: How have the faculty, students and administrators at Ohio University engaged with IoT technology to enhance D3M?

RQ2: What are the perceived advantages and drawbacks of IoT technology among faculty, student and administrators in D3M?

RQ3: What beliefs and perceptions are affecting the adoption of IoT technology in higher education?

Significance of the Study

As educators seek for novelty in strategies to improve their student's academic performance, the findings of this study could enhance awareness about alternative approaches to data-informed pedagogy. Adopting IoT curricula could help to improve the teaching and learning process by providing a richer learning experience and facilitating real-time actionable insight into students' performance. Student data collected in an IoT enabled learning environment could facilitate strategies used to customize content and instructions that address areas of learning concerns. This study could also increase faculty awareness about the possibility to create smart lesson plans that improve their efficiency by leveraging real-time data on student behavior to support student's learning styles, needs, and aspirations.

The study may increase student's awareness about the principles of IoT; how it can be used to improve their learning through increased access to information and self-tracking their learning journey; and how it can help reduce the cost of education through seamless learning. The study could encourage students to untether learning spaces to ensure time and place are not barriers to learning.

Currently, administrators and decision-makers in higher education are facing tremendous uncertainty in the face of budget cuts and global competition in higher education. Therefore, this study could increase awareness about the potential opportunities and benefits of integrating IoT in higher education amongst policymakers. The outcome of the study is likely to contribute to theoretical discourse on IoT and D3M that could be used to inform policy in the realm of higher education.

Assumptions

While the researcher primed participants about the context in which IoT and D3M was used in the study, the study was based on the assumption that all the participants were familiar with the central phenomena of the research study. The study assumed that integrating IoT technology in higher education will enhance data-driven decision-making in the teaching and learning process. The researcher assumed that the participants are honest in their response to the interview questions.

Limitations of the Study

The sample size and scope of the study was limited to faculty, students, and administrators of Ohio University. A mid-sized university and therefore, the findings may not be generalizable to other institutions of higher educations. The data from this case study may not be an accurate reflection of other institutions of higher education.

The credibility of this study was limited to the dependability of the instruments used in conducting the study.

It was unknown if the participants in the study had experiences with IoT technology that differed from those in other institutions of higher education.

This study took place during summer semester when most faculty and students were away for the summer break. Therefore, the findings of the study are based on data collected from interviews and document reviews, with limited triangulation from member checking, and reflective journal notes (Appendix C). Including a focus-group discussion would have enriched the quality of data collected.

Another possible limitation of the study stemmed from the participants' limited understanding of IoT technology from an educational perspective.

The credibility of this study is also limited to the knowledge of the researcher as an IT professional.

Delimitation of the Study

This study was delimited to how IoT technology could enhance D3M in the teaching and learning process. The study was delimited to a qualitative research approach because the researcher was interested in exploring about IoT in D3M in higher education.

Focus group discussion was not considered as a data collection instrument because it would have been challenging to have all the participants at the same time given that the data collected was conducted in the summer.

Definition of Terms

The focus of this study was to explore how IoT technology can enhance D3M in the teaching and learning process in higher education. In the course of this study, there are several unique terms, and the words are defined below as used in the context of the study.

Big Data refers to any data set that is high in volume, velocity, and variety.

BYOD is a policy that allows user access to organization provided services and data on a user's set of personal devices. In higher education, Flavin (2016) pointed out that BYOD permits students to use their own devices (smartphones, wearables and tablet computers) to support their learning

Context-aware computing refers to "the use of context to provide task-relevant information and services to a user" (Abowd et al., 1999, p. 304).

Cloud computing refers to the use remote network servers connected to the Internet to store, control and process data remotely rather than on local servers or personal computers.

D3M refers to making decisions backed up by empirical evidence.

IoT refers to an emerging networking paradigm that interconnects a large number of everyday objects (devices) to each other and to the Internet to enable "anytime, anywhere" access to information (Whitmore et al., 2015).

Internet of Everything (IoE) – an intelligent network of people, process, data and things (Cisco, 2013).

Smart devices refer to electronic devices that connect to other devices or networks via different wireless protocols such as Bluetooth, NFC, Wi-Fi, 3G, RFID, etc., and are capable of operating to some extent interactively and autonomously.

Ubiquitous learning refers to learning anywhere at anytime

UTAUT2 is theoretic framework used to explain and predict peoples' technology acceptance behaviors for novel information technology products. In that, it describes the intention to use technology.

Abbreviations

IoE – Internet of Everything

IoT – Internet of Things

IT - Information Technology

NFC - Near-field communication

RFID - Radio-frequency Identification

UTAUT - Unified Theory of Acceptance and Use of Technology

Chapter Two - Literature Review

This chapter describes the IoT paradigm; the theoretical framework informing this study and discusses the potential opportunities and benefits of incorporating IoT technology in higher education. Finally, it reviewed the factors affecting the adoption of IoT in higher education.

Internet of Things (IoT)

With the rapid advancement and ubiquity penetration of Internet technology, we are experiencing a world where everything (devices) is capable of being interconnected to the Internet – providing anytime, anywhere access to information. The IoT is standing at the core of this new technological wave of pervasive computing that is building a global network of the information society that supports new and advanced services (Patel & Cassou, 2015). IoT is developing a comprehensive infrastructure for an information society. This nascent technology is tethering the physical and virtual devices based on the existing interoperable information and telecommunication technologies (ITU, 2012).

According to Weiser (1991), “the most profound technologies are those that disappear. They weave themselves into the fabric of our everyday life until they are indistinguishable from it” (p. 94). This notion is what makes Mark Weiser credited as the "father of ubiquitous computing." His prescient idea of ubiquitous computing was a prelude to the development of ubiquitous connectivity. While categorically ubiquitous computing is considered the third generation of computer technology - based on the principle of one person using many computers (Manwaring, 2015; Rückriem, 2015). The “Internet of Things,” a phrase coined by Kevin Ashton in 1999, was by then described as uniquely identifiable interoperable objects connected through radio-frequency identification (RFID) technology (Asseo, Johnson, Nilsson, Neti & Costello, 2016). However, the evolution of IoT can be traced back to ubiquitous computing (Patel & Cassou, 2015) as shown in Figure 2.2. Thus, IoT is categorized as the fourth generation of computer development (Abowd, 2016).

IoT is a network of physical objects (things) connected to the Internet and other networks through uniquely identifiable IP addresses – enabling data collection and transmission through embedded sensors, electronics, and software (Whitmore et al., 2015). It allows the interconnectivity of Internet-aware devices. The IoT platform is built on the principle of pervasive computing – meaning one person using many computers (Manwaring, 2015). The rapid development and ubiquity penetration of the Internet technology is attributable to the upturn in smart devices. Therefore, we are transitioning towards an era where every physical device has the potential of being internetworked (Xia, Yang, Wang, & Vinel, 2012). Various supporting technologies are attributable to the growth in IoT-centered technology. These include the advent of IPv6, growing number of wireless networking technologies (such as RFID, NFC, Bluetooth, etc.), advancement in smart devices, the increase in broadband availability, increase in processing power, reduction in the cost of connected devices and energy efficient systems (Prince, 2012). Relatedly, the emergence of cloud computing and big data analytics has enabled the technological ecosystem that is supporting the rise of IoT (Rose, Eldridge & Chapin, 2015).

The proliferation of smart technologies is transitioning IoT to a new phase of ubiquitous connectivity known as the Internet of Everything (IoE) – an intelligent network of people, process, data and things (Cisco, 2013). Additionally, Gómez et al. (2013) reported that the advances in nanotechnology have supported the creation of miniature devices that can be embedded in a range of systems and the added functionality of connecting to the Internet efficiently.

Today, IoT is fostering new technological innovations that are digitally transforming many industries. These include, automotive (Rose et al., 2015; Zhou, et al., 2016), supply chain management (Lee & Lee, 2015), healthcare (Gómez, Oviedo, & Zhuma, 2016; Mano, et al., 2016; Suvarna, Kawatkar, & Jagli, 2016), aviation (Chen, 2016), transport sector (Villanueva, et al., 2012), pharmaceutical (Jara et al., 2010), and military defense facilities (Zheng & Carter, 2015).

This growing trend has been fostered due to the convergence of wireless technologies, advancement in microcontroller and the internet – making any object a smart device that can communicate unobtrusively (Lee & Lee, 2015) as shown in Figure 2.0.

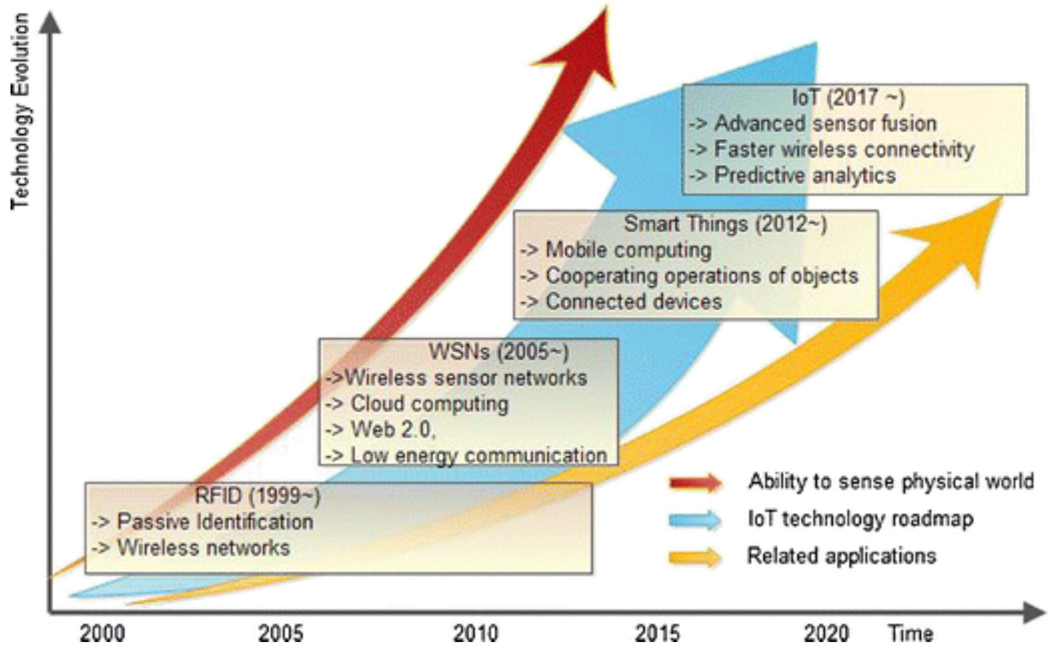

Figure 2. IoT Roadmap

Theoretical Framework

In the domain of information science, researchers have proposed different user acceptance models to explain the factors influencing information technology acceptance and use. Some of the models include, the Theory of Reasoned Action (Fishbein & Ajzen, 1975), Technology Acceptance Model (TAM) (Davis, 1998), Theory of Planned Behavior (Ajzen, 1991), Motivational Model (Davis, Bagozzi, & Warshaw, 1992), TAM2 (Venkatesh & Davis, 2000), and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003). However, TAM is one of most frequently cited models used to understand the factors affecting the adoption of information technologies (Bangert & Alshahri, 2016; Farahat, 2012).

TAM is an information systems theory that models why users come to accept or reject new technology (Davis, 1989). TAM provides a basis to trace how external variables influence internal beliefs, attitudes, and intention to use technology (Al-Momani et al., 2016). TAM hypothesizes that the adoption of technology is a function of two constructs - perceived usefulness and perceived ease of use. Perceived usefulness refers to “the degree to which a user believes that using a particular system would enhance their job performance. Whereas perceived ease of use is the extent a prospective user of technology expects the potential system to be free of effort” (Davis, 1989, p.319).

Also, given the confinement of TAM and the other individual models mentioned above in regards to the acceptance and use of technology, Venkatesh et al. (2003) developed the UTAUT model as an integrated framework that consolidates the empirical similarities and findings from previous research studies that employed TAM related theories. They reported that the predictors of use behavior and behavioral intention are functions of four fundamental constructs - performance expectancy, effort expectancy, social influence, and facilitating conditions. They also reported that gender, age, experience, and voluntariness of use are likely to influence the impact of the four constructs on use behavior and behavioral intention as shown in Figure 2.1.

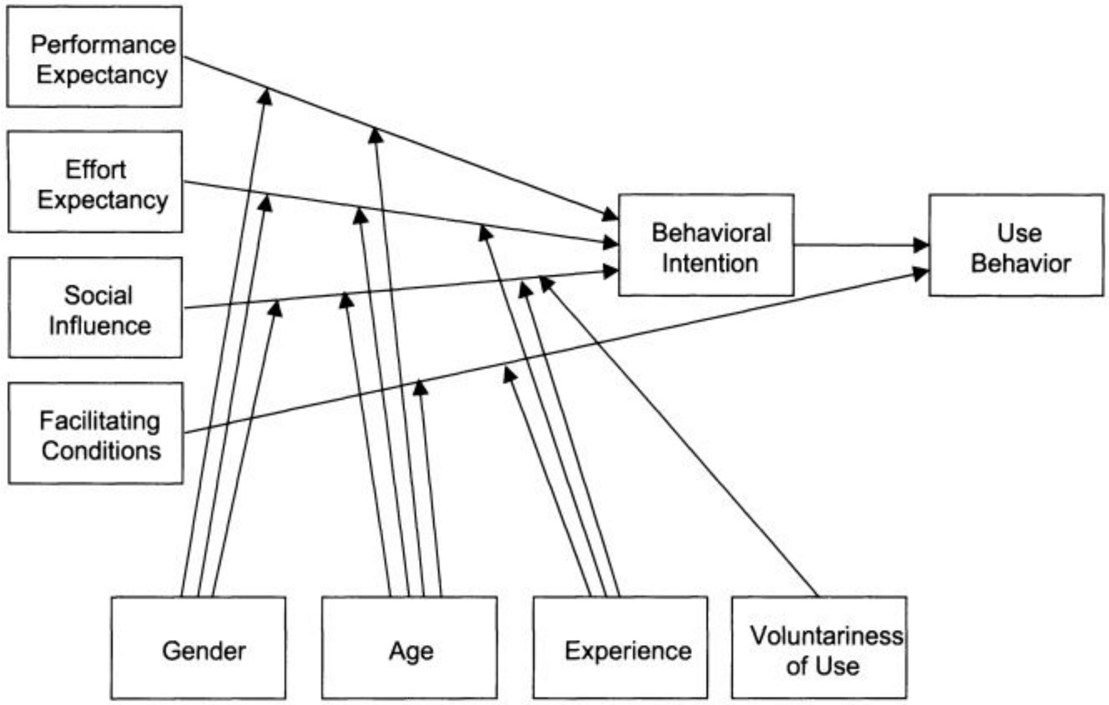

Figure 3. UTAUT Model
Source: Venkatesh, et al. (2003)

By consolidating the conceptual and empirical similarities of previous models, a longitudinal study (Venkatesh et al., 2003) of UTAUT reported a variance of 70% in behavioral intention to use and about 50% in actual use of technology in the organizational context as compared to each of the previous individual theories.

As indicated by Alvesson and Kärreman (as cited in Venkatesh, Thong, and Xu, 2012, p. 158), "new settings can bring about a few sorts of essential changes in hypotheses. For example, rendering initially theorized relationships to be insignificant, altering the course of relationships, altering the magnitude of relationships and creating the new relationship". Given that UTAUT theorized employee technology acceptance and use within an organizational context, Venkatesh et al., (2012) modified UTAUT to UTAUT2 model to explain employee technology acceptance and /or use from the context of consumer technologies. The authors incorporated three constructs into UTAUT to include hedonic motivation, price value, and habit. These additional constructs are theorized to exhibit significant changes in the variance explained in behavioral intention and technology use. The constructs of the UTAUT2 model includes performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit as shown in Figure 2.2. The UTAUT2 framework hypothesizes that these constructs influence behavioral intention and/or use behavior of technology amongst consumers. Specifically, the moderating variable - voluntariness of use was dropped from the UTAUT2 model because it was not pertinent in a consumer choice context. However, the UTAUT2 framework retained age, gender, and experience as the third variables that are posited to moderate the impact of the seven antecedents of UTAUT2 on behavioral intention and use behavior of technology by consumers.

Albugami and Bellaaj defined the predictors of UTAUT2 as follows:

- Performance expectancy (PE): Is the extent to which users believe that using the system will help them attain gains in job performance.
- Effort expectancy (EE): Is the extent of ease associated with the use of the system.
- Social influence (SI): Is the degree of importance being recognized by others to use a novel technology.
- Facilitating conditions (FC): Is the extent to which an individual believes that organizational and technical infrastructure is in place to support their use of the system.

- Hedonic Motivation (HM): Is the perceived enjoyment when using technology, despite the expected performance consequences.

- Price Value (PV): Is the consumer's cognitive trade-off between the cost of using the applications and the monetary cost of using them (Venkatesh et al. 2003, p. 161).

- Habit (HT): Is the extent to which people tend to perform behaviors automatically because of learning.

In comparison to UTAUT, Venkatesh, et al., (2012) revealed that the additional antecedents proposed in UTAUT2 created a considerable change in the variance explained in behavioral intention from 56 to 74 % and technology usage from 40 to 52 %.

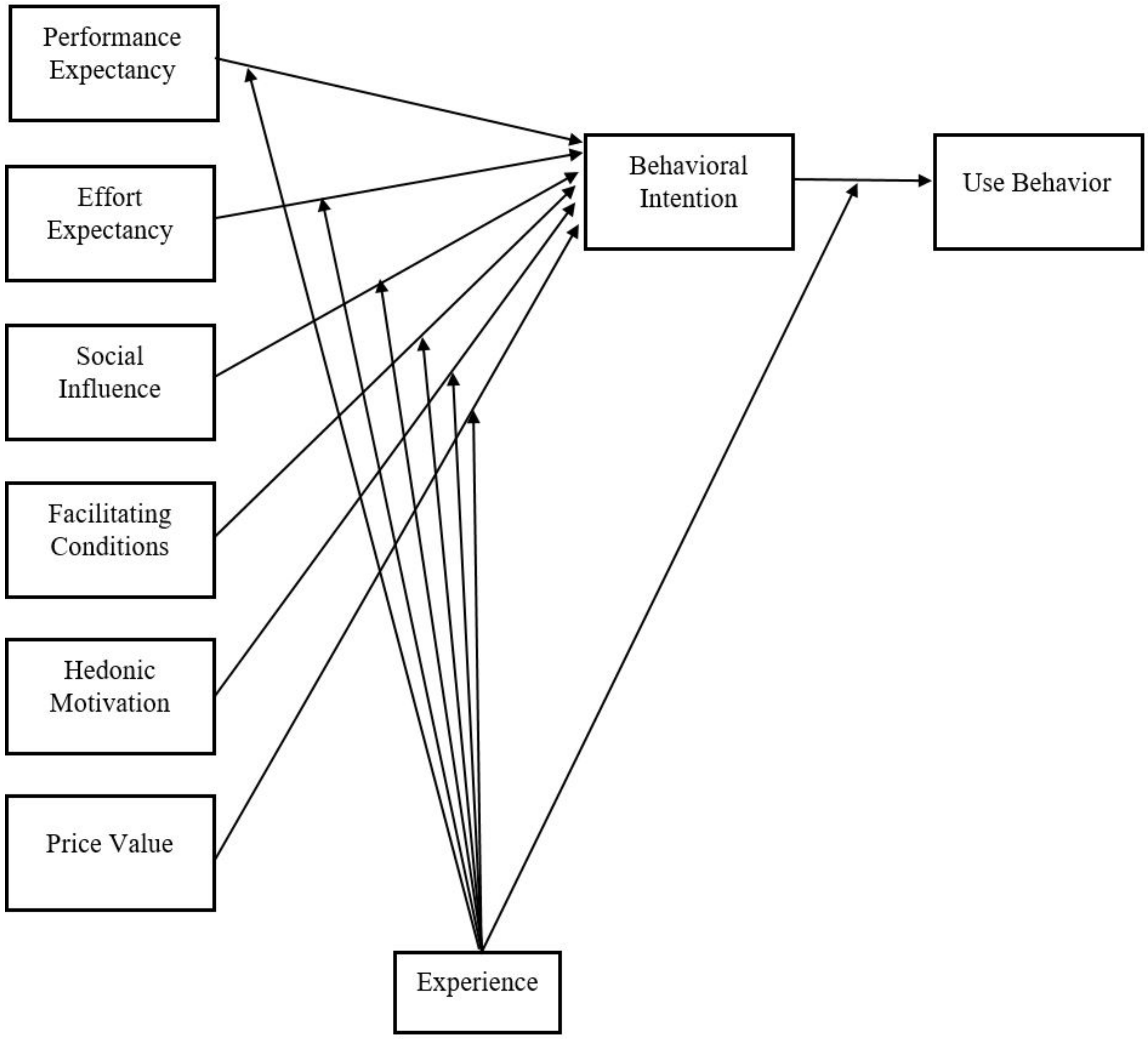

Figure 4. UTAUT2 Model
Source: Venkatesh et al. (2012)

Many researchers (Huang & Kao, 2015; Khan & Adams, 2016; Raman & Don, 2013), posited that UTAUT2 is a powerful predicting framework that is effective for explaining and analyzing technology acceptance and use behavior for novel information technology. The UTAUT2 model informed this study. Given that the study was conducted was within a university setting and the researcher purposefully selected information-rich participants, therefore, two moderating variables were dropped. Gender and age were dropped from the model because it did not have a significant influence on the participants behavioral intention and use behavior to adopt IoT technology. However, this model was critical in determining and interpreting the factors affecting the adoption of IoT technology in higher education. According to Al-Momani et al., (2016), performance expectancy are primary determinants that influence an individual's intention to adopt new technology. In this study, perceived usefulness explained the potential opportunities and benefits of incorporating IoT in higher education. The UTAUT2 model guided the design of the interview questions specifically to determine the factors that influence the adoption of IoT technology.

IoT in Higher Education

As the educational sector transitions from traditional towards a digital approach to teaching and learning in response to the learning needs of the 21st century students, the proliferation of connected devices will be in the ascendency as learning tools. This technological flux is poised to transform higher education profoundly in various ways (Marquez, et al., 2016). As we live in a time where the abundance of information and the exponential development of the contemporary knowledge and the improvement of new learning is testing educators to reexamine modes of instruction and learning at a global level (Selinger, Sepulveda, & Buchan, 2013). There is need to impart students with competitive skills that address the issues in the current work environment.

Technological innovation is becoming an impetus to learning that will transform education from a knowledge-transfer approach to a self-coordinated, engaging, and interdisciplinary model of education that enables learners to be co-creators of knowledge and learn cross-disciplinary skills that supports them to work in the digital milieu (Ervin, 2017).

As per Lenhart (2016) by 2015, up to 73% of U.S. teenagers had access to smartphones, which was used both for communication and as a source of information to build their knowledge. Relatedly, Camera (2015), reported that nearly 100% of all U.S. public schools have instructional computers connected with Internet access. Therefore, this offered students the opportunity to experience new ways of learning. Furthermore, Morpus (2016) similarly reported that 70% of middle school students and 75% of high school students used laptops for educational purposes. Capterra (2014) argued that having access to computers as tools of learning enables students to automate their classroom tasks such as note taking, schedule checking, and research. On a broader perspective, the Gartner report (2015) posited that by 2016, there would be 6.4 billion Internet-enabled devices that are connected to cloud-based services – meaning there was a 30% increase IoT devices from 2015. The report further predicted that by 2020, there would be about 50 billion devices connected to the Internet, which will surpass the anticipated human population growth. Therefore, if the anticipation intonated above holds, then it is likely that the IoT-centered technology is poised to disrupt the old hierarchical approach of teaching and learning. Ultimately, this trend will change how we understand and harness technology as tools of learning in higher education.

According to Selinger et al., (2013), "…students learn by being actively engaged in relevant and authentic activities—and IoT technology makes this increasingly possible" (p. 3). Selinger et al. succinctly asserted that IoT technology would profoundly transform learning from a knowledge transfer model to a collaborative, active, self-directed, and engaging model. Gros & López (2016) reiterated that technology-rich learning fosters students to become co-creators of knowledge as opposed to being passive learners. This may enable faculty to transition from first person teaching towards a learner-centered approach to teaching. Therefore, if university takes advantage of the available educational technologies and encourages their students to be active participants in a technology-centered learning environment, this motivates students to become self-regulated learners who strive to develop and explore their unique academic and career interests - as they produce an authentic and professional quality of work that demonstrates their learning.

In a technology-driven learning environment, faculty needs to take up the role of a coach, advisor, and facilitator of learning as they provide opportunities for students to explore the nuances of creativity that arise in a digitally connected world and also take charge of their learning (Ervin, 2017). Gómez et al., (2013) investigated the potential opportunities for ubiquitous learning. Their report showed that the increased access to educational content through collaborative learning environments enhanced student academic performance. Moreover, they called attention to that there is a definite change in learning results when everyday objects are embedded with IoT innovation and utilized as learning tools. They noted that this fosters authentic learning since it links particular teachable moments to the students' natural setting.

Today, as we experience the dropping cost of broadband Internet, institutions of higher education are equipped with high-speed wireless networks – allowing more access from smart devices within the campus community. Therefore, this augments the potential of IoT technologies such as enhanced teaching and learning resulting from a more productive learning experience and increased student engagement in experiential and situated learning without place, time and device restrictions. According to Johnson (as cited in Selinger et al., 2013), ubiquitous access to information supports the creation of connected communities of practice where students can supplement their coursework through sharing ideas with other students and a whole world of experts. For instance, IoT-enabled devices support live streaming of videos of experts in specific areas invited to teach classes anywhere in the world. Therefore, Cisco (2013) posited that this seamless platform of communication does not only have the potential to increase knowledge availability, but it also avails students with unique value-added learning experience considering that students can form distance learning opportunities based on mutual study interests. Relatedly, Cisco mentioned that based on the pervasive aspect of communication supported by IoT, this renders itself as a platform for collaborative research where both faculty and students can work on a shared project from anywhere at any time as a way of bringing different disciplines in one space. Similarly, Demirer, Aydm, and Celik (2017) reported that with the pervasiveness of smart devices, IoT is augmenting the technological dimensions of seamless learning in formal and informal setting.

According to Marquez, et al., (2016), the surge of smart devices has not only morphed the way we interact, but it has also had an impact on the teacher-student interaction. Which has enhanced not only the teaching and learning process, but it has also expanded on students' context of learning. They proposed a model for integrating everyday objects within the educational domain to virtual academic communities (VAC). To include "groups of individuals linked by common interests, committed to continuous learning processes, whose primary objective is the shared construction of knowledge, using ICT as a means of expression, as a communication tool, as a teaching resource and even as a management tool" (p. 204). This is intended to interface physical and virtual spaces within education institutions with the intention to support teaching, learning, and communication activities amongst others. Furthermore, Marquez et al., (2016) pointed out that integrating IoT into the application domain provides an unprecedented opportunity to collect student data on aspects such as learning activities, the use of educational resources, and students' accomplishment in connection to syllabus objectives. Such information can be analyzed to design strategies that enhance teaching and learning.

With extant studies on educational data mining showing the critical roles that it can espouse to learning such as discerning learning processes and the potential ways of improving teaching (Romero-Zaldivar, Pardo, Burgos & Kloos, 2012). Vujovic and Maksimovic (2015) emphasized that IoT-enabled learning spaces support ubiquitous access to information in novel ways and contexts that connect people, processes, data and things. Relatedly, other studies showed that student data could also be used to create empirically tested curricula and assessment structures (Melton, 2016) and classrooms on demand through smart devices (Kim, Cho, & Lee, 2013). Similarly, data generated through classroom video recording of instructors, instructors' feedback to students, instructor's achievement, and publications can be used to evaluate instructors' pedagogical approach, and the trove of information from such data can be harnessed to design and support professional development.

Furthermore, as ubiquitous technologies advance towards infusing artificial intelligence in network processes and systems, Green (2015) posited that we are experiencing the era of Cognitive IoT where no device is an island. The inescapable network of IoT enabled smart gadgets are likely to generate an exponential volume of data that could be transformed into knowledge by educators.

As indicated by Cisco (2013), IoT advancement can moderate information inequality by supporting pervasive learning situations will not only increase access to education, but it will also extend the impact and quality of learning opportunities for all. Besides, Cisco additionally called attention to that the development in IoT innovation is not only poised to offer new educational opportunities for all but it will also have a positive impact on the quality of education for even students with disabilities. For example, Microsoft is developing cognitive IoT platforms (Seeing AI project) that will synchronize smart wearable glasses to an artificial intelligence headset installed with voice command app to enable visually impaired people to discover their surroundings through a video to voice synchronized service. Therefore, given that the smart glasses have a high definition camera that transfers visual information into a voice command, this gives visually challenged learners the opportunity to navigate their surrounding through technology. Additionally, this system will enable visually impaired people to recognize text through a technologically assisted reading. Relatedly, Domingo (2012) noted that using smart devices creates an enabling learning environment where special need learners can build their self-confidence and regain their independence. For instance, rather than frequently requesting for assistance while using small text written cards, visually impaired students can use smart cards that automatically enlarges font size through the help of a sensor.

Dissimilar to the convention instructive framework where physical nearness is expected of both the instructor and student, smart IoT enabled devices can bring students to virtual classrooms either synchronously or non-concurrently (Keane and Russell, 2014). Their results showed that emerging cloud technology provides students with disability the opportunity to improve their academic achievement, build their confidence and autonomy. Further, they reiterated that such technologies provide instructors with a better understanding of the capabilities of students with disabilities. Similarly, smart technologies offer the opportunity not only to the homeschooled students but also to physically impaired homebound students. Furthermore, ubiquitous learning provides such learners the opportunity to explore new capabilities such as participating in classroom peer-to-peer interactions using technology-enabled tools such video chatting and video conferencing Apps – a situation that Groff (2013) described as “cognitive journey around the world” (p. 12).

A study by Bagheri and Haghigni Movahed (2016) compared opportunities between new, and the traditional business model of education. Results of the study showed that integrating IoT to current educational approach added unique proposition in the form of reduced cost of administration through automated processes; enhanced learning through personalized instructions and increased student collaboration and engagement.

Considering that the culture of learning in the 21st century is influenced by the access to digital content (Blain, 2016) pointed out that the benefits of digital textbooks transcend cost saving. Additionally, with smart books instructors have the opportunity to monitor students' learning over time - while providing timely feedback. This sort of data-centric assessment of learning will enable instructors to create a curriculum that will focus on imparting skills that match the needs to of today's workforce. Relatedly, Melton (2016) noted that e-textbooks have drastically cut student spending because of the ability to purchase specific chapters of digital textbooks. A study conducted by RCCC's e-Text initiative (2014) reported that not only does taking textbooks online save students approximately 50% of the cost of course material but it also increases the level of classroom engagement and retention because students access their course materials from anywhere on any device. Therefore, the ubiquitous learning environment can support the creation of technology-enriched curriculum that provides unique learning opportunities for students from a low socio-economic background.

Given that we live in an era, where pervasive connectedness has enabled us to access information anywhere and everywhere, this primary aspect of the IoT platform holds a high potential for supporting learning through flipped classrooms (Förster, Dede, Könsgen, Udugama & Zaman, 2017). Flipped classes as one of the novel approach used by instructors to enhance learning by helping students improve their self-efficacy (Lai & Hwang, 2016) - by making the best use of class time, for instance, making clarifications to specific concepts and addressing students' questions. Ubiquitous connectivity will enable students to remain in close access to library resources even during flipped classroom activities.

In today's highly diverse student population, the traditional approach of instruction has become anachronistic. As higher education enrolls realizes more numbers of students, this has also resulted in the increased diversity not only age, ethnicity, and gender identity among others but the difference is even manifesting in the form of prior knowledge and skill sets amongst today's students. Therefore, as learning increasingly becomes possible to measure owing to the rich trove of data generated by students' online learning activities. Instructors can harness on this opportunity to design flexible learning activities that will match the identified skill sets that students need to improve. Integrating emergent technologies such as IoT in the classroom makes it possible for today's non-traditional students to balance education, work, and family through a competency-based approach to education (Gros & Maina, 2015). Thus, the specific competencies with relevance to student's career path can be the basis of their assessment. Relatedly, Mitchell (as cited in Kelly, 2016, p. 1) argued that "if you can measure student learning and mastery of competencies and if that can happen independent of time and space, then let's certify learning in small chunks." Given that students develop different sets of skills from a range of learning environments, digital badging can support the documentation of specific learning achievements that students have attained towards a broader result. This form of micro-credentialing allows students show their educational attainments during job acquisition.

To bridge global educational inequality, IoT-enabled educational tools have supported the development of ubiquitous learning platforms in the form of open learning environments (Veeramanickam & Mohanapriya, 2016). Smart devices such as phones, tablets, laptops and wearables installed with social media apps have set up virtual learning spaces for massive open online courses (MOOCs) that has given students the opportunity to access quality learning material, which they would not have been able to locate locally due to financial constraints. Furthermore, given the plethora of student data mined from MOOCs, instructors can tailor content that addresses specific student's needs and learning styles. Open learning environment such as MOOCs are also developing into academic networks where people are not only having access to high-quality content but also sharing information - transforming MOOCs into mutual knowledge hubs. Therefore, this kind of virtual information societies is creating immense learning opportunities for students who only really on primary education for their learning.

According to Gilman, Milara, Cortés & Riekki (2015), the components of ubiquitous learning systems are primarily created to support learners as compared to instructors, developers, and researchers in a mobile learning realm. However, they found out that this form of unobtrusive learning does not only empower students to control their pace of education, but it also enables them to set up their goals within the confines of a course - with the ability to review unfamiliar content (Hwang, Lai, & Wang, 2015). Relatedly, Ciampa (2014) reiterated that self-paced learning provides students the flexibility to choose what to learn and this has been found to increase students' motivation and level of engagement. Apart from the convenience that ubiquitous learning extends to students, faculty also realizes the benefits of universal learning in the forms of increased efficiency as it relieves them from the traditionally manual grading of student's assignment. Therefore, providing them with more time to focus on individual students' learning needs.

Furthermore, the digital footprints resulting from these seamless learning platforms leave trails from individual students' learning experiences. Such data can be gathered and analyzed to reveal unique learning patterns that can be utilized to predict and improve student's academic performance (Tikhomirov, Dneprovskaya & Yankovskaya, 2015). Similarly, Clark & Mayer (2016) reported that the trove of information extracted from this digitized form of learning could also enhance instructor's level of effectiveness. Instructors will have the ability to customize students' assessment and tailor learning activities that address individual student needs - to ensure all students reach their full potential.

Despite the high cost of higher education, the surge in smart technologies has the potential to fill the knowledge chasm between students from the different socio-economic background. As indicated by Bagheri and Haghighi Movahed (2016), data from IoT-driven campus facilities can be harnessed to design efficient IoT-management system. This will drive down the cost of education resulting from energy wastage, costs associated with keeping campuses secure, and classroom access control. Relatedly, Ally and Samaka (2013) postulated that as more learners adapt to using smart devices to access digital information, this is likely to lower the cost of textbooks as more textbooks are being converted to e-textbooks. Wu, Lee, Chang, and Liang (2013) affirmed that virtual classrooms would save students the cost of transportation – considering that ubiquitous learning enables portability and flexibility in knowledge acquisition.

According to O'Brien (2016), the lack of engagement and procrastination are main factors affecting student motivation in learning. Different studies have shown that integrating technology as learning tools increases student's level of engagement in knowledge acquisition (Kong & Song, 2015; Diemer, Fernandez & Streepey, 2013). Therefore, designing seamless learning experience has the potential of fostering learners in an active form of learning that can enhance student retention rates and learning outcomes.

According to Takpor and Atayero, (2015), health-related issues have been found to affect students' motivation and the ability to learn. Educational institutions have to prioritize students' access to quality healthcare to guarantee students' academic success. Given that healthcare sectors have championed IoT application in various ways ranging from monitoring patients to responding to patients’ health status in real time, this is increasing access to quality healthcare at reduced costs. IoT-driven healthcare strategies such as eHealth solutions and wearable devices can be leveraged to improve students’ healthcare. Takpor and Atayero demonstrated that RFID technology could be used to implement Electronic Medical Records (EMR) – digital paper-based medical file as an eHealth solution to ubiquitously monitor students susceptible to high-risk blood pressure using wearable devices.

From the vantage point of emergent technologies, we can approach learning from a new front – emergent pedagogy that explores existing pedagogies in the context of our connected knowledge society (Gros & Maina, 2015). IoT enabled learning environment enables virtual spaces where objects can be represented, and access to their stimulus received virtually from anywhere (Barbosa, Barbosa, Oliveira, & Rabello (2014). These seamless learning platforms use context-aware smart devices to build models that make learning widely accessible dynamically. "Ubiquitous systems connect virtual and real objects and people and events, to support a continuous, contextual and meaningful learning process" (Vict, 2015, learning, para. 2).

Until recently, if a student needed help with homework, they had limited options to consult – teachers were the primary source of information. However, in the current era of IoT supported learning environment, space and time cannot be considered a limiting factor to learning in an IoE enabled learning environment because students have ubiquitous access to educational resources. This has also fostered collaborative learning between students and their instructors through the sharing of learning materials (Gros & Maina, 2015).

As we embrace this ubiquitous norm of connectivity, the academic realm is starting to recognize and explore the contours of the broader information surrounding us. This is providing access to pervasive learning environments, which have the potential to enable flexible classroom activities. This enhances digital content delivery and increased learner engagement, and enables educational institutions to lower costs of operation (Crow & Dabars, 2015). Further, instructors and students can experience new ways of learning such as a personalized and adaptive form of learning (Vujovic & Maksimovic, 2015; Osisanwo, Izang, Kuyoro & Chukwudi, 2016). Furthermore, IoT is steadily transforming the use of educational technologies from static applications to more interactive tools of learning (García-Sánchez & Luján-García, 2016). Relatedly, Marquez et, al., (2016) expressed that integrating smart education objects with VAC transforms such objects "from being passive elements in educational environments to becoming more active objects and more involved in supporting the teaching-learning process" (p. 202).

Given the potential opportunities of IoT technology in a learning environment, this has the potential to influence new ways of teaching and learning using real-time actionable insight into students' performance (Bagheri & Haghighi Movahed, 2016). Relatedly, Selinger (as cited in Mongkhonvanit, 2015), noted that "the increase in the number of smart devices has given learners access to a plethora of information. Using multiple devices, students have access to campus networks. And, using their IoT supported devices, this allows them to collect data and collaborate with peers and experts around the world to analyze, interpret and manipulate the information. This will enable them to contribute in a meaningful way to the development of social and scientific understanding. As a result, learning will become more contextualized, relevant and meaningful" (p.2).

Vujovic & Maksimovic (2015) found out that IoT promotes student-centered teaching, student-to-student, and faculty-to-student collaboration. Additionally, they also noted that the scalability of IoT supported education makes learning convenient, flexible and cost-effective. The proliferation of smart classroom technologies such as digital highlighters and intelligent boards is simplifying learning experience because using apps from smart devices; students can seamlessly access documents saved on cloud storage. Relatedly, with more students, particularly in higher education transitioning from the use of the conventional paper books towards digital options of taking notes and reading – smartphones, tablets, and laptops. This puts students at a closer reach to information – giving them the opportunity to learn at their pace and enabling them to learn from anywhere at any time. Relatedly, Asseo et al., (2016) postulated that educational IoT-based devices would support adaptive learning through tailored individual students' learning needs.

Adaptive learning device plays a crucial role in gathering and sharing data that could be utilized shape the students' learning experience.

In spite, some educational institutions already using some aspects of IoE in their operation, student assessment remains a significant hindrance to the broader adoption of instructional technology. The mode of student assessment still relies on the manual paper-based approach of assessment. However, the pressure is mounting on higher education to find new ways of assessing 21st century skills such as collaboration, communication, creativity, and problem-solving. The increased use of educational technologies with capabilities of ubiquitous connectivity is likely to support the use of E-assessment for the skills required in the current knowledge economy (Lloyd, 2012). Instructors can also leverage data generated from classroom technologies to support effective and efficient evaluation of learning and data-driven instruction to strengthen students' learning experience (Collier, Burkholder, & Branum, 2013).

As a result of the increased use of digital technologies, today's students are classified as "digital-age learners" because of being technologically savvy and their free agent model of learning (Murray, 2016). These students' ubiquitous form of access to information and approach of knowledge acquisition has transcended the conventional learning environment and learning practices. As reported by Siemens (2005) informal learning is an important aspect of a learning experience "… technological innovation is modifying (rewiring) our brains. The tools we use to define and shape our thinking" (significant trends, para. 3). Therefore, higher education can harness data from the students' ubiquitous access to data and information to realize the following opportunities.

Regarding the potential of IoT in enhancing teaching and learning, Johnson (as cited in Selinger et al., 2013) pointed out that ubiquitous access to information will enable the creation of a connected community of practice where students can supplement their coursework through sharing ideas with other students and a whole world of experts. Through live streaming, experts in specific areas can be invited to teach from anywhere in the world - giving students a unique value-added learning experience. Hung, Lin, Hwang & Chen (2016) posited that this seamless platform of communication could enable collaborative research between students and experts from different disciplines. On a related note, other authors (Hwang, Lai, & Wang, 2015; Lai & Hwang, 2014) have also stated that ubiquitous learning environment support innovative and effective instructional approaches such as the flipped classroom approach to learning – where in-class instruction time is swapped by at-home practice time. This provides students with the opportunity to reflect on concepts concerning a situation and environment, which promotes creativity in learners. Thus, preparing students to thrive in the current knowledge economy.

With machine to machine communication as one of the standards of the IoT platforms, the use of sensor-based technology in monitoring the environment provides researchers with the opportunity not only to conduct collaborative studies but also enables them to collect authentic data from sensors integrated into monitoring devices. In a research project "Stream to Cloud," Ogallo (2016) demonstrated that remote sensor technology built on a delay and tolerant network (DTN) architecture allows the monitoring of environmental parameters remotely - by streaming near real-time data from remote locations to a cloud database. DTN systems enable data portability between transponders and access points.

Ogallo additionally reported that the emergence of ubiquitous networks for environmental monitoring untethers scientists from the field – thus reducing both the cost of fieldwork and the researcher's carbon footprints.

According to Jackson (2013), tomorrow's employers are in search of employees who can work efficiently in teams. Since integrating technology in classroom motivates students to work on collaborative projects with the class and even with teams across the globe, therefore, educational institutions need to embrace the Internet beyond the primary application for searching information. For instance, using ePals pen pal website, teachers can facilitate this as a safe space for kids to not only communicate but also collaborate on projects that will help them learn more about different cultures. This will help students to build collaborative skill even from traditional classrooms.

As the educational institutions experience the growth in non-traditional students who are faced with time and physical location as barriers to pursuing education, there is growing need to expand access and convenience of learning to adult students. NMC Horizon (2017) reported that adult learners often expect the convenience to learn and work anywhere while maintaining a constant access to learning materials whenever time allows. The report emphasized that the advent of always-connected devices provides more flexibility in how, when, and where people learn.

IoT enabled education offers the opportunity to link learning with real-world scenarios. Hether, Martin, and Cole (2017) reported that integrating IoT allowed technologies such as augmented reality (AR) and virtual reality (VR) into learning experience offers learners a nexus of classroom skills to a real-world context. They particularly noted the opportunity that these technologies offer to students in the medical related course to safely practice dealing with the uncommon but potentially life-threatening situation. In that, the medical student can practice within a virtual environment without the stymie of ethical concerns. Relatedly, Ahn et al. (2016), noted that experiences in virtual environments might influence individuals to consume different perspectives, even after leaving the simulated learning environment.

Enhancing Campus Safety

In response to the current security threats, the preponderance of campus safety and security are the concerns topping the priority list of university administrators (Davey, Wootton, & Marselle, 2016) and other stakeholders (Qin, Li, Zhang, Gao & He, 2014). According to Zebra Technologies (2015), institutions can leverage on the ability of IoT system to track objects to provide safe and secure campuses. For instance, "School buses can be equipped with location-tracking devices, so students, parents, and administrators always know where their bus is. ID cards can ensure only those who are authorized are accessing specific areas on campus. And security guards can use mobile devices to instantly notify teachers, administrators and even local police of a security breach" (Enhanced school safety, para.5).

Given that external intrusion is remain one of the emergency situations that school administrators have to expect, integrating IoT technology as a monitoring tool can help in thwarting intruders (Qin et al., 2014). Zebra Technologies (2015) also noted that internal bullying and student caused violence are situations that call for different approaches to addressing. They reported that integrating IoT systems with alert buttons, smart security cameras and GPS-enabled smart cameras in school buses could be used to monitor the buses in case of an emergency. Furthermore, GPS-enabled buses also enable commuters to track the location of buses to minimize waiting times at the bus stop. Smart campus building designs will enhance school safety by remotely monitoring and controlling smart locks – with locks that are capable of initiating a lock down in case of an intrusion. Additionally, intelligent devices can also stream surveillance videos to the law enforcement authority for real-time monitoring of emergencies.

Smart Resource Management

Given the large quantity and variety of assets that educational institutions have to track. This may include textbooks, laboratory equipment to computer-related devices. There is a need for improved inventory accuracy and process efficiency in managing these assets. Therefore, integrating IoT technologies embedded with RFID tags can facilitate the seamless monitoring of these resources. Not only will this IoT solution enable administrators to trace the location of these resources on a real-time basis but also using predictive analytics from smart asset trackers, this could provide timely information for decision making. In that IoT-enabled predictive maintenance (Zebra Technologies, 2015).

Energy management is one of the public IoT applications undertaken by governments and public institutions to automate the generation and distribution of energy to customers efficiently. Using Smart Grids that are IoT energy management application, integrating intelligent systems provides efficient mechanisms of balancing power generation and energy consumption. This also supports the monitoring of real-time energy consumption while providing customers with the real-time cost of energy use (Kim, &

Kim, 2016). Therefore, as educational institutions strive to achieve efficient energy management, adopting IoT-driven energy management system can be a reliable approach to reducing the cost of energy. IoT systems have the potential to bring significant value to educational institutions in the form of automated systems such as HVAC (Heating Ventilation and Air Conditioning), academic technologies, and safety system (Chuck, 2016). Integrating smart devices in campus building designs to meet green building standards will reduce the cost of energy management through Eco-system monitoring (Bagheri & Haghighi Movahed, 2016).

According to Arun (2015), smart LED bulbs connected to a centralized management system can save 70-80% of energy cost compared to regular light systems in buildings. Therefore, adopting IoT technologies in a building design transforms it to LEED certified building that enables efficient energy use by using data generated from sensors embedded in green structures to optimize the entire building performance - IoT systems will automatically monitor and control HVAC systems, lighting, water wastage and other devices that consume energy.

As IoT-enabled devices continue to minimize spatial and time difference required to access information sources, Hoy (2015) posited that libraries could adopt IoT technologies to position itself as unique learning centers where library patrons can take advantage of librarians' IoT skills to learn the use of smart devices. Relatedly, a survey report by OCLC (2015) pointed out that some librarians have familiarity with smart devices. They noted various ways in which libraries can integrate smart devices. For instance, for inventory control, mobile payments, ticketing, and event registration, access, and authentication, HVAC room configuration, mobile reference, resource availability for both content and physical plant (rooms, AV equipment) and smart books enhanced by other IoT-enabled systems.

Despite the limitations of barcode technology for access control and asset tracking, this technology is still used by some educational institutions (Sinha & Chanda, 2014). Additionally, barcode systems are vulnerable to security flouts, labor-intensive (because of individual scanning barcode), expensive due to wear and tear, and its inability to store any information rather than being a pointer to a database. However, RFID provides more effective and efficient system for access to campus facilities and tracking items within educational institutions because of its capability to store information (Sinha & Chanda, 2014, Zhang et al., 2016). Integrating RFIDs to IoT-driven facilities management will not only increase the range of distance for reading RFID tagged items, but it will also heighten the level of securing items and provide more storage capacity to append the users' reference information (Turcu, Turcu, Popa & Gaitan, 2015).

Relatedly, Turcu et al., (2015) reported that with the ever-stringent budgets, education administrators are always on the lookout for the most optimum way of enhancing operations efficiency within educational institutions. Given the number of movable items that institutions loan to their students and staff such as computer-related equipment, cameras, books, and automobiles. Venna, Manjulatha and Soumya (2016) noted that the successful management of these resources could be enhanced using tracking ability of IoT technology - to enable real-time asset visibility. Using RFID tracking systems embedded in IoT network, such institutional resources can have RFID tags attachment for easy tracking (Zhang et al., 2016) – this will help in reducing operational costs. Issuing staff and students with RFID tags could easy access to campus facilities such as sports centers, libraries, cafeteria, etc. As the range of possible uses for tracking is expanding, through RFID-equipped backpacks and wristbands, students can be accounted for in real time which will minimize time-consuming activities like recording attendance; the same backpacks can also work as student's access to school buses. While on routine fieldwork, maintenance workers who come across faulty vending machines can remotely notify the respective school office about a vending machine that requires maintenance using a handheld RFID integrated device (Ambica, Manjulatha & Soumya, 2016).

Big Data Application in Education

The surge in connected smart devices such as phones, tablets, and wearable into classrooms is supporting the growth of ubiquitous learning environment (Hwang, 2014). The context-aware virtual learning environment is trending in the form of smart devices assimilated into the structures of our everyday routines. Therefore, gradually IoT technology is becoming a mindset as opposed to being envisioned as a futuristic technology. This is demonstrated by the surge in smart devices embedded in everyday things such as cars, homes, store shelves, wearable health monitors and planes (Cisco, 2013). However, despite the increasing adoption of these smart devices, the real value in this form of ubiquitous connectedness is in the incredibly rich trove of information from the data generated by IoT devices.

According to Gartner report (2011), "information has become the oil of the 21st century and analytics is the combustion engine" (para. 13). Our increased use of digital technology has resulted in an unprecedentedly exponential growth in data. Shacklock (2016) pointed out that data has been identified as one of the key trends driving change in the 21st century and this phenomenon has been described as Big Data – to mean a large volume of both structured and unstructured data.

Considering that the 21st-century learning culture starts with digital content, the educational sector is awash in data - generated from various education-related research. Therefore, the present state of education is more likely to be better understood through analyzing and drawing meaning from the accumulated student data. Accordingly, the challenges faced in education can be addressed by mining educational data to enhance efficiency and increase competitiveness (Eynon, 2013).

To understand the value of data in education, there is a need for increased investment in analytics (Dede, 2016). Further, Dede noted that this should not be a panacea to all the problems faced in the education sector. However, educational Big data can be leveraged to enhance decision making regarding issues of teaching, learning, and schooling. For instance, examining a student's footprint can be used to track a student's patterns of learning – so that instructors can design individualized instructions that address a student's learning needs. Similarly, Young (2017) reported that educational institutions could foster student success by leveraging on student data to create "digital safety nets" that rely on predictive analytics to monitor signs of both academic and financial issues that students may be facing which could result to their dropout from college. Young emphasized that this can be an automated system that sends out an alert requiring an automated and human intervention process that requests a struggling student to meet with their academic advisor for support – meaning this can be used to support students who are a risk of dropping out, improve completion rates and graduation rates.

Factors Affecting the Adoption of IoT

Despite the potential opportunities that IoT provides in enhancing D3M, some factors are impeding the adoption of IoT technology into higher education. Typically, these factors have been themed in the following categories: technical challenges, privacy issues, data security, energy consumption and network congestion.

Until now, there is only a paucity of studies that have attempted to identify the factors affecting the adoption of IoT (Gao & Bai, 2014). Gao and Bai's study used TAM to investigate factors affecting the adoption of IoT in China. They found out that the perceived usefulness, perceived ease of use, social influence, perceived enjoyment and perceived behavioral control significantly determine the behavioral intention to accept IoT in China.

While information sharing is not something new, the indelible nature of our digital footprints results has created concerns especially due to personal data collected without the owner's permission (Whitmore, & Agarwal, 2015). There are growing concerns regarding individual privacy especially as we grapple with how to balance convenience and personal privacy in today's digital world. Therefore, with the ongoing discourse on digital privacy not yet ensconced, there is a need for more research on how to reduce the vulnerability of IoT devices. While numerous studies have emphasized the possibilities that come with IoT technology, the same infrastructure that enables information sharing may also jeopardize their privacy and security (Garrity (2015). Also, Garrity reported that large-scale and targeted surveillance might turn the ‘Information Society’ into the ‘Surveillance Society,' as identity management systems improve without parallel emphasis on anonymity and ownership of personal data (p. 42).

According to Hsu & Lin (2016), the adoption of IoT application is not only affected by the cost of owning IoT devices, but the perceived privacy risk associated with using these smart technology is considered a threat. Hsu and Lin defined perceived privacy risk “as an individual’s belief regarding potential losses of confidential, personally identifying information through the use of IoT services” (p. 4). Ziegeldorf, Morchon, and Wehrle (2014) also noted that despite the potential benefits realized from IoT applications, if incorrectly implemented the very advantages could become privacy threats arising from challenges such as ubiquitous privacy-aware management of individual data or methods to control and avoid ubiquitous tracking and profiling.

As more institutions of higher education transition to the use of digital technology in their operations, they are increasingly becoming favorite targets for data mining (Poremba, 2012). These data breaches affect both at individual and professional levels. Furthermore, Poremba noted that colleges and universities are prone to cyber-security breaches for various reasons. For instance, given the varying degrees of cyber security awareness amongst the students, university networks are prey to hackers; a large number of computer and smart devices and high-speed Internet makes institutions of higher education prime targets for cyber-criminals. To reverberate on data security, Kambourakis (2013) stated that while educational technologies are shifting towards mobile learning platforms, this support numerous learning opportunities but it also comes along with increased threat to data security especially as institutions embrace cloud computing and the BYOD approach which emphasizes non-restrictive access to institutions resources from personal devices.

In the educational institutions, schools are moving towards high-tech classrooms – incorporating specialized educational apps and other digital programs into their curricula. For a student to use such educational apps, the student will be required to create a profile - in this process, the student's personal information is collected, and this information may include names, dates of birth, hobbies, first pets owned, grandparent's names and so on. The reason being that such information is important for creating user profiles, monitoring the learner's progress while using the educational apps, measuring learning outcomes and designing personalized learning experience. As the information having collected is stored in some cloud database, this creates fear about the student's privacy and security of their personal information. Also, some websites used in class could contain cookies that continue to monitor and convey the student's online history. According to the PBS News Hour (March 2016), such detailed information collected from students is likely to be used in decision-making regarding those students. For instance, suppose an insurance company bills their clients for medical insurance based on the data that was collected 20 years ago related to a student’s dietary in the school’s cafeteria. This would violate the privacy of such a client, which calls for scrutiny of business ethics.

A report from the Ponemon Institute, IBM, and Arxan as reported by Forrest (2017), pointed out that up to 80% of IoT apps and 71% of mobile apps are not tested vulnerability because of the rapid release of these apps in response to user demands. This raises security concerns related to the IoT platform.

According to the US National Intelligence Council report (Intelligence, 2008), despite IoT being heralded as the ubiquitous communication platform that will contribute invaluably to economic development and military capabilities, they listed IoT-driven technologies as one of the six "Disruptive Civil Technologies." As more everyday things are integrated with sensors and turned into Internet nodes, these devices are likely to increase the potential for vulnerabilities around data security.

While proponents of technology-centered education mainly envision the educational affordance regarding the efficiency that technology brings to classrooms, however, Warner (2015) argued that other factors such as the community of learning, quality, and equality are also crucial as opposed to envisioning value in education from only the perspective of efficiency. He further, pointed out that the techno-futurist vision of technology-optimized education is mainly focused on student engagement. However, he noted that this deprives students the joy of the freedom of classroom experience and creativity because technology centered on control.

According to Varadharajan and Bansal (2016), IoT networks are a confluence of disparate smart computing devices. Therefore, given the unstandardized designs, developments, and growth of these devices, this renders this technology to be an easy platform for cyber insecurity. The interoperability in the IoT ecosystem presents challenges for developing software security. Thus, there limited unified mechanism to avert every potential cyber threat originating from these devices due to their different security and privacy needs (Islam, Kwak, Kabir, Hossain & Kwak, 2015). Therefore, the lack of standards may slow the adoption of this technology.

Relatedly, Knight (January 2017) pointed out that as IoT becomes a standard in many industries, there are prone to be more questions surrounding data ownership. Especially as more organizations share IoT data with third parties – with the motivation being to monetize data or even as compliance to regulatory policies. This has become a pertinent concern considering that there no clear guideline determining ownership of IoT data. Therefore, in higher education, the issue of data ownership becomes pertinent given that the data generated by smart devices on campus is likely to be accessible even to third-party vendors providing services to educational institutions.

While the discourse on Big Data is mainly permeating around data-driven decision to increase efficiency and reduced costs in education, there are issues related to data mining that needs to be considered. Eynon (2013) pointed out that questions regarding ethical concerns are a stymie to the full embracement of the implementation of Big Data in the educational realm. While ethical concerns have been considered in other sectors, the education sector is yet to conduct a thorough analysis regarding the implementation of Big Data. Additionally, there is concern regarding the kind of research that can be performed using Big Data in education. Given that research can only be undertaken to answer research questions relating to data that has to be collected or that has already been collected. Therefore, Big Data may limit the kind of research questions based on only the available data or data that is already available.

Despite the opportunities realized from ubiquitous learning, the digital divide is still a concern – a study conducted by Hansen and Reich (2015), found out that different levels of basic access to emerging technologies affect student's success depending on their level of economic status. They also noted that in comparison to students from affluent backgrounds, 41% of eighth-grade math students from low socio-economic backgrounds regularly used computers for drill and practice – this limited their access to rigorous STEM learning opportunities for students from disadvantaged backgrounds. Therefore, there is concern regarding equity in access to online information because not all students have equal access to technological resources. Relatedly, students from lower income background are most likely to have limited access to ubiquitous learning platforms. Therefore, supporting students' access to digital tools of learning is germane to their success. PBS (2016) reported that students in low-income communities in Southern California do not have access to Internet access and this was found to affect their quality of learning. To address this digital divide, the Coachella Valley Unified school district Superintendent initiated Wi-Fi access on school buses to enable students to have access to the Internet to support their learning beyond the confines of school Wi-Fi.

Despite the confidence in cyber-security measures instituted in campuses, user adherence to cyber policies is often the "weak link" in a situation of cyber-attacks within universities and colleges. Because of the unique balancing act of access and security, this often exacerbates cyber breaches in higher educational institutions because of the arduous implementation of technological solutions to data security (Hehmeyer, 2016).

The nascent era of the Internet of Things (IoT) becomes part of our daily life. Some studies have posited that information security and privacy concerns are critical barriers affecting the widespread adoption of IoT technologies (Henze et al., 2016; Arias, Wurm, Hoang, & Jin, 2015). Furthermore, Danny (2015) pointed out that the phobia for the IoT may seem implausible; however, we are already seeing the scary scenarios such as smart TVs that have the capability of collecting data about the owners viewing habits and the ability of the Smart TV to capture any sound from the TV viewers.

As more institutions embrace the benefits of IoT-enabled devices, hackers are increasingly taking advantage of the vulnerability of unsecured IoT devices to building botnets that used to attack campus networks (Palmer, 2017). Sánchez et al., (2015) and Federal Trade Commission (2015) also reiterated that the deployment of more unstandardized smart devices is likely to increase the level of connectivity and data collection; it would increasingly become difficult to control the numerous devices and the amount of user data harvested by different companies.

In a survey of 2000 respondents in the US with a focus on their behavior and preference on the adoption of IoT technologies. Accenture (2014), found out that the awareness of technology, its usefulness, cost of technology, security, and data privacy are vital factors affecting customer behavior in adopting connected devices and smart technology

Using a conceptual model based on perceived IoT privacy, expected usefulness, trust in IoT services and personal interest in IoT, Kowatsch and Maass (2012) found out that perceived privacy risks, particular interest, data security and transparency of information use negatively affected the intentions to adopt IoT services amongst IoT experts in Spain. Relatedly, other researchers (Al-Momani et al., 2016; Jacobsson, & Davidsson, 2015) also reported that the perceived usefulness, perceived ease of use, privacy, knowledge, and awareness of the technology affected the behavioral intention to adopt of IoT technologies.

Despite many research studies reporting that digitalized learning enables collection of student data relating to their behavior and learning activities to design technology-assisted differentiated instruction that meets individual students learning needs, learning styles and aspiration. However, there is an argument against the model used in individualized learning. Willey (2015), a critic of personalized learning pointed out "student-faculty relationship should be based on care, encouragement, and inspiration in the future, and learners need not be relegated to taking direction from a passionless algorithm." Willey (2015) argued that technology-assisted differentiated instruction denies learners the opportunity to use their metacognitive skills in determining what learning approach is the most appropriate for them – creating a dependency syndrome.

As digital technology becomes a more prevalent tool for learning in higher education, educational institutions are increasingly becoming prime targets for cybercriminal activities – including theft of student information and intellectual property, and compromise of individual privacy. According to a report by VMware (2016), 87% of universities in the United Kingdom have been victims of cyber-attacks. Therefore, as academic institutions strive to maintain the free flow of information between students, faculty, and administration, the academic ideal of unrestricted dissemination of information is likely to create vulnerability to campus networks because of the conflicts with the countermeasures designed to reduce cyber threats. Relatedly, as indicated by PCWorld (2016), potential cyber threats related to IoT devices remains a factor to determine its adoption. For instance, the 2016 outages of popular websites caused by the compromise of IoT enabled devices used to initiate massive distributed denial of service (DDoS) attacks against a dynamic domain name service (DNS) provider - this disrupted access to some popular websites such as Twitter, PayPal, GitHub and many others.

Given the unprecedented amount data generated by smart devices, the issue of user privacy and data security risks remains a loophole in the massive adoption of the ubiquitously connected devices (Brill, 2014; Hutchinson, 2014). Therefore, "without assurances, pervasive development of IoE will not take place across educational institutions" (Cisco, 2013, Successful Implementation of IoE in Education para. 2). The integration of IoE devices into educational institutions will call for a review of the IT policy regarding the security of both personal and institutional data and disseminate awareness regarding privacy issues. Furthermore, Cisco reported that in spite of data collection being the primary focus of setting up ubiquitous networks, data integrity remains one of the main challenges of the IoE platform. Therefore, if the education sector is to realize the value in integrating smart devices, it is important to maintain data integrity, authenticity, timeliness and data completeness.

According to Herold (2017) “artificial agents” have a much greater capacity than humans to process big data that is available in the current society. This capacity makes these agents pertinent in the 21st century. To affirm this, Osoba and Welser (2017) reported the influence of artificial intelligence is manifested through algorithms that influence everyday activities such the news articles we read and the associated advertising, risk assessment for convicts, access to credit and capital investment, etc. However, they caution that that implicit biases and individual frame of reference of individuals who develop the algorithms become a concern. Andreas Ekström (2015, January) reiterated in his TED talk "behind every algorithm is always a person, a person with a set of personal beliefs that no code can ever completely eradicate" (8:29). Furthermore, Reidsma (2016, March) emphasized "behind every algorithm is also a company, with obligations to its business model and shareholders" (para. 4). Furthermore, Osoba and Welser posited that such autonomous bias might seem to serve a less diverse population due to these sub-conscious biases. Therefore, if not used correctly, integrating IoT in education is could result in automation bias due to the programmer's frame of reference. Additionally, using such automated tools in education may only reinforce already existing biases especially in when demographic data such as race, ethnicity and socioeconomic status as used as predictors for student success (Ekowo & Palmer, 2017). According to Wexler (2017), "if students are considered at risk, given attributes they can't change, IoT enabled systems are likely to fortify existing issues, as opposed to unraveling them" (para. 12).

With digital technology developing faster than the available policies and regulation, this is causing legal challenges. A report by Waddel (2017) highlighted why the IoT needs a code of ethics – they reported that there are no legal frameworks to hold anybody legally responsible. They picked out the example of the malware attack (Mirai) that was used to convert unsecured IoT devices, including IP video cameras and digital video recorders into botnets that caused internet outages and network disruption to popular websites in the US. Relatedly, Barman and Cerf (2017) questioned about the social and ethical behavior in the IoT ecosystem. They argued that while there is no need to limit technological innovation, there is need of creating effective models for governing IoT to guide social behavior and ethical use of IoT technologies that promote efficient cyber security and safety.

Chapter Three - Methodology

This chapter describes the methodology that was used in the study to explore how IoT technology can enhance D3M in higher education. It provides details of the research strategy and techniques applied in conducting the study. The following sections form the basis of this chapter – research design, site selection, population and sample selection, the role of the researcher, credibility and dependability strategies, data collection approaches and data analysis of the study. In the research design section, the researcher describes and provides an elaboration on the rationale for using qualitative research approach in the study, how the credibility and dependability of the study were established. The site selection and participants' section describes the site of study and the approach and criterion used to select the participants of the study. The data collection section describes the research instruments used in the study and how credibility and consistency were ensured to maintain the rigor of the study. Finally, the data analysis section describes the data analysis technique used in the study.

Research Design

A qualitative research method was used to conduct this study. This research approach was considered the most appropriate to get insight into how IoT technology can enhance D3M in the teaching and learning process within the realm of higher education. As indicated by Yin (2014), a qualitative approach is the most appropriate technique for gaining a thorough and comprehensive understanding of a phenomenon of study. In the context of IoT technologies, Al-Momani et al., (2016) affirmed that "…IoT concept is new and researchers are attempting to conduct qualitative studies to identify the factors that affect the intention to use the new technology” (p. 363).

Relatedly, Morse (as cited in Creswell, 2014) emphasized that qualitative research approach is suitable when conducting “a new area of research; where the subject has never been addressed with a certain sample or group of people; and existing theories do not apply to the particular sample or group under study" (p. 50). To affirm this, Marshall and Rossman (2011) reiterated that a qualitative research design is relevant in explorative studies. Furthermore, Morse posited that a qualitative research approach is appropriate under the following situations: The concept in the study must be relatively new due to lack of previous studies. There is a notion that the possible theory could be inaccurate, inappropriate, incorrect or biased. There is need to explore and describe the phenomenon and to develop a theory. When quantitative research may not be suitable based on the nature of the phenomenon (as cited in Creswell, 2014, p. 152). Other authors also reported that qualitative research approach is appropriate when the study is conducted in a natural setting. When the researcher is a key instrument in the study, and the researcher must provide a holistic account (Creswell, 2014; Hatch, 2002; Marshall & Rossman, 2011).

Given that this study explored how IoT technology can enhance D3M in higher education, this is an emergent technology with a dearth of empirical studies especially concerning its application in the teaching and learning process within the educational domain. Therefore, a case study research approach was deemed suitable for conducting this study. Yin (2014) defined a case study as “…an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly defined" (p. 16).

Stake (as cited in Denzin & Lincoln, 2008) distinguished three types of case study - intrinsic, instrumental and collective case study. An intrinsic case study is when a researcher conducts a study to get a better understanding of a particular case (p. 121). The motivation of intrinsic case study is personal. While an instrumental case study is when the researcher primarily examines a case to provide a better understanding of an issue or "to redraw generalization" (p. 123). Finally, in a collective case study, the researcher investigates a phenomenon through multiple cases. Therefore, unlike an intrinsic case study that addresses a specific issue within an individual case, instrumental and collective case studies may allow for "analytical generalization" of the findings to several cases. Further, Yin posited that analytical generalization might "take the form of lessons learned, working hypothesis or other principle deemed applicable to other situations" (p. 68). Therefore, in this study, an instrumental case study approach was adopted to explore how IoT technology can enhance D3M in the teaching and learning process within higher education.

Additionally, Yin reported that while the various research strategies are not mutually exclusive, there are more merits in using a case study in situations when "…the "how" or "why" type of questions. It is suitable when studying a contemporary phenomenon within a real-life context over which the investigator has little or no control" (p. 14). Therefore, this research approach allowed the researcher to address the "how" questions in the interview guide as noted in the Appendix A. The research questions of this study included the following:

1. How have the faculty, students and administrators at Ohio University engaged with IoT technology to enhance D3M?

2. What are the perceived advantages and drawbacks of IoT technology among faculty, student and administrators in D3M?

3. What beliefs and perceptions are affecting the adoption of IoT technology in higher education?

To inform and organize this study, the UTAUT2 model (Venkatesh et al., 2012) and the literature reviewed was used to guide this study. According to Yin (2009), theoretical propositions are essential for informing case studies as a guide for data collection and interpretation.

As indicated by Ihantola and Kihn (2011), the strength of qualitative research lies on understanding and addressing the threats that weaken the trustworthiness of the study. Therefore, the researcher used the unified framework of construct validity (Messick, 1995) to establish the credibility and consistency of the study. The aspects of construct validity used in the study include content, substantive, and generalizability aspects of construct validity that served to bolster the rigor of the research.

Population and Sample Selection

Faculty, students, and administrators of Ohio University comprised the population of this study. The participants were selected through purposive sampling - "a strategic selection of information-rich cases that are subjected to in-depth study" (Patton, 2014, p. 169). This approach allowed for the selection of informative participants who provided insightful information not collectible from other sources. Relatedly, Johnson and

Christensen (2012) mentioned that purposive sampling "…is when the researcher specifies the characteristics of the population of interest and locates participants with those characteristics" (p. 179).

The site of the study was purposefully selected, and the criteria for choosing this site was based on convenience, accessibility and the likeliness that the preferred study site allowed the research questions in the study to be thoroughly explored (Yin, 2009). The case study site was at Ohio University. The oldest university in Ohio and one of the oldest public universities in the US. As of the spring semester 2016, Ohio University had a total enrollment of 38,651 students.

After the IRB approval (see Appendix B), the researcher conducted a pilot study. The researcher recruited two volunteer participants who met the criteria for participation in the research. The pilot study allowed the researcher to test the instruments of the study. Modifications were made to the interview protocol based on the findings from the pilot study. With this, the researcher built a stronger generalizability aspect of construct validity to ensure the credibility and the consistency of the interview protocol.

To reduce bias from being introduced in the primary study, the participants from the pilot study were not included in the main study. During the pilot study, the researcher requested the participants for any artifacts that they had used to enhance their understanding of IoT technology. Participants provided artifacts such as IoT related journal articles, blogs, magazines, and links to webinars, and podcasts.

After the pilot study, participants for the main study were recruited from Ohio University - a university in the Midwest of US. Participants were recruited through an email invitation requesting them to participate in the study voluntarily. The primary criteria for selecting candidates for the study was contingent that they had an understanding and knowledge of the central phenomenon of the study. Out of the 25 participants invited to participate, the response rate was 20 participants and only a sample of 17 participants were considered in the study. The final sample size for the study was determined based on theoretical saturation. This is a phase in data collection and analysis where the researcher samples and analyzes data until no new information can be extracted from any further interviews (Strauss & Corbin, 2014). Theoretical saturation is an important guiding principle for data collection in qualitative research (Mason, 2010). Therefore, the researcher collected and analyzed data until a point where no new information came from new interviews and artifact from the participants.

The categories of participants included six faculty members, four administrators, and seven students (three undergraduate and four graduate). The participants were selected in these different categories because the researcher anticipated that each group experienced and interacted with IoT technology for a different purpose, which could influence their decision to adopt IoT technology.

The criteria for selecting participants in the faculty group was determined by the participants' understanding of the central phenomenon of the study. The participants were also expected to have at least five years of teaching experience within an institution of higher education. This number of years could include a teaching assistantship position. This was because, within this period, the selected participant could have experiential knowledge of the phenomenon of interest in the study.

The criteria for selecting participants in the administrator's category was that they had to be instructional technologists and they had to have an understanding about the central phenomenon of the study. The participants were also expected to have experience working with any IoT related technologies in the course of their line of work.

Finally, the criteria for being selected in the student group was that the participant had to be full time enrolled students at Ohio University either as an undergraduate or graduate student. The student had to be above 20 years of age. The student was also expected to have an understanding of IoT related technologies.

An email inviting volunteers to participate in the study was used to recruit participants. The individuals' who volunteered to participate in the study were given a two-week notification to confirm their participation, time, date, and location where the interview was conducted. Following their confirmation, a follow-up email containing a consent form (in Appendix C) and thank you note for accepting to be part of the study was sent out. The consent form gave the participants description of the study, criteria for eligibility to participate in the study, the timeframe of the interview, confidentiality clause and contact information of both the researcher and researcher's advisor.

Role of the Researcher

As indicated by Creswell (2014), qualitative researchers are the key instrument in data collection; however, this "presents a range of strategic, ethical, and personal issues into the qualitative research process" (p. 237). Therefore, in order to maintain the trustworthiness of this study, the researcher presents the notion that some of the interpretation of findings in the research may include his perspectives drawn from personal experiences as an information technology professional that may influence the accuracy and authenticity of the findings.

During the period of the study, the researcher worked as a graduate assistant in the Curriculum and Technology Center at Ohio University. Therefore, the researcher believed that it was imperative to consider the concept of reflexivity as an essential component in maintaining the rigor of the study. Hatch (2002), describes reflexivity as the researcher's ability "to keep track of one's influence on a setting, to bracket one's biases, and to monitor one's emotional responses" (p. 10). Given the researcher's professional and personal experience related to the central phenomenon of the study, the researcher considered it imperative to admit the potential bias that may be reflected in the discussion of the findings based on personal prejudice.

Pilot Study

After approval of the IRB, the researcher conducted a pilot with two volunteers who met the criteria to participate in the study. The pilot study was undertaken to establish consistency in the interview protocol, determine the relevance of the interview questions and the interview time (Marshall & Rossman, 2011). As indicated by Yin (2014), "a pilot case study helps to refine the data collection plans concerning both the content of the data and the procedures to be followed" (p. 96). The pilot study provided the researcher with the opportunity to verify the consistency of the interview guide and modify the interview questions. Additionally, the pilot study helped the researcher to ensure the instruments aligned with the research questions, as well as to test the general communicative flow of the interview protocol.

To ensure the suitability of the data collection instrument, after the pilot study, the researcher shared the interview protocol with an IoT technology expert who provided feedback concerning the content validity (Ahmad & Agrawal, 2012). After the pilot study, the researcher also presented to the participants a reflective summary of the interview transcript to confirm if it reflected their perspective.

Credibility and Dependability Strategies

From a qualitative perspective of a research study, credibility, authenticity, transferability, dependability, and conformability establish the trustworthiness of a study (Lincoln & Guba as cited in Creswell, 2014, p. 254). To ensure the credibility and dependability of a study, Creswell (2014) suggested that qualitative researchers might use triangulation, member checking, and auditing to improve the trustworthiness of a study. The researcher applied these strategies in order to enhance the rigor of the study.

Given the potential bias inherent in the convenience sampling approach, flexibility in data collection and analysis, and the subjective interpretation of the findings, the unified framework of construct validity (Messick, 1995) was used to establish the credibility and dependability of this study. Construct validity is the integration of any evidence to support the significance of the test score (Messick, 1989). The aspects of construct validity applied in the study include content, substantive, and generalizability. These strategies served to bolster the rigor of the study.

As indicated by Messick (1995),

> the content aspect of construct validity includes evidence of content relevance, representativeness, and technical quality. The substantive aspect of construct

> validity refers to the theoretical rationales for observed consistencies in the test responses, along with empirical evidence that the theoretical processes are engaged by respondents in the assessment tasks. And, the generalizability aspect examines the extent to which score properties and interpretations generalize to and across population groups, settings, and tasks (p. 745).

Multiple strategies were used to ensure the content aspect of construct validity. This included data triangulation, member checking, direct quotations of the findings from participant response, and auditing. As indicated by Creswell (2014), using multiple methods of data collection, data points and data analysis, triangulation, ensured the credibility and dependability of the study. Triangulation is a process of drawing multiple sources of evidence to increase the credibility of research findings (Creswell, 2014). Data triangulation uses evidence from different sources of data to corroborate similar findings. In this study, the researcher used individual interviews, document analysis and member-checking to allow for cross-data validity checks. These multiple sources helped the researcher not only to corroborate the response from the different participants – faculty, administrators, and students but the researcher found diverse answers that emerged as themes. Thus, data triangulation ensured the credibility and accuracy of the study. The varied source of information strengthened the construct validity of this study.

The researcher quoted verbatim the response of the participants in the findings of the study. This represented an accurate voice of participants. Hence validating the content aspect of construct validity.

By collecting multiple sources of data and data types - individual interviews, document analysis and respondent validation, this enabled the corroboration of the findings and themes that emerged. Thereby establishing the credibility and dependability of the study and the evidence it presented (Merriam & Tisdell, 2015). According to Miles, Huberman, and Saldana (2014), "triangulation is a way to get to the finding in the first place-by seeing or hearing multiple instances of it from different sources by using different methods and by squaring the finding with others it needs to be squared with" (p. 300). Relatedly, (Yin, 2014) noted that using multiple sources of data in a study strengthens the content aspect of construct validity.

While in essence qualitative research may have issues of authenticity and trustworthiness arising from miscommunication between participants and the researcher (Carlson, 2010), the researcher verified the accuracy of the participant's interview response through member checking. This gave the research participants the opportunity to review the transcribed data for accuracy and resonance with their experiences (Birt, Scott, Cavers, Campbell, & Walter, 2016). As indicated by Doyle (2007), member checking is a framework that "encourages negotiation of meaning between the participant and the researcher" (p. 890). According to Merriam and Tisdell (2015), member checking is a technique in which the data, preliminary interpretations, and conclusions drawn from the study are shared with the participants to clarify what their intentions were, to confirm if the findings reflect their perspective, correct errors, and provide additional information if necessary.

A general interview guide approach was used in conducting this study. Similar questions were posed to different participants in the study as a technique of collecting information. This interview approach provided findings that were generalizable of IoT across the participants. Additionally, these questions sought to establish participants understanding and application of IoT in D3M. By asking similar questions, the researcher was able to establish evidence for the substantive aspect of IoT from the responses by various participant answering similar questions. The findings from the pilot study also positively contributed in establishing substantive aspect of construct validity. The finding bolstered the researcher confidence to proceed with the main study.

In order to minimize the researcher's bias, member checking was conducted to establish the content aspect of construct validity. Some participants were provided a copy of their interview transcript to review and ensure that the transcript reported an accurate reflection of their perspective. According to Maxwell (2013), member checking can be used to eliminate misinterpretations of the interviews and minimize the researcher's bias stemming from any misunderstanding of the participant response. The transcription reports where shared with some participants to validate and reconfirm across all participants the content relevance of the themes and patterns that emerged from the data. Through member checking, the preliminary research report was shared with IoT technology experts to get an evaluation of the report from experts' judgments to confirm its content relevance. Furthermore, the researcher shared preliminary copies of the research findings with some of the participants. This enabled participants not only to provide feedback on the findings but also the researcher's interpretation of the findings. This was important for ensuring consistency and dependability of the data collected (Merriam & Tisdell, 2015).

The literature reviewed and the UTAUT2 theoretical framework was used as a basis to specify the boundaries and structure of the data collected. Relatedly, to ensure the substantive aspect of construct validity, the process of data collection and analysis was guided by the literature reviewed and the UTAUT2 framework. They were also used to guide the emerging themes from the data analysis process. The lessons learned from the pilot study were reviewed for the appropriateness for conducting the main study.

The generalizability aspect of construct validity was established through various strategies. A pilot study was conducted before data collection for the primary study to enhance the degree of generalizability of the data collection instrument. Findings from the pilot study allowed the researcher to review and modify the interview protocol; determining the duration of the interview process; revise the criteria for selecting potential participants and improve the interview guide. This process increased the consistency of the data collection instrument. The findings from the pilot study provided an opportunity to revise the research design for the main study. It enhanced the researcher's confidence and competence in conducting the main study. Additionally, the lessons learned in the pilot study contributed to the systematic data collection.

In order to boost the rigor of this study, pattern matching was used to conduct a detailed analysis of the themes that emerged from the data coding phase of the study.

To ensure the credibility and dependability of this study, the participants who participated in the pilot study did not have prior knowledge of the interview questions. The participants in the pilot study were not included as study participants in the primary research to eliminate carryover biases.

The researcher read the transcripts more than once to minimize apparent mistakes from the transcription process – listened to the recorded interviews to ensure it aligns with the transcript.

To ensure the credibility and consistency of the study, the researcher conducted an external audit. The researcher sought the help of a volunteer experienced in qualitative research methods to conduct a thorough review of the different phases in the study. The researcher recommended to the auditor to probe answers to the following questions listed below as suggested by Schwandt and Halpern (as cited in Creswell, 2012; p. 260): "Are the findings grounded in the data? Are the themes appropriate? Can inquiry decisions and methodological shifts be justified? What is the degree of researcher bias? What strategies are used for increasing credibility?"

Data Collection

The instruments used in this study comprised of individual interviews and document analysis (see Figure 3.1). Interviewing is a "meeting to exchange information and ideas through questions and responses, resulting in a communication to gain an understanding of meaning about a particular topic" (Janesick, 2011, p. 100).

While document analysis is "a systematic procedure for reviewing or evaluating documents - both printed and electronic material" (Bowen, 2009, p. 27). According to Yin (2014), the evidence in case study can come from many sources of data because "the major strength of case study data collection is the opportunity to use many different sources of evidence" (p. 119). The multiple sources of data minimized systematic bias resulting from the use of one data collection approach. The approach of redundancy in data gathering also served to clarify participant's response from the interviews.

The interview questions were designed to ensure participants' responses were contextually framed within the literature reviewed and the UTAUT2 framework. The researcher developed a semi-structured interview protocol that was pilot-tested before conducting interviews for the main study. Content aspect of validity was established in the interview guide by designing the interview questions based on the literature reviewed. Additionally, the researcher enlisted the view of a qualitative research expert to determine if the interview questions where appropriate is answering the research questions. The protocol comprised of three sets of questions with sub-questions aligned to the research questions.

For the document analysis, the researcher requested the participants to any documentary sources that they have used to enhance their understanding of IoT technology. The participants provided artifacts including course syllabi, IoT related journal articles, IoT projects reports, magazines, and website links to blogs, webinars, and podcast.

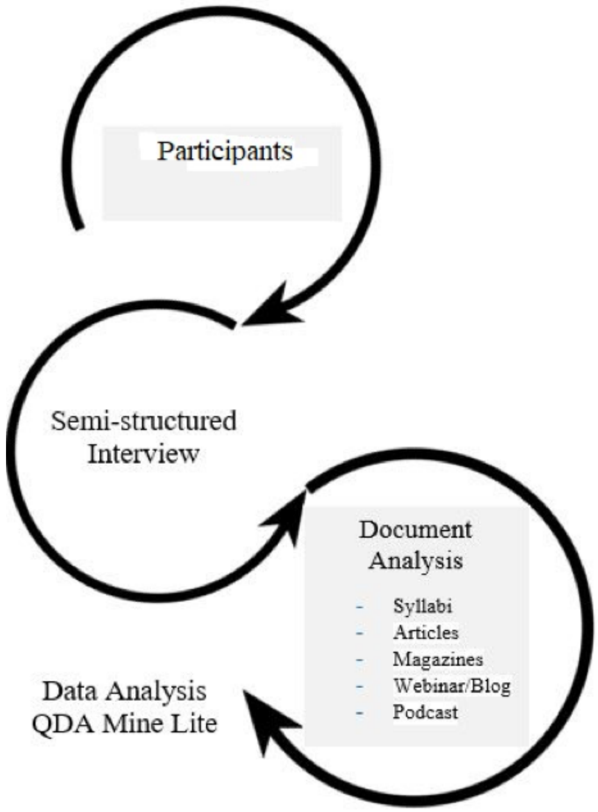

Figure 5. Data Collection Process

Interviews

Individual interview was used as the primary data collection instrument. Interviews are appropriate for data collection when behavior, feelings, and personal interpretations cannot be observed (Merriam & Tisdell, 2015). Interviews are appropriate for collecting data on past experiences that are not replicable.

The interview protocol was designed to collect data showing how the participants have engaged with IoT technology, the perceived advantages and drawbacks of IoT and the factors influencing the adoption of IoT. The interviews occurred over a period of ten weeks between June and August of 2017.

The structure of the interview protocol had a series of open-ended questions that captured the participant's responses in line with the research questions of the study (Creswell, 2012). This approach was opportune to allow the participants to elaborate on their response and it also gave the researcher the opportunity to probe the participants response to the interview questions.

The researcher sent out emails seeking for participants interested in participating in this study. After participants confirmed their participation, a convenient location for the interview was determined. Most of the faculty and administrators agreed for the interview to be conducted within their offices. Before the start of each interview, the researcher and participant reviewed the informed consent form – this was to give the participant a description of the study. The interview sessions lasted less than an hour. The researcher defined IoT and D3M in the context of the study. The researcher also sought the permission of the participants for a recorded interview. A smartphone App was used to record the interviews. In the course of the interview conversation, the researcher took some notes as a memo to clarify some aspects of the interviewee's response.

For the three participants who could not physically be available for interviews, a recorded phone interview was used to accommodate their participation. Two of the participants were interviewed through a Skype phone call and other was through the traditional cell phone interview. The researcher sent the participants an email containing a consent form and the researcher's phone number. Before the start of the interviews, the researcher encouraged the participants to ask any questions if they needed clarity to ensure the participants had a good understanding of what the interview would entail.

The semi-structured questions allowed the investigator to use a conversational approach to inquiry. This approach allowed the respondents to elaborate on the subject in the study. Also, this method gave the interviewer the flexibility to probe the participants to further elaborate on their response. The open-ended nature of the interview structure also gave the research participants an open forum to respond. This approach aligns to Yin's (2014) argument; case study researchers have two roles during the interview. Firstly, "to follow their line of inquiry, as reflected by your case study protocol. Secondly, to ask actual (conversational) questions in an unbiased manner that serves the needs of your line of inquiry" (p. 110).

The semi-structured interviews allowed the researcher some discretion about the order in which to ask the research questions. The conversational approach of the open-ended interviews enriched the data for coding (Patton, 2015).

After each interview, both the researcher and an independent transcriptionist not affiliated with the study transcribed the interview responses within 24 hours of the interview. The interviews were transcribed using Nuance Dragon software and saved as a Microsoft Word document. After the transcription phase, the researcher read through transcripts and deleted any text that was not relevant to addressing the interview questions. Guest, MacQueen, and Namey (2012), emphasized the need to winnow data – a process that is focused on some part of the data while disregarding the unnecessary part. After sifting the extraneous text from the transcripts, the researcher reread the transcripts to get a general sense of the information collected about the research questions. During the transcript winnowing, memos of interest to the research questions were noted to help in the coding process. Aga (as cited in Creswell, 2013) suggested that researchers "read the transcripts in their entirety several times …trying to get a sense of the interviews as a whole before breaking it into parts" (p. 183).

Following the winnowing process, the transcripts and recorded interview files were securely uploaded to OneDrive cloud storage a HIPAA compliant storage (Health Insurance Portability and Accountability) provided by Ohio University.

After transcription, member checking was performed to review the transcripts against the interview recording. Thus, eliminated any transcription errors and any incorrect assumptions that could have emanated due to the researcher's bias. The process gave the participants an opportunity to review and clarify on the accuracy of their interview response. This process helped in strengthening the credibility of the study (Merriam & Tisdell, 2016).

Document Analysis

The researcher asked participants for any artifacts they have used to enhance their understanding and knowledge of IoT technology. This documentary source, interview data and member checking allowed for data triangulation of the findings. The documentary source provided by the participants included course syllabi, IoT related articles, reports on IoT projects, blogs, magazines, webinars, and podcast.

Most of the most of the faculty, administrators, and three graduate students agreed for the individual interviews to be conducted in their offices, when the researcher requested for any documentary sources that they had used to build their understanding of IoT technology, within reach of their office they provided IoT related artifacts. However, for most of the students and other participants who participated in a phone interview, the researcher had to send a reminder text and email requesting for the IoT related artifacts that they had promised to share with the researcher. Therefore, the researcher is not aware if sending reminder text and emails piqued the participant's interest in sharing IoT related artifacts.

Similar to other qualitative research analytical approaches, document analysis entails examining and interpreting document generated data to gain an understanding and empirical knowledge of the phenomenon of a study (Corbin & Strauss, 2008). The researcher used a document analysis approach to review and analyze the documentary sources to determine its relevance to the study. The documentary analysis is "a systematic procedure for reviewing or evaluating documents - both printed and electronic (computer-based and Internet-transmitted) material" (Bowen, 2009, p. 27). According to Glesne (2016), documents not only support interviews but they can develop the researcher's knowledge and understanding of the phenomenon under inquiry. The researcher also used the document analysis to examine the artifact for credibility, and accuracy in relation to the study. To add on, Patton (2002) noted that document analysis in qualitative research provides "record documents, artifacts, and archives" (p. 293).

The artifacts provided insight not only into the context of the research participant's forte; it also generated data used to contextualize the findings from the individual interviews. Additionally, the information from the document analysis supported the modification and the design of new interview questions. The document analysis provided supplementary data that allowed for corroboration of the findings from the individual interview. As indicated by Yin (2014), "the most important use of documents is to corroborate and augment evidence from other sources. Because of their overall value, documents play an explicit role in any data collection" (p. 107). This convergence of information established the content aspect of construct validity. Thus, enhanced the trustworthy and rigor of this study. Yin further noted that because of their unobtrusive element; documentary sources could repeatedly be reviewed.

The document analysis provided a means of understanding the developments in IoT technology within Ohio University. Documents analysis provided background information as well as insight about IoT in higher education. This knowledge and insight helped the researcher to understand the specific issues and conditions that impinge upon the adoption of this technology.

Data Analysis Process

A practical approach to data organization and synthesis was applied to report the data findings as shown in Figure 3.2. Data analysis in qualitative research is the skill and art of making sense of patterns and themes to formulate answers to research questions of a study (Creswell, 2012).

A content analysis approach was undertaken in this study. According to Patton (2015), "content analysis is any qualitative data reduction and sense-making effort that takes volumes of subjective material and attempts to identify core consistencies and meaning" (p. 541). Relatedly, Krippendorf (2013) described content analysis as a "research technique for making replicable and valid inferences from texts (or other meaning matter) to the contexts of their use" (p. 24). In this study, UTAUT2 theoretical propositions and the literature reviewed informed the data analysis.

During the interview phase, content analysis was initiated concurrently during the data collection phase. The process allowed for the "organization of information into categories related to the central questions of the research" (Bowen, 2009, p. 32). Qualitative data analysis is a recursive process that should co-occur during and while data collection is in progress (Miles et al., 2014). The ongoing data analysis enabled the researcher to design strategies for collecting new data and fill gaps in the data collected. Additionally, the researcher was able to share transcripts with the participants when there was a need to ascertain if it reflected their response to the interview questions.

For the process of condensing the data for analysis, the researcher unitized the recorded interviews and documentary sources into three categories that represented faculty, administrators, and student responses. At the end of each interview, the researcher listened to the audio recording to get a general sense of the interview response in relation to the research questions. This segued to the transcription phase.

Transcription of the recorded interviews happened within 24 hours of each interview. The time frame was important to keep track of some nonverbal response during the interview. The transcripts were saved as a Microsoft Word 2016 document with an anonymous file name for the anonymity of the respondents. Saving the transcript as a Microsoft Word file allowed for the file to be imported into QDA Miner Lite computer assisted qualitative analysis software.

After the transcription process, the researcher read through each transcript while separating different segments of the transcript into paragraphs relating to various points of the participant's response to the interview questions. These sections were essential for the coding purposes. As the researcher was reading the transcripts, concurrently he reviewed the artifact provided by the respondents in order to discover any relationships between the documentary sources and the participant's response in the transcript. In the process, the researcher was able to add comments and pre-code the transcripts by highlighting some overarching keywords, ideas, and phrases that were of interest to the research questions. This process facilitated the preliminary analysis of the data which was conducted through an exploratory method of coding. Exploratory coding is when "a preliminary assignment of codes to data is performed in preparation for more refined coding" (Saldaña, 2015, p. 165).

The artifacts from the participants were reviewed and analyzed through document analysis. The researcher used an iterative process to combine the principles of content analysis and thematic analysis to organize and synthesize information from the artifacts into categories that reflected the research questions of the study. Corbin and Straus (2008) emphasized the need for the qualitative researcher to identify and separate pertinent from non-pertinent information from artifacts. During the document analysis, predefined codes were used to establish categories of data generated from the documentary sources. According to Marshall and Rossman (2011), researchers can use concepts from conceptual framework and citations from literature review to suggest possible themes for data analysis.

For detailed data analysis, the transcript was imported into the QDA Miner Lite version 2.0.2 for coding. According to Saldaña (2015), qualitative coding is a construct generated by a researcher to symbolically assign summative and salient attributes to data for the analytic process. In the first cycle coding, provisional coding approach was conducted to map segments of the collected data to constructs of UTAUT2 framework and literature reviewed. Further, Saldaña succinctly stated that provisional codes are predetermined list of codes generated from literature review, conceptual framework, research questions, and researcher formulated hypothesis. Further, Saldaña reported that provisional codes could be modified or deleted to include new codes. To justify the link between ideas and evidence through the constructs of theoretical framework, Guest et al., (2012), suggested that it is possible to link themes to theoretical models because "applied thematic analysis situates the coding process in the realm of evidence rather than ideas" (p. 75). As the researcher reread the transcripts imported in QDA, there emerged short sentences and phrases in the data that related to the predetermined codes found in the literature reviewed and the theoretical framework guiding this study. The short sentences and phrases identified in the coding process were highlighted using different font colors to represent specific codes.

After the first cycle coding, the researcher unitized the codes into categories and sub-categories having similar meanings to the research questions of the study. Krippendorf (2013) posited that unitization "is the process of introducing distinctions within a given but not yet differentiated continuum; identifying sections that are relevant to research" (p. 276).

Following the unitization of codes from the first cycle coding into categories and sub-categories, the researcher condensed the categories into general patterns. After analyzing the different groups of codes from the first cycle coding, the researcher noted that some patterns merited further refinement. Therefore, a second level coding using a pattern-coding approach was undertaken to condense the codes from the first cycle coding. As indicated by Miles et al., (2014), second cycle coding is an approach of aggregating code summaries from the first cycle coding into a small number of themes. During pattern coding, several of the initial ideas that emerged were reorganized into more coherent and precise themes that reflected the research questions of the study. The themes transcended the participant's response. Thus, establishing the generalizability aspect of construct validity. Saldaña, (2015) defined themes as "a phrase or sentence that identifies what a unit of data is about and what it means" (p. 139). The emerging themes reflects the literature reviewed and the propositions from the UTAUT2 model. The codes, themes and sub-themes that emerged are described in tables 4.1, 4.2 and 4.3 in chapter four.

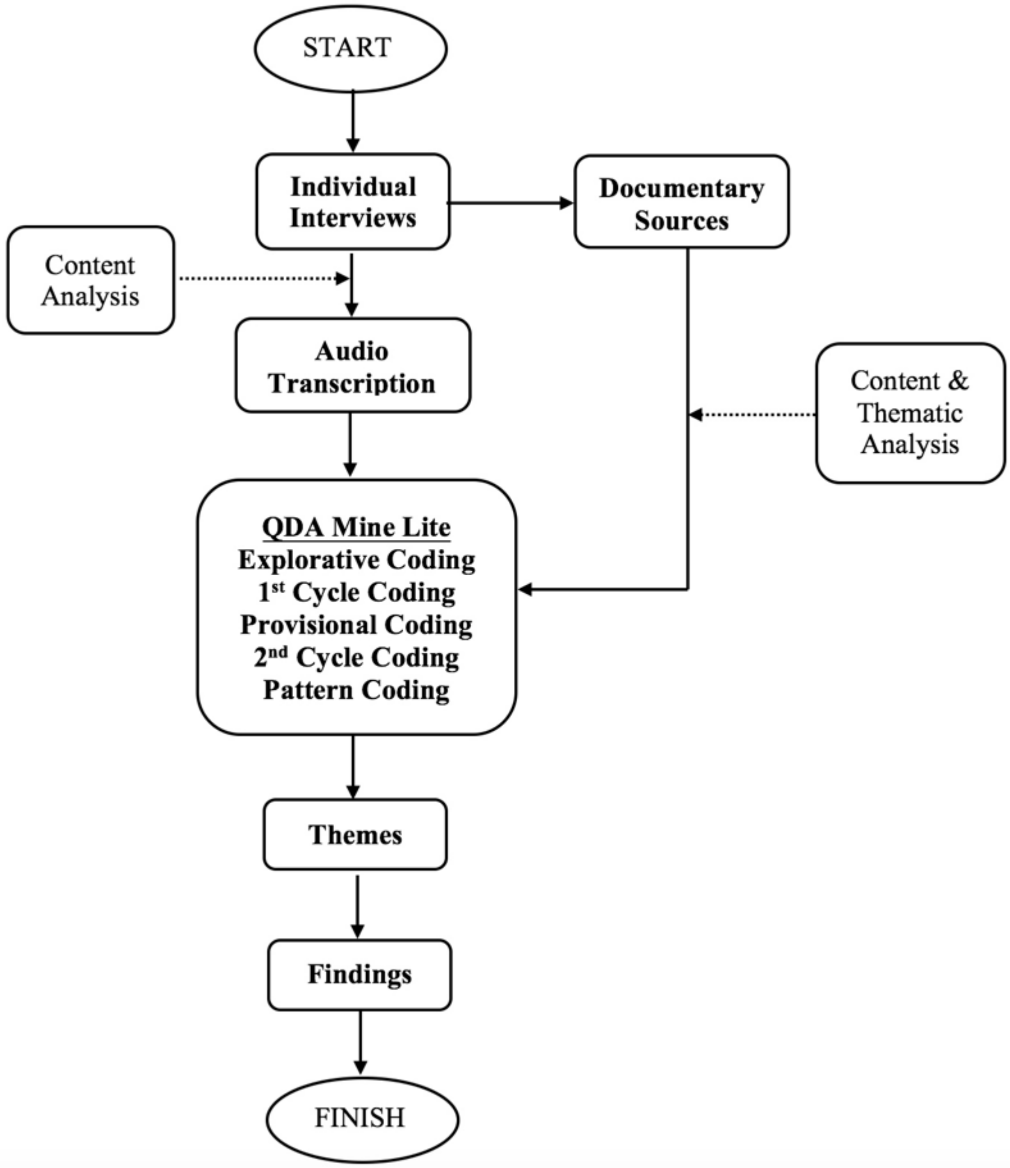

Figure 6. Data Analysis Process

Ethical Consideration

The privacy and anonymity of the participants in the study were maintained to meet the expectations of Ohio University Institutional Review Board (IRB). The researcher did not contact any participants before the approval by the Ohio University IRB. Anonymous identification codes were used for the confidentiality of the participants during the recorded interviews and during the data analysis.

Before the data collection, all participants received an adult consent form without signature requirement. This was to maintain anonymity and confidentiality of participants. This form described the study, the criterion for a participant to be eligible to participate in the study and participants were informed about the data collection tools and study design.

During the data analysis, the researcher removed any discernable personal identifiers relating to the participants. Additionally, the researcher confirmed to the participants that the collected data and the written report would be accessible to them upon request.

To ensure consideration for the rights of the participants, the researcher notified the participants about the data collection approach, how the data collected was to be used and the recording devices that would be used to capture the interview. In order to protect the anonymity and confidentiality of the participants, each recorded interview was given an anonymous code as a label to the audio file. The process was intended to guard for the participant's identity; additionally, to preserve the utmost confidentiality of the subjects.

The researcher protected the privacy of the participants by deleting any word or phrase that could be used to identify the participant. Furthermore, OneDrive cloud storage that meets the HIPAA compliance was used as a repository for the transcripts. The transcripts are saved in OneDrive for up to three years and then after will be deleted leaving no discernible records.

The researcher also considered personal integrity and prejudices during the ethical consideration in the study by ensuring that the study findings and conclusion was an accurate reflection of the interpretation of the collected data.

Chapter Four - Findings

The purpose of this research was to explore how IoT technology can enhance D3M in higher education. A case study research design was adopted to conduct the study. The participants in this study were composed of six faculty members, four administrators and seven students from Ohio University. Data were collected using individual interviews and document analysis. This chapter presents the summary of the data analysis process, findings of the study. This case study answered the following research questions:

RQ1: How have the faculty, students and administrators at Ohio University engaged with IoT technology to enhance D3M?

RQ2: What are the perceived advantages and drawbacks of IoT technology among faculty, student and administrators in D3M?

RQ3: What beliefs and perceptions are affecting the adoption of IoT technology in higher education?

Summary of Data Analysis Process

The researcher applied an inductive approach of the data analysis. Data analysis began concurrently during the data collection process. Merriam and Tisdell (2015) emphasized that data collection and data analysis in qualitative research should be conducted in tandem to facilitate an intensive data analysis after collecting all the data.

After the interview process, the researcher transcribed the audio recording and saved it as Microsoft Word document. After the transcription, the researcher read the transcripts while listening to the recorded interview to correct any transcription errors. This process facilitated the initial phase of member checking. In the process, the researcher created memos of some keywords and phrases that had links to the research questions. These were used later to facilitate an intensive data analysis. After the final review of the transcript, the transcripts were emailed to some participants to review for any bias. This process offered an opportunity for member checking (Yin, 2014).

The researcher reviewed the transcript multiple times during the data analysis phase. This process facilitated data condensation, and classification into the different participant group and research questions. This process segued into the phase of coding and theme discovery (Miles et al., 2014). The documentary sources provided by the participants were reviewed and integrated into the data analysis to corroborate findings from the interview data.

Following the transcription process, the transcripts were imported as Microsoft Word files into QDA Mine Lite. This facilitated an intensive data analysis process. As the researcher read the transcripts uploaded in QDA, the participant's response to the research questions were labeled in different colors and linked to an established list of codes generated from the UTAUT2 model and literature reviewed. The provisional coding approach was used in the first cycle coding not just to link participant's response to established codes but also to condense and group the ideas into categories. However, some codes emerged from the transcript and could not be linked to the primary codes generated from the literature reviewed and the UTAUT2 framework. These were highlighted and labeled as new codes.

Following the analysis of the categories from the first cycle coding, there was a need for further reorganization of the emerging categories. Therefore, the researcher conducted a second level coding - a pattern coding approach to condense the group of ideas into a small number of coherent and precise themes.

Presentation of Findings

The findings of the pilot study recommended modifications to the interview questions. This helped in reorganizing the question to maintain consistency in the flow of the interview guide. The questions were also modified to increase its clarity. The findings of the pilot case study also showed that the interview process could take less than one hour. The time frame allowed for giving the participants a preamble about the context in which IoT and D3M are defined in the study; and responding to any questions from the participant before the interview begins and the actual interview process. The suggestions from the pilot study was used to modify the criterion for selecting participants of the study.

The findings of the main study are grouped into themes structured based on the research questions of the study.

Research question 1. How have the faculty, students and administrators at Ohio University engaged with IoT technology to enhance D3M?

From the data analysis, three themes emerged after thematic coding of the data. The overarching themes that emerged include ubiquitous access to information, personalized learning and increased student engagement as shown in Table 4.1.

Table 1
List of Codes and Themes

RQs	First Coding	Second Coding - Themes
RQ1	Adaptive online learning Self-directed learning Remote research projects AI electronics – Alexa, Apple home kit Home automation projects Customized content to diversify presentation Integrating IoT and HoloLens	Personalized learning
	Active learning Wearable technologies Maker spaces - Robotics 3D pens Gamification Digital content delivery Virtual reality headsets	Increased student engagement
	Anywhere anytime access to information IoT-enabled virtual reality Remote guest lecture Remote tech support Online teaching and learning e-Textbooks Remote environmental monitoring Remote data transmission Automated lab experiments Google glass	Ubiquitous access to information

Themes #1 – Personalized learning. In spite, the variation in the kind of activities faculty have engaged in while using IoT related technologies for D3M based on their different disciplines, they noted that IoT has the potential to enhance the teaching and learning process. Participant V013 mentioned that if IoT is implemented into the education sector, “It can be used to design of lesson plans that combine different pedagogies to accommodate the diverse group of learners, their learning styles, and aspirations." The participant further explained that as an educational tool, IoT has the potential to empower students with their learning. Student would be able to pace their education relative to their unique needs.

Participant V015 and V021 share a similar thought about an IoT enabled curricula. They explained that IoT as a learning platform has the potential to support a student-centered approach of learning. Their argument was that this approach of learning can bolster student's confidence while supporting an enriched learning process. Participant V026 said "I have used Fitbit as a teaching tool to automate access bio-metric and bio-feedback by tracking participants and capturing data on their sleep patterns and activity patterns using a smartphone." The participant further noted that using personal data, students are more like to understand and related to their personal data than using abstract data.

Concerning personalized learning, a faculty participant V015 who self-identified as an early adopter of IoT technology and currently having an intermediate level of proficiency in the technology said that "I have applied my knowledge of IoT related technologies to execute dynamic classroom activities using IoT devices." The participant emphasized that the dynamic learning activities has not only increase student engagement but it has also provided learners with the opportunity to use their competencies in enhancing their learning. Participant V014 mentioned that "My students have designed IoT systems to monitor environmental parameters, and automate home appliances." Subsequently, the participant noted that currently equipping students with IoT skills increases their opportunity in the job market. The participant also believes working with

IoT enabled projects with students enhanced their students' level of engagement and participation. Each student was able to work on personalized tasks that marched their skill set and competence. Concerning personalized learning, participant V024 highlighted that "In an IoT enabled curricula students benefit from not having to spend lots of time on content they have already mastered since instructions can be tailored to their learning needs."

The student's response to RQ1 indicated that they had used IoT related technology such as smart watches, smart pens, virtual and augmented reality headsets, intelligent lights and other smart mobile devices to capture and access information anywhere at any time. Participant V020 said, "Using smart technologies, I have been able to contextualized my learning."

Participant V010, said that "As the cost of IoT consumer devices continues to decline, I have bought and built an IoT-enabled system to control my house electronic appliances using Alexa – the intelligent personal assistant developed by Amazon." The participant revealed that using IoT technology has enabled him to align his enthusiasm for working with automated systems to his academic research project. Some of the students interviewed noted that they hoped IoT-enabled education could come in the near future because they envision that such an education system may support IoT-based competence assessment.

The administrators who comprised mainly instructional technologists indicated that IoT-enabled education has enormous potential to facilitate the customization of education. Participant V012 explained that "I have used IoT related technologies to capture data on computer software and hardware usage. This helped me to modify the computer lab schedule to addressed the student's needs." Additionally, the explained that the data on student learning activity patterns helped them support faculty in creating courseware that addressed student's learning needs.

Themes #2 – Student engagement. The faculty interviewed mentioned that the IoT ecosystem is likely to enhance ubiquitous learning. Participant V014 stated that "I believe that IoT enabled education has the potential to foster peer-to-peer learning developed around a community of practice." Other respondents noted that this nascent technology could facilitate and enhance distance-learning opportunities. Participant V02 alluded to have used IoT enabled virtual and augmented reality headsets to engage their students in a virtual trip around different topics around the globe. The participant stated that this learning experience gave students not only virtual knowledge but also a contextual understanding of concepts that could be replicated in real-world situations.

Some, faculty elucidated that IoT enabled education lends itself to improve authentic learning. They noted that during authentic learning; students are highly engaged and motivated to learn. Participant V012 said that,

> Working with my students to build a prototype IoT enabled home has not only increased their level of engagement but it has also motivated them to learn about different aspects of the smart house projects such as programming skill, assembling of the model house, and HVC system.

Participant V016 pointed out that IoT educational model is likely to support pedagogical trends such as competency-based learning, problem-based learning, and project-based learning which fosters a decentralized approach to knowledge acquisition. Participant V019 said that, “As a member of a maker space club, this has been an enriching opportunity to share and learn different aspects of IoT project.”

Participant V026 mentioned that adapting IoT as an education tool is likely to support active and collaborative learning. The participant explained that this would give students the opportunity to bridge hands-on knowledge and real-world experience.

The student participants stated that based on the principle of connectedness that builds the IoT technology, this facilitates increased engagement between different skill sets. Participant V023 stated that “I believe working with peers with common interest exposes student to a diverse group of people from different demographics, disciplines and varying levels of expertise that is paramount in advancing the culture of innovation.” Participant V010 mentioned that “My research interest in prototyping home automation using the readily available off-the-shelf IoT devices has enabled me to engage with different experts. He mentioned that IoT technology supports the curiosity-based approach of learning.”

Participant V014 indicated that if IoT is integrated into the learning process in meaningful ways that provide more opportunity for student-faculty interaction. IoT-enabled curricula could avail students the opportunity to post questions and comments that can be replied in real-time. Such a platform could allow faculty to modify their instruction based on student feedback and also support introverted students in expressing their opinions.

Themes #3 - Ubiquitous access to information. The participants emphasized that being able to access information anywhere anytime using IoT enabled devices has made them more efficient because of the opportunity to work at their convenience. Faculty noted that as institutions of higher education strive to increase digital tools of learning to provide students with rich educational experience, integrating these devices to the IoT enabled education has the potential to expand access to learning materials and enhance the productivity of both students and faculty. Participant V026 said "I have used web-based application that plugs to my phone and up to 240 students in 3 different locations have the capability to connect to that same learning environment to enhance their learning."

Students explained that with the multiple digital platforms available today within the IoT ecosystem, they could learn and work ubiquitously. Participant V022 noted that the ability to have constant access to learning materials not only has the potential to foster learner autonomy, but it also promotes habits for lifelong learning.

The instructional technologist expounded that IoT-enabled education has the potential to support high-quality remote presence. In that, students who are unable to be physically present in the classroom can still participate synchronously through virtual platforms. Participant V018 stated that "Today, students no longer must be physically present in a laboratory to run science experiments since IoT can connect experiments and instruments to the Internet for remote control and monitoring." The participant also explained that similarly students do not need to be physically present in the classroom but could connect from different location. Other participants pointed out that an IoT enabled class has the potential to enhance lecture capture in ways that students can use to pace their learning and remotely access archived content for future reference.

There was unexpected finding from some administrators who indicated that they have engaged with IoT enabled systems to automate licensing of software installed in the educational technology provided to students. They noted that receiving automated notifications that shows when the warranty on classroom technologies will run out made their work more efficient. Also, they emphasized that this has helped them to seek replacements for equipment within the warranty period.

An unexpected finding from faculty also noted that IoT ecosystem has the potential to enhance professional development without untethering them from their routine activities. They stated that this platform could give faculty the opportunity to share best practices in teaching and learning with fellow faculty. The participants also mentioned that they can seek answers to questions that may not be addressed within their individual institutions.

Research question 2. What are the perceived advantages and drawbacks of IoT technology among faculty, student and administrators in D3M?

From the response to this research question, four themes emerged as the perceived opportunities resulting from adopting IoT in higher education during the thematic coding. These include collaborative learning, customized teaching and learning, parity to diverse learners and ubiquitous and context-aware learning as shown in Table 4.2. Three themes emerged as drawbacks of integrating IoT at its present state to institutions of higher learning. These include privacy issues, data security, connectivity challenges.

Table 2
List of Codes and Themes

RQs	First Coding	Second Coding - Themes
RQ2	PROS Enhanced teaching and learning	PROS Enhanced teaching and learning experience Sub-Themes
	Increased student collaboration and engagement Combine different pedagogies to accommodate the diverse learners Modern learning experience Automating mundane tasks – attendance Experiential learning Supports different disciplines in one space Interactive learning experience	*Collaborative learning*
	Real-time feedback Increased student engagement Digital learning platforms Active learning Turns learners into creators Provides safe learning environment Supports a mindset of practice over theory	*Student-centered teaching*
	Facilitates adaptive courseware Links people, process, data and devices Supports flexibility to consume content and knowledge Self-pace learning Supports customized learning Using data to optimize learning	Customized teaching and learning
	Facilitates seamless retrieval of information Untethers researchers from the field Wearable IoT devices Remote guest lectures	Ubiquitous and context-aware learning
	Grant parity for the diverse group of learners Lower cost of education Enhanced operational efficiency Provides safe and secure learning environment	Parity for diverse learners

Table 2: Continued

RQs	First Coding	Second Coding - Themes
	CONS Privacy issues Increased hacking Lack of data transparency Data security Cyber attacks Data integrity Technical challenges Network congestion Interoperability challenges of IoT devices Energy constraints	CONS Privacy concerns Data security Connectivity challenges

The participant's response showed the following as the potential opportunities of IoT in D3M in higher education:

Theme #1 – Enhanced teaching and learning experience. Integrating IoT technology to higher education has enormous potential to provide students with an enhanced learning experience such as collaborative learning, and customized teaching and learning. IoT-enabled curricula can enable learners to get real-time insights into subject areas they would otherwise only learn from their textbooks.

Sub-theme #1 – Collaborative learning. Collaborative research from different perspectives emerged as an essential theme amongst faculty. Participant V021 mentioned that collaboration is vital for developing practical and comprehensive solutions. The participant further noted that to achieve this, there is need to foster communities of practice that support evidence-based approaches to learning. Concerning collaborative researcher, participant V011 stated that "I think the collaboration between corporate institutions and educators has the potential to promote an interdisciplinary and authentic approach to education which is more relevant in today's world." Participant V019 stated that "Pragmatic knowledge building could be achieved through collaborative research between students, faculty and industry professionals as they explore the potential of IoT is managing societal problems."

Additionally, faculty pointed out that as institutions of higher education strive to meet their primary responsibility of offering their students education that leads to gainful employment, participant V022 mentioned that an IoT-enabled school is well placed to provide students with real-world skills that bolster employability, workplace development and promotes collective intelligence build on the premise of social skills. The respondent further explained that with many of today's learners inundated with a plethora of information generated from smart devices, IoT provides a platform to improve teaching and learning experiences. It integrates IoT and D3M to espouse purpose learning. The participant explained that this model of teaching avails learners the opportunity to build a foundation to learn critical skills that are applicable across different domains. Relatedly, V012 explained that as students learn skills that is applicable across disciplines, this allows faculty multiple ways to assess learning outcomes within an IoT enabled education system.

Participant V016 noted that integrating IoT as a pedagogical tool is likely to add a new dimension of teaching collaboration and accessibility especially in courses that require the use of laboratory resources. However, participant V018 mentioned that while IoT technology has the potential to facilitate collaborative learning, the participant also elucidated that she hopes that higher education institution can use IoT not only to expand their online presence but also to reduce the price of tuition.

A student participant (V023) stated that as institutions of higher education support today's learners to take on the primary role of managing their learning, using IoT technologies are tools of learning augments access to crowd-sourced content that can be used to enrich learning. Relatedly, participant V011 said "I believe integrating everyday objects to learning fosters understanding and increased levels of engagement."

The instructional technologist (V013) explained that at the current state of IoT technology, institutions of higher education might not consider its immediacy despite the enormous opportunities that it's likely to bring to the education sector. However, the participant indicated that the ability of IoT to facilitate faculty to get a better understanding of concepts that their students struggle to comprehend could help them design instructions that address specific areas of concern.

Sub-theme #2 – Student-centered teaching approach. Faculty indicated that as IoT and pedagogy becomes integrated, the traditional teacher-student roles are likely to change. Participant V019 stated, "I believe IoT can foster amongst students a mindset of practice over theory". The participant explained that an educational environment explicitly focused on supporting learning with the IoT has the potential to promote a student-centered teaching approach accompanied by enhanced student-to-student and faculty-to-student collaboration. Participant 026 emphasized that "As intelligent technologies get into the learning environment; the technology changes the dynamics and the potential of interactions between student-student and student-faculty side."

Concerning student-centered learning, participant V019 elucidated that as today's students evince the attitude of creativity and critical thinking, "Adopting IoT based curricula will not only pave the way for increased creativity, but it could support the confluence of different disciplines in one space."

Participant V024 stated that since IoT enabled devices facilitates data gathering, having access to data that reflects student's behavior and learning patterning would enhance the designing of courseware that bridge student's learning needs and styles. Relatedly, participant V012 emphasized "IoT devices can be integrated in class as adaptive learning tools that present students with different learning options to foster engagement and the motivation to learn."

Theme #2 – Customized teaching and learning. The faculty mentioned that while integrating IoT technology to the teaching and learning process is likely to provide increased convenience for students; it also has the potential to make the teaching process more efficient for professors. Participant V026 expressed that the surge in connected devices as learning tools means that instructors have alternative ways to assessing their students. The participant further pointed out that whenever applicable, faculty do not need to grade tests on paper or perform some mundane tasks manually.

It was apparent during the interview that faculty believed integrating IoT to pedagogy has the potential to enhance individually tailored instructions that match specific students learning needs and aspirations. Participant V021 pointed out that as IoT becomes a tool for teaching and learning, students are likely to gain skills that are relevant to the current digital economy. Such skills could improve their job placement rate upon graduation.

Further, three faculty elucidated that the convenience to learn anytime-anywhere untethers learning spaces to ensure that time and place is not barriers to learning. V017 stated, “Since the inter-disciplinary approach to learning can thrive within an IoT enabled education system, this offers students the opportunity to pursue their research on topics that interest them at their own pace and convenience.”

With more employers looking out for 21st century skills from job applicants, participant V020 noted that performance-based assessment has become eminent for reflecting the unique skill sets that today’s students exhibit. The participant further expounded that IoT-enabled education can facilitate the processes for assessing nuanced skills within individual students.

A student participant (V011) noted that IoT could be used to optimize the classroom learning environment using sensor data from IoT enabled classroom. The student further pointed out that instructors can harness such data to adjust classroom conditions to ambient levels that suit the time of the day and the subjects being studied.

Two participants (V022 and V018) mentioned that they prefer to use IoT technology to automate mundane tasks that they already do – such as take notes and transcription.

With IoT’s seemingly endless capabilities, this brings together different disciplines into one space that provides students with unique opportunities to enhance their education using real objects as tools of learning. Participant V025 noted that integrating IoT and its supporting technologies such as artificial intelligence and virtual reality allows for the development of adaptive courseware. The participant further pointed out that the most relevant aspect of IoT enabled education may support personalized learning, provide real-time feedback and motivate learners through engagement. Participant V012 mentioned that "I designed personalized instructions for students to use as they work on simulated patient." Additionally, the participant noted learner-centered instruction offers students the confidence to learning within a safe learning environment.

Two administrators mentioned that IoT-enabled curricula have the potential to promote ownership of learning by students. Participant V014 emphasized that an IoT-enabled education is likely to capture even the most nuanced data that reflects student's learning. Further, the participant expressed that student data can be harnessed to offer unique learning experience at relatively lower costs. Participant V012 stated that "As the advancements in IoT technology becomes more intelligent, these technologies are likely to transmit more high-level information rather than raw data that can be evaluated to facilitate quick decision-making."

Administrators indicated that as more devices join the IoT ecosystem, there will be increasing amounts of data generated from each device. Participant V012 stated that leveraging such data can help faculty to develop better curriculum and assessment structures. The participant also noted, "As administrators we can use insights from such data to understand students better and help optimize the resources available to each student." Ultimately, the administrators indicated that leveraging data generated by IoT devices connected to campus networks facilitates predictive analytics that can be used to advance students' academic progress. Participant V014 said, "Predictive analytics could be used as digital safety net to identify students who are at risk of dropping out of college due to academic or financial challenges."

Participant V024 mentioned that, using student data generated from IoT enabled class, instructors are likely to recognize concepts that students struggle to understand in their course. The participant expressed that the ability to know what aspect of instructions students struggle to understand provides faculty the opportunity to modify content in order to address areas of student's learning concern.

The administrators also indicated that if university leaders invest in innovative educational resources that enhance student success, this will offer instructional designers the opportunity to reflect on student learning patterns and create courseware that address learning challenges.

Theme #3 - Ubiquitous and context-aware learning. The faculty pointed out that the potential of IoT enabled research can untether researchers from the field. Participant V026 noted that IoT as an educational platform not only enhances efficiency in conducting research but it also improves researcher's experience of the real environment as they are applying digital information to real life scenarios. The participant further reiterated that the ability to monitor remote areas not only facilitates seamless retrieval of information but it supports timely intervention when required.

The student participants indicated that IoT technology could improve student's academic performance. Participant V023 said, "IoT technology has the potential to support around-the-clock remote access to an academic tutor." The participant also expressed that if institutions of higher universities make IoT technology integral to their curricula, this will facilitate them to link their learning to real-world situations.

Participant V019s explained that information provided by IoT learning environment empowers faculty to deliver improved education. Since it provides faculty with a window to evaluate the success of their strategies, their students' perspective, and other aspects of their performance. The participant also indicated that such a tool could relieve faculty from mundane task as they focus on improving the teaching and learning process.

As educators strive to facilitate students in taking charge of their learning, participant V014 emphasized that an IoT enabled classrooms supports active learning. The participant alluded that this may take the form of scaffolding whereby personalized instructions build on adaptive learning digital textbooks suggests suitable learning activities depending on different criteria derived from learner's contextual elements.

While IoT has not pervasively been adopted into the teaching and learning process at Ohio University, the administrators envisioned that it will be successfully integrated into the education system slowly and in nuanced ways. Participant V024 expressed that as the pedagogical applications of IoT are still relatively new, it is not currently practical to predict and describe the full array of potential applications in education. However, the participant noted that there is a promising opportunity for integrating IoT into the classroom to blend the real world into education experience. The participant referenced the example of virtual reality (VR) system in classes, that allows students to apply knowledge and skills learned in the course material to real-world scenarios. The administrators expressed excitement that IoT in education environment could facilitate the interaction of people (students and faculty) and objects (physical and virtual) in the academic environment.

Theme #4 - Parity for diverse learners. Faculty noted that given the typical barriers in education such as socio-economic status, language barrier, and physical location. Participant V019 indicated that IoT enabled education has the potential to bridge the opportunity gap in knowledge. Meaning it could help untethering learners from physical sites to ensure that time and place are not barriers to learning. Participant V026 expressed that the ubiquitous ecosystem of IoT has the potential to support research studies remotely. Therefore, lowering the overall cost of conducting field research. Additionally, the participant pointed out that in situations when students are unable to go into field experience, using IoT supported technology like virtual reality systems provides the opportunity to take students on an immersive virtual journey that brings field experiences into the classroom.

Students mentioned that as the developments in the IoT ecosystem supports the proliferation of smarter connected devices, integration IoT in curricula prepares students for increased competition in the workplace. Participant V023 noted that when student learning IoT related skills, this offers them a building foundation within the IoT technology on which they can apply as they work with more advanced applications in the working environment.

The response from the students indicated that as technologies are rapidly changing, integrating IoT in the curricula does not only support experiential learning but also supports learners to appreciate emerging technologies.

The administrators expressed that while there are already some educational technologies, tools, and apps that create appropriate learning experiences, the ubiquitous nature of IoT if integrated into the classroom has a lot to offer students requiring modified learning plans. Participant V014 mentioned that IoT as a learning platform could provide a safe and secure learning environment for introverted type of learners.

While several themes emerged from the participant's response to the potential opportunities of IoT in D3M in higher education, some commonalities surfaced during the interview discussion on the drawback of adopting IoT technology in higher education. The following themes emerged to reflect the pitfalls: Privacy concerns, data security, and connectivity challenges.

Theme #1 Privacy concerns. Faculty mentioned that as IoT technology gets accepted in college and university campuses, this is likely to generate volumes and variety of data. The respondents indicated that in the digital era of learning platforms, users of this kind of platforms leave digital foots that dawns a new meaning on privacy. Participant V019 posed the following questions, "Who has access to student and faculty's data? What is the purpose of such data?" With the uncertainty of answers to these questions, the participant expressed concern about the absence of information transparency within the IoT ecosystem. Participant V017 mentioned that "Integrating IoT to cloud-based services enhances its real value. However, while most paid versions of cloud-based services guarantee encryption of their customer's data, and allows customers the freedom to download their data when they have to leave the cloud-based platform. But there is no guarantee that the customer's data has completely been deleted from the cloud-based platform since they do not have full ownership. This creates privacy concerns because there is no transparency in data ownership within the IoT ecosystem."

Some faculty also noted that while the education sector is still grappling with unconscious biases perpetuated based on socio-economic, gender, and racial differences, there are concerned that IoT enabled education is likely to manifest these unconscious biases through implicit algorithmic preferences that reflect the software developers frame of reference. Participant V016 said, "At the current state, are educational technologies likely to show unconscious bias that may present false positives that influence academic performance and graduation rates of minority students in higher education? – I don't know." Participant V017) emphasized that "I do not have to be swayed by catchy statements such as IoT is going to revolutionize education. IoT can be a tool that is supposed to enhance learning. Earlier on, some researchers claimed that radio was going to be the breakthrough in education. As in, it was to revolutionize the educational system. In the 1980s similar claims were made about how recording and distributing cheap instructional videos using VHS camera was to revolutionize education. These assumptions did not turn out to revolutionize education as claimed because currently, we can send educational content (both video and audio) through multiple radio frequencies making such claims misconceptions."

Participant V010 mentioned that as early adopters of IoT technology, I can see its potential to enhance the learning process. However, the participant indicated his concern that, “If third-party organizations provide IoT services, then there is likely to be issues regarding individual privacy and confidentiality.”

The administrators explained their concern, when IoT technology becomes integral as part of the educational technologies, its unobtrusive aspect presents unique challenges that transcend data privacy. Participant V014 referenced the example of unconscious use of embedded smart devices within a learning environment. Relatedly, participant 019 said “I wonder if a student would feel supported when ‘Alexa virtual assistant’ says to them, I see that you have scored poorly in your last three assignments, is there help I would offer or do you want me to schedule an appointment with your instructor? Would this be considered helpful by the student or would it be considered invasive?”

In addition to privacy, the respondents expressed their concern about confidentiality in situations of cross-border data flows and the different regulations to address cybersecurity breaches. They also noted the lapse in regulations when it comes to legal liability arising from the unintended use of IoT technology. In regards to data privacy, participant V012 stated, “I have a feeling that there is always the big brother element regarding who gets to use collected data.”

Participant V017 said, “My concerns primarily center around security and data privacy. Since interconnectivity and data sharing are the backbone of IoT technologies, the application of such devices towards teaching and learning raises concerns regarding what/how much data is collected and how that data is transmitted and stored.”

Theme #2 - Data security. Faculty explained that as we experience the proliferation of IoT devices developed without necessary and standard security, the volume of data collected and transmitted by these devices through multiple channels renders them vulnerable to cyber-attacks. Participant V019 emphasized that the connectedness within the IoT ecosystem provides more decentralized points of cyber-attack. The participant referenced the example of Mirai botnet attack in October 2016 that compromised IoT enabled consumer appliances to initiate a distributed denial of service (DDoS) attacks on the domain name server provider that crippled some of the most favorite social media websites including Twitter, Spotify, and PayPal. One faculty (V019) stated that, “Data security in IoT system remains a concern because most, at least initially IoT used basic text essentially where there's no encryption. It's just opened to being broadcast, and so you could have a great deal of concern where people using that as an entryway into a system depending on how it's connected or at least co-opting those devices to hack into internal networks.”

Participant V023 expressed that the heterogeneous nature of IoT devices makes data security in the IoT ecosystem an enormous issue. The participant emphasized that the heterogeneous nature of embedded software running IoT devices creates interoperability challenges in connecting these devices to traditional campus networks. Therefore, this heightens the vulnerability of IoT ecosystem to cyber-attacks.

Participant V025 indicated that despite the numerous opportunities of IoT application, it poses multiple vulnerabilities that significantly increases the potential for cyber breaches. The participant further noted that as an emerging technology, IoT devices end up in the hands of users while running on unpatched embedded operating systems and software that leaves such devices vulnerable to cyber-attacks. Participant V014 alluded that the absence of standards to guide the development of IoT devices could result in products that operate in disruptive ways within the IoT ecosystem.

Theme #3 Connectivity challenges. The participants acknowledged that interoperability remains the biggest challenge of implementing IoT technology within legacy IT systems. They elucidated that IoT is an emerging technology-driven mainly by small startup companies. Meaning, most IoT devices are heterogeneous in their medium of data transmission. Additionally, they emphasized while communication is central to the successful implementation of the IoT ecosystem, the increasing number of different IoT enabled devices on campus networks is likely to create an interoperability challenge of connecting to the current network structure.

The participants also noted that since IoT ecosystem is built on a paradigm of decentralized networks, they mentioned that this defies the structure of the legacy networks that work in a server/client relation for authentication and authorization to be part of a system.

Research question 3. What beliefs and perceptions are affecting the adoption of IoT technology in higher education?

This question ensured that the participant’s response was framed contextually within the UTAUT2 model. Therefore, the findings to RQ3 align to the constructs of this model. It is hypothesized that the seven antecedents of the UTAUT2 framework are influenced by moderating variables including age, gender, and experience to determine the behavioral intention and use behavior of consumers to adopt new technology. In this study, there was no data collected on gender and age. While the researcher did not explicitly ask participants how many years of experience they had using IoT technology in the education setting, however it was found out that participants who had experience using IoT devices in other settings out of the educational realm where more likely to adopt this technology to enhance their teaching and learning process. The researcher did not consider the moderating variables during the interviews because the moderating variables were not anticipated to influence the participants' acceptance to adopt IoT. Albugami and Bellaaj defined the predictors of UTAUT2 as follows:

- Performance expectancy (PE): Is the extent to which users believe that using the system will help them attain gains in job performance.
- Effort expectancy (EE): Is the extent of ease associated with the use of the system.
- Social influence (SI): Is the degree of importance being recognized by others to use a novel technology.
- Facilitating conditions (FC): Is the extent to which an individual believes that organizational and technical infrastructure is in place to support their use of the system.
- Hedonic Motivation (HM): Is the perceived enjoyment when using technology, despite the expected performance consequences.
- Price Value (PV): Is the consumer's cognitive trade-off between the cost of using the applications and the monetary cost of using them (Venkatesh et al. 2003, p. 161).

The participants had various responses to the research questions three as shown by the codes in Table 4.3. Their beliefs and perceptions that influenced them to adopt IoT technology converged around six central themes that reflected the proposition of the UTAUT2 framework as shown in Table 4.3. These include performance expectancy, effort expectancy, facilitating conditions, social influence, hedonic motivation and price value.

Table 3
List of Codes and Themes

RQs	First Coding	Second Coding - Themes
RQ3	Increase in productivity Efficiency Untether researcher from the lab Enhance collaborative research Limited empirical research to support effectiveness of IoT in education Reliability of IoT technology Battery life Power constraint power	Performance expectancy
	Efficiency in education Managing mundane tasks Lack of technical expertise Fear of technological change Limited understanding of IoT Time constraints Steep learning curve Interoperability issues Network congestion Fear to fail – integrating IoT into curricula Readily available information on DIY Increase access to information	Effort expectancy
	Emerging technology as educational tools Inspiration from early adopters Marker space movement	Social influence

Table 3: Continued

RQs	First Coding	Second Coding - Themes
	Institutional policy Professional development Change management practices Need for collaborating working environment Guidance from faculty	Facilitating conditions
	Keeping abreast with emerging technologies Manage routine tasks	Hedonic motivation
	Acquisition cost Implementation cost Inadequate institutional resources	Price value

Theme #1 – Performance expectancy. Performance expectancy emerged strongly amongst faculty especially those who conduct laboratory and field research. They noted that the ability to use IoT technology to enhance productivity and efficiency were most prominent in influencing their behavioral intention and use behavior of this technology. Participant V026 and V016 emphasized that IoT has the potential to untether researchers from the field using sensor technology as they collect and autonomously transmit data from remote study locations. Therefore, this capability makes this technology ideal for enhancing field research.

The participant V021 explained that IoT has the potential to break the disparate silos of research undertaken within institutions of higher education by supporting interdisciplinary research. The participant reiterated that duplicative research work across colleges and schools within institutions of higher education is slowing down the common goal of producing new scientific knowledge. Participant V015 elaborated that IoT technology provides an ecosystem where the different disciplines within higher education can work within a shared space to leverage their synergies on research projects.

The student participant V023 noted that error occurrences in colleges are prone especially when there is duplicative work conducted across different offices using non-integrated systems. The participant expressed that there is a need for integrated systems build on IoT platform to enable cross-departmental access to the information. Participant V011 questioned that "Why do we have to continue with the inefficiency of using paper slips to register for some courses?" The participant envisions IoT as an integrated system that can bring all university departments within a shared working environment.

The performance expectancy also emerged as a substantial factor that influences the decision to adopt IoT technology amongst the administrators. They noted that the ease of use of IoT technology is an essential factor in determining if it can be integrated to enhance their efficiency in supporting the teaching and learning process.

Theme #2 – Effort expectancy. Effort expectancy emerged thematically across the participant responses. Most of the faculty who identified themselves as early adopters expressed excitement about using IoT technology because of the potential opportunities that this technology is likely to play in the teaching and learning process. They explained that IoT is expected to make their job processes more manageable and enhance their efficiency, effectiveness, and productivity.

Participant V019 mentioned that he is likely to adopt IoT in the teaching and learning process if there are guaranteed efficiencies such as reduction of time and effort required to complete mundane tasks such as grading, taking students roll call, and class registration among many. However, the participant noted that there is likely to be an increased desire to apply IoT as educational tools if it can intuitively be used to accomplish specific tasks. Participant V011 stated that "If IoT technology is technically challenging to integrate into pedagogy or if it is not relevant for teaching particular aspects of my course, then this would influence my decision to adopt this technology."

Relatedly, participant V019 said that, "It would be an interesting dilemma if you have a constant level of interruption in class when someone's struggling with technology then there are people distracted when they try helping an individual. So, the supposed efficiency creates a greater disruption in trying to obliterate."

The participants also mentioned that having an understanding of IoT-enabled education is an essential factor for user acceptance. Therefore, if IoT technology is to be embraced in higher education, both faculty and students must perceive it as useful. However, participant V025 mentioned that "Although my general view is these technologies are important in an education system, the challenge I find as an end user of these technology is on how to keep up with managing data."

The response from the student participants showed that they have a high preference for digital content. They emphasized that they are more likely to use IoT technology if it can reduce the amount of effort in their learning such as enhancing ubiquitous access to information and untethering them from physical learning spaces.

Theme #3 – Social influence. Social influence was found to be a high predictor of behavioral intention and user behavior to adopt IoT technology amongst the participants. Faculty noted that the desire to keep abreast of trending technology influenced their choice to choose IoT related technologies. Participant V011 said “I gravitated toward working with IoT devices because of the influence from collaborative projects I have done with some of my colleagues who I consider to be techie.”

The researcher also found out that there is drive from some community members that include faculty, student and other IoT enthusiast within Athens City to form an active maker space club. The members conduct summer camps with a focus on learning and building IoT related devices. Participant V017 mentioned that the maker space movement within Athens City had influenced his decision to use IoT devices.

The student participants emphasized that it is essential to keep abreast of emergent technologies such as IoT technology. Participant V022 noted that “I believe having an understanding of IoT affords me with the skills applicable in today’s digital economy.” Further, the student participants explained that they have opted to adopt IoT technology because they perceive themselves as being technologically advanced. They also believe this has allowed them to conduct trending research projects that are likely to positively influence the kind of job opportunity they seek after college.

Theme # 4 – Facilitating conditions. The administrators noted that despite the effort by institutions of higher education to attract and accommodate student's technological needs, having their smart gadgets connected to campus Wi-Fi must be carefully weighed against implementation challenges and security threats that are likely to evolve.

Participant V015 indicated that education policies are paramount when it comes to adopting new technologies. The participant further reiterated that policies that encourage and explicitly support the integration of IoT into the teaching and learning process are crucial. The participants noted that it is essential to have strategies that foster change management practices to reduce barriers to technology adoption. Also, they mentioned the need for professional development programs that should incorporate IoT tools to encourage early adoption of these technologies. They noted that this would help educators develop innovative methodologies and appropriate pedagogies that reshape classroom experiences. However, participant V017 noted, "Beyond embracing a particular educational tool, there is the need for faculty support to determining how best facilitate an IoT enabled learning environment."

Participant V021 explained that it is crucial to set up policies that facilitate collaboration in the IoT ecosystem between institutions of higher education and private industry to promote its successful implementation within higher education.

The students pointed out that the role of faculty is paramount in influencing students to adopt IoT. They elucidated that faculty members have the flexibility to select their pedagogical tools and given their power of choice, this is paramount in controlling the decision of tools that meet their pedagogical needs at the lowest cost for students.

Theme #5 – Hedonic motivation. There were similar sentiments amongst the study participants regarding their enthusiasm towards adopting IoT technology. Participants pointed out that they have adopted IoT related technologies to keep abreast with emerging technologies. They further reiterated that autonomously managing mundane tasks has been a driver in taking this emerging technology.

While habits did not explicitly emerge as a critical factor affecting the adoption of IoT technology amongst the respondents, participant V019 stated that “Keeping up with technological trends motivated me to start experimenting with IoT technologies.”

Theme #6 – Price value. While the cost of adopting IoT was not an outstanding factor in influencing IoT use amongst faculty, both students and administrators mentioned that despite the positive reputation that IoT has received from other sectors, the costs and inadequate institutional resources to support effective technology integration had influenced its use.

Administrators mentioned that despite the primary objective of institutions of higher education being to educate students; however, there are other competing interests for the limited resources which may affects the institution-wide adoption of IoT currently at Ohio University. Participant V024 pointed out that “In spite the proliferation of educational technology, Ohio University is yet to adopt IoT as an educational tool fully.” The participants explained that the integration of the IoT into the education system will be gradual due to the cost and challenges of implementation.

Chapter Five - Discussions, Implications and Conclusions

The purpose of this study was to explore how IoT can enhance data-driven decision-making in higher education. This chapter presents the discussions, implications and the concluding remarks of the study. The discussion section provides an interpretation of the findings of the study. The implication section provides a reflection on the lessons learned and how finding of the study apply to different stakeholders in higher education. The chapter ends with concluding remarks that summarizes the findings and recommendations for future research.

Discussion of the Findings

This descriptive case study design allowed participants to share their experiences of interacting with IoT technology. The discussion aligns to the research questions of the study. The findings provided insight into how the participants engaged with IoT technology, their perceived advantages and drawbacks of using IoT technology in D3M and factors influencing the adoption of IoT.

There were three specific findings related to how the participants engaged with IoT technology to enhance D3M. The findings show that the participants have used this technology to augment ubiquitous access to information, personalize learning experience and enhance student engagement.

Despite the immense opportunities that are likely to be realized from integrating IoT technology into the teaching and learning process, some studies (Aagaard, 2015; Taneja, Fiore & Fischer, 2014) have reported that digital devices can be a distraction not only to the user but also to the other students in proximity. The authors said as students use digital learning tools for non-class related purposes, this negatively impacts their learning. Therefore, in preparation for an IoT enabled education system, faculty need to set expectations for classroom technology use explicitly. Such expectations should be part of the student orientation and syllabi to promote the constructive use of IoT devices as learning tools while discouraging the unconscious distraction.

The administrators believe that an IoT enabled education offers students a context situated learning experience. The experience in turn leads to numerous opportunities to collaborate and engage with other learners. Furthermore, the administrators expressed excited about the promise of collecting student data in an IoT enabled learning environment. They indicated that student data could inform them about students learning behaviors and activities. With the promise of capturing data on student's behavior and learning activities that had historically been impossible, IoT enabled education provides education administrators with the opportunity to identify warning signs of students at risk of dropping out due to academic or financial challenges. This platform also enhances the opportunity to design teaching and learning strategies that offer individualized instructions to match students learning styles, needs, and aspirations. These findings are broadly consistent with the study of Bagheri and Haghighi Movahed (2016) who reported that IoT enabled education facilitates learning and teaching on any platform ubiquitously. Additionally, they stated that data collected from IoT devices could be used to offer individually tailored learning experience. Relatedly, they mentioned that embedded sensors and mobile devices in an IoT enabled classroom facilitates active learning with the opportunity for increased engagement and collaborations between students and faculty.

Inevitably, in an IoT enabled educational setting, student’s experience self-regulated learning. This learning approach improves their meta-cognitive skills and supports them to self-pace their learning. This discussion confirmed Kiryakova, Yordanova, and Angelova (2017) report that stated that smart devices are essential for reporting and keeping track of learner's achievement. Such data containing student profiles can be analyzed to retrieve the pertinent information that reflects how students acquire knowledge and skills.

As D3M becomes a new normal in higher education, educators are looking for ways to tracking different aspects of their students including their performance, engagement, and behavior. Integrating IoT into the curricula offers the opportunity to store and analyze student data. Such data could be used to design personalized instructions tailored to match students learning needs and expectations. Data from these measurable aspects of student can be leveraged to create strategies that enhance learning experience. The information sifted from such data can be used facilitate teaching and learning strategies that exploit individual students’ context such as learning needs, styles and aspirations using adaptive learning tools.

With more students coming to the institution of higher education with multiple IoT enabled devices, these institutions need to understand how and when their students connect their devices to campus networks. This information can be used to make decisions regarding the kind of infrastructure to be provided to the students. Similarly, as these institutions increasingly support today’s learners to take ownership of their learning, an IoT enabled education enhances access to crowd-sourced information. This ubiquitous access to information allows students the flexibility to gain knowledge across different contexts. Demirer et al., (2017) reported that with the prevalence of smart wireless devices, it has become apparent that IoT technology is enriching learning in both formal and informal setting. Additionally, they noted that IoT is augmenting the technological dimensions of seamless education by supporting the nexus between in-class and out-of-class learning experience as shown in Figure 4.1.

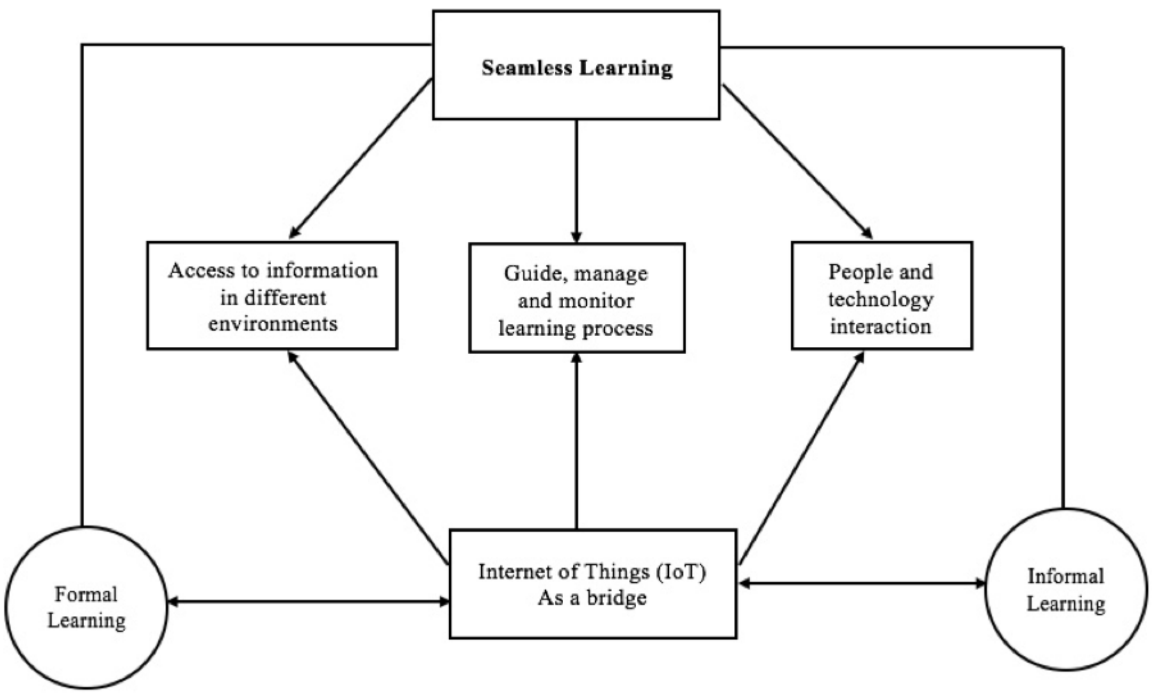

Figure 7. IoT in Seamless Learning
Source: Demirer et al. (2017)

The participants mentioned that they have used IoT enabled technology to keep track of campus resources through access control. This unexpected finding showed that IoT technology could be used to seamlessly monitor resources while having the ability to predict when resources need to be replaced. The administrators mentioned that using IoT enabled facilities management system, they can identify and determine who is using campus resources such computer labs and access to experimental labs after normal working hours. Such information could be used to schedule lab usage and to determine when lab resources need to be replenished before it runs out.

While the pedagogical application of IoT technology is relatively new in higher education, the findings of this study shows that there are many potential applications. The findings indicate that the most promising opportunity of integrating of IoT into D3M includes improving the learning experience, customized teaching and learning, parity to diverse learners, and context-aware education.

One of the most promising opportunity of integrating IoT into the classroom is the possibility of bringing real-world context into education experience. Adopting IoT technology in education has the potential to facilitate authentic learning. As a tool of learning, this helps students to relate theory to practical applications. For instance, IoT enabled technologies such as virtual reality (VR) and augmented reality (AR) allows students to apply the knowledge and skills from class into the real-world setting. Relatedly, such a learning environment provides instructors with the opportunity to assess specific competencies that may not be possible in the real-world scenarios because of ethical concerns. These findings are broadly consistent with the study by Hether et al., (2017), they reported that the use of IoT enabled technologies are common in health-related courses such as the study of human anatomy. They also noted that this allows students in medical education to safely practice within uncommon but potentially life-threatening situations.

On a different note, Ahn et al. (2016), emphasized that the experiences in virtual environments may influence individuals to consume different perspectives, even after leaving the simulated learning environment.

As the education sectors strive to impart today's learners with critical skills applicable in different scenarios, faculty need to offer students training that transcends siloes of technology skills toward a broad understanding of the current digital environments. Therefore, integrating IoT into curricula presents students with exciting learning possibilities that can enable them to adapt their skills to new contexts intuitively. This form of experiential learning transforms students from passive learners into creators of knowledge because it fosters pragmatism. This finding concurs with the report by NMC Horizon (2017) that emphasized that higher education is better placed to be an incubator that spurs innovation. The report also stated that higher education could bolster a culture of entrepreneurial thinking by churning graduates who can improve the current workforce.

As the use of in-the-moment data becomes the new normal in designing strategies that support the teaching and learning process in higher education. In an IoT integrated education system, the use of smart devices as learning tools offers the opportunity for more student data to be collected even in real-time. The insights from such data can be gleaned to design customized lesson plans that match individual students learning needs, styles, and aspirations. Integrating student data to automated systems provides a safe learning environment that can be used to support instructional interventions such as personalized feedback, tailored reminders, and alerts sent to individual students about the due dates of the assignments. These findings concur with other studies that reported that the proliferation of IoT enabled devices in institutions of higher education enables collection of data that can be harnessed to interpret student's behavior and activities (Osisanwo, et al., 2016; Vujovic & Maksimovic, 2015).

Considering diversity in terms of background, ability, age, and experience of today's students, an IoT enabled education has more it can offer students with modified learning plans while maintaining the standard and quality of education. The multiple IoT embedded devices create a new level of importance when used to create appropriate learning experiences for diverse groups of learners. From the finding of this study, IoT enabled education untethers learning spaces to ensure that time and places are not barriers to learning; thus, supporting anytime-anywhere learning. Keane and Russell (2014) in their study emphasized that unlike tradition educational system where physical presence is required of both the teacher and student, IoT technologies can bring students to virtual classrooms either synchronously or asynchronously.

As part of today's diverse group of learners, non-traditional students have the opportunity to pursue higher education and undergo professional development while maintaining their routine activities. IoT enabled school has the potential to expand access educational opportunities to older students while providing them with the convenience of learning. Typically, these learners face social and economic pressures since they work full-time jobs and have families to support. IoT enabled curricula can be used to support the principles of competency-based learning in order to assess adult students on how they link their competencies to their education.

This finding concurs with the report by NMC Horizon (2017) that noted, the advent of always-connected devices fosters flexibility in how, when, and where people learn. Further, they reported that as the education sectors strive to achieve an inclusive learning environment that supports the education of special needs students. IoT technology could provide the appropriate learning environment for these learners and help with their social integration.

Despite the limitless applications of IoT, findings from this study noted that there are three fundamental pitfalls of integrating IoT in D3M in higher education. These include privacy issues, data security, and connectivity challenges.

While IoT technology holds immense promise for improving D3M, however, there are privacy and security concerns that need to be tended if the full value of IoT is to be realized in higher education. The proliferation of IoT enabled devices into institutions of higher education turns campus networks into prime targets for cyber-attacks. Even as university put effort to accommodate the growing number of smart devices connecting to the campus network, it is crucial to consider the implementation challenges and security threats that are likely to evolve.

As data security and ethical concern remain common themes that arise during the discussion about IoT, as more smart gadgets connect to the campus network. What happens to the vast volumes of data generated by these devices? Without a definite answer to this question, this remains a concern to be considered before the full implementation of IoT as an education tool.

Given the plethora of devices within the IoT ecosystem, it is a challenge connecting these devices to the current model of communication architecture that relies on a centralized authentication approach to connect to the network. IoT technology is designed on the principle of a decentralized network that supports a peer-to-peer model of communication. Additionally, heterogeneity within the IoT systems not only causes an interoperability issue on the hardware part of this technology because of the different vendors within the IoT spaces, but the incompatibility in the interface and data transfer protocols in addition to other factors such as the mobility of these devices, energy limitations, memory limitations and computational limitations can be a challenge to information sharing. Islam et al., (2015) attests to this challenges in their report. They noted that because of the diversity in IoT products due to different manufactures and vendors, interoperability issues are prevalent within IoT-based healthcare services.

Due to the likely increase in data sharing within an IoT enabled education system, security of data becomes an increased risk factor. This vulnerability becomes a more critical issue especially when third-party service providers are contracted to support the processes within an IoT ecosystem.

Information transparency becomes a critical issue because within an IoT ecosystem there are several layers of services implemented by different systems. Therefore, who has access to user data within an IoT ecosystem? This kind of question continues to arise as different sectors grapple with how best to address the current cybersecurity threats. Relatedly, at the present technological state of IoT, integrating this nascent technology to classroom runs the risk of shifting the instructor's role to that of a technician as they are overseeing technology implementation rather than as a facilitator of learning. Therefore, while it is inherent for instructors to be technologically proficient, providing professional development that improves the instructor's use of IoT technologies in their pedagogy will influence the adoption of IoT technologies. Faculty can also join forums that focused on how instructors can adopt IoT technologies in their pedagogies.

Further, adopting IoT technologies into classrooms could create other instructional challenges since the focus of faculty and students may be drawn away from learning the underlying theories and critical reflection to the experiential aspects of learning. To affirm this, Kolb (2015) noted that the integration of nascent technologies into learning spaces tends to shift the role of instructors to technicians rather than facilitators of learning. They added that this instructional challenge could impede critical reflection.

The beliefs and perceptions reported to influence the adoption of IoT technology in higher education include performance expectancy, facilitating conditions, effort expectancy, social influence, hedonic motivation and price value. These factors were guided by the propositions of the UTAUT2 framework (Venkatesh et al., 2003, 2012).

Performance expectancy had a strong influence on the adoption of IoT technology amongst the participants in the study. It became clear that the potential of IoT technology to create a shared working space where different disciplines can leverage their synergies to collaborate on research projects improves productivity. Additionally, using IoT to untether learning from physical spaces promotes seamless learning as in time and place seize to be barriers to education. Relatedly, faculty are more likely to adopt IoT as educational tools it improves their efficiency in conducting routine and mundane tasks such as grading, taking students roll call and class registrations.

The participants were most likely to adopt IoT technology for teaching and learning if it guaranteed efficiencies. However, there is a need for professional development to increase awareness about IoT technology and an appraisal on how it fits into curricula. Therefore, facilitating conditions that support ongoing training about IoT technology and how it can be integrated into the teaching and learning process is essential to increase awareness.

Perceived efficiency was another factor that participants indicated as a driver to adopting IoT technology for teaching and learning. It is important to note that faculty buy-in into IoT can only be realized through training and support to increase acceptance level and desire to use IoT technology in institutions of higher education. In order to enhance faculty buy-in into integrating emerging technologies like IoT, administrators need to increase faculty awareness about why such technologies can not only improve their efficiency but also supports their effort in enhancing learning.

While there are costs associated with acquisition and implementation of new technologies, this did not have a direct influence on faculty behavior towards adopting IoT technology. In that faculty and students would in most instances use the technology availed to them by administrators. Cost can therefore be perceived as a concern for the administrators while efficiency was a concern for faculty. However, for faculty to be efficient with the availed technology, the administrator needs to set up policies that support professional development to increase awareness about IoT technology and how it can be integrated into the curricula.

Higher education can be incubators of IoT technological innovations if IoT is integrated into the teaching and learning process. Therefore, higher education needs to facilitate its use as learning tools and management platform across a broader population within institutions. Thus, if IoT technology is to gain traction across institutions of higher education, it is crucial to understand where different people are in the spectrum of technological awareness.

As campus networks remain prone to cyber-attacks, this is exacerbated by weak passwords set up by users. As IoT increasingly becomes part of the campus network, there is a need for cybersecurity awareness amongst students, faculty, and administrators within higher education. This discussion aligns with the findings from a survey of 250 IT professions from higher education and 300 students that was conducted by the technology firm CDW-G (2017). The study found that 76% of students admit to engaging in risky behavior while connected to the campus network. The risky behavior ranged from using publicly available Wi-Fi, visiting questionable websites, helping non-approved individuals to access campus networks and opening messages from unknown senders.

Implications

Beyond the challenges of implementing IoT technology into higher education, the findings and conclusions drawn from this study point out some implications for practice. The section describes effects of the study to faculty, students, administrators, curriculum, and finally implication for policy.

Implication for faculty. As the current educational system gets disrupted by technological advances, it is important to acknowledge that faculty will remain the most important influence on student's acquaintance with IoT related technology. Therefore, there is a need for faculty development with a focus to enhance their awareness of IoT technologies, and learn how to integrate IoT to their pedagogies. This will in turn positively contribute to graduating students that are astute with current technological trends in preparation for an IoT enabled workforce.

IoT technology has the potential to become a catalyst that will morph the education system from passive learning to a collaborative, active, self-directed, and engaging model of learning. This would help students not just to increase their knowledge but also develop the skills needed to succeed in today's digital society. Therefore, it is pertinent for professionals in higher education to keep abreast with this anticipated future trends.

Additionally, with the disruptive technology, the role of faculty is gradually transforming from teacher to facilitator and coach. As stated earlier, faculty are still a crucial link to students learning process, but IoT will most likely alter student-faculty interactions. Therefore, current and prospective instructors need to be judicious with current technological trends in preparation for an IoT enabled learning environment. In effort to prepare faculty to work with emerging educational technologies, professional development becomes a necessity focused on enhancing their awareness of IoT technologies and how it can be integrated to their pedagogies.

As faculty adopt IoT technology in their pedagogy, this will facilitate them in designing strategies that support personalized learning such as flexible learning environments and tailored education paths that enable students to own their learning. Faculty can leverage the connectedness aspect of IoT technology to design learning spaces that are more interactive and collaborative.

Implication for curriculum. As technologies are rapidly changing, integrating IoT in the curricula does not only support experiential learning, but it also facilitates learners to develop attitude that appreciates technology as a tool that can enhance efficiency. These connected learning environments can generate student profiles with data on aspects such as attendance, performance, and productivity. Using artificial intelligence capabilities and data analytics, student data can enable a holistic view of learner engagement and knowledge advancement that can be used to foster personalized learning experiences.

In the contemporary workforce, it is likely that employees will need to have some knowledge of IoT technology. In order to foster this fluency, it is import to impart students with an understanding of IoT technology and how it can be applied in real work situations. Therefore, it is essential for faculty to design teachable moments that can help students to make connections between the application of IoT technology and the intended outcomes. Leveraging IoT technology in creative ways allow students to adapt its use from one context to another intuitively. García-Sánchez and Luján-García (2016) argued that IoT applications are steadily transforming educational technologies from being static applications to more interactive tools of learning.

Implication for students. As more students increasingly juggle schooling among other personal and professional commitments, IoT-enabled education can support their academic engagement by seamlessly connecting learners to academic resources. For the students, this might mean more self-directed learning. This learning approach can be an advantage for college-ready students but a challenge for traditional college-age students. On the other hand, the self-directed learning fosters a culture of lifelong learning. With proper coaching, mentoring and facilitation of learning from faculty this will likely lead to experiential learning that would have more meaning than other forms of learning.

The motivation for self-directed learning enhances the quality of the learning experience. While IoT technology is likely to help students to bridge time and physical space in learning, this is not only giving students the opportunity to manage their education, but it is also fostering authentic learning because using their smart devices empowers them with their own data. Relatedly, if students can see physical signs of their learning in real time, then this will support them as they self-pace their education. Similarly, as more students opt to use IoT devices as part of their project to automate routine and mundane tasks, they end up embracing a culture of learning by experience. This in turn elevates them into active contributors to the knowledge ecosystem.

As a learning tool, IoT technology promotes authentic learning. It provides learners with the opportunity to interact with real-world objects which fosters an increased understanding of subject matter. In an IoT enabled education system, students have the opportunity to self-track their learning journey. Additionally, within a smart learning environment, students have seamless access to data that supports the formation of connected groups of practice. Such data can be used to supplement their coursework through sharing ideas with an entire universe of specialists.

Finally, IoT enabled education is likely to reduce the cost field research amongst student. IoT supporting technologies like virtual reality allow students to take virtual field trips without leaving their classroom. Ahn et al. (2016), specified that encounters in the virtual learning environment could impact learners to expend alternate points of view, even after leaving the simulated earning condition.

Implication for administrators. As the cost of IoT devices continues to decline, more institutions of higher education will embrace this nascent technology into their teaching and learning process. However, it is important for administrators to note that if the real value of an IoT enabled pedagogy is to be realized, this approach of pedagogy requires having a significant number of devices to support an IoT curriculum. This raises the cost for acquisition, implementation and maintenance of an IoT enabled education system.

Administrators need to understand that while IoT technology could facilitate data-informed teaching and learning, most often tools used to improve student success can be invasive to their privacy. IoT enabled devices are capable of capturing data on student attendance, how regularly they contribute to discussion boards and even their grades. However, students may be uncomfortable having such data shared with prospective employers. Therefore, it is fundamental that as administrators sign contracts with vendors providing IoT services, the agreement has to ensure that the option to opt-out of data-sharing is set as the default. This memorandum can ensure that student data is not collected and monetized for other purposes.

While collaborative learning has become the new normal in enhancing student's learning experience, IoT-enabled education is likely to heighten the need for interdisciplinary instruction design. Therefore, administrators need to develop policies that foster collaborative research. Similarly, instructional designers need to develop a better understanding of course design within connected and integrated learning environments.

While the primary objective of institutions of higher education is to educate students, the realities of higher education include competing for grants and resources. This type of academic conflicts can foster silo mentality. However, as higher education strives for interdisciplinary collaboration, an IoT enabled education lends itself as a tool to create bridges between departments and colleges within institutions of higher education.

For successful implementation of IoT within higher education, there is a need for the development of comprehensive policies that facilitates the integration of IoT technologies in the teaching and learning process at the institutional level. Such a policy needs to include students, teaching and non-teaching staff within institutions of higher education.

Implication for policy. Educational policies are paramount when it comes to adopting new technologies. There is a need for policies that encourage and explicitly support the integration of IoT into the teaching and learning process. These policies will change management practices. The change will in turn, reduce barriers to technology adoption and professional development programs. The outcome of such policy would be reshaped classroom experiences that are both innovative and appropriate for advancing academic success for faculty and students.

It is important for educational administrators to note that while IoT technology is likely to increase the number of aspects of education that can be measured, over-reliance on data can lead to false positives when it comes to learning. The models used to arrive at pedagogical decision making must be challengeable and peer-reviewable. Therefore, direct student-instructor relationships are still required to capture non-communicative learning challenges that students' may be experiencing.

It is a critical time for emerging technologies in higher education as educators are experimenting with the adaptive-learning system to offer students enriched learning experiences. Increasingly, smart devices are being used to collect student data. Through predictive analytics, insight information is used to increase student retention and completion rates. However, despite the immense opportunities that IoT can bring into higher education, there is need to review its ethical concerns before it's fully implemented.

Concluding Remarks

As the current education system transitions from traditional to a data-informed education process, the adoption of IoT technology within the institution of higher education is slowly gaining traction. The implementation of IoT technology in higher education can provide potential affordances to the teaching and learning process. The opportunities include authentic learning experience, increased collaborative learning, improved student-centered teaching, and an augmented individualize learning consistent with the learners' needs and preferences, ubiquitous and context-aware education, and support parity for diverse learners. As IoT gets integrated to the teaching and learning process, the education sector is likely to move a competency-based and multiple pathed learning.

Although IoT has several potential applications in the teaching and learning process, it is crucial to consider its drawbacks before its full implementation in higher education. The study found out that at the current state of IoT technology, privacy concerns, data security, and connectivity challenges as the primary concerns of integrating this technology in D3M within higher education.

The findings of this research study recommend future research. A recommendation for additional research is needed to determine best practices that can be used to integrate IoT technology into the curricula.

There is a need for future research to establish best practices for faculty development to increase their knowledge of IoT technology awareness and guidelines for incorporating IoT technology into their pedagogy.

Considering the level of awareness about IoT technology amongst the potential participants for the study, there is a need for more research to explore the level of awareness about IoT technology in the education sectors and how pedagogical strategies can be designed to implement it as a learning tool.

More research can be conducted to focus on developing best practices from faculty who are early adopters of IoT technology within institutions of higher education. This can be critical to persuading more faculty to adopt IoT technology into their pedagogy. This can also be used to form a network of faculty members to persuade further adoption among late adopters or laggards.

Another recommendation for future research would be to study how institutions could address cyber-attacks in the advent of IoT integrated curricula.

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Appendix A - Interview Protocol

I would like to thank you for volunteering to participate in this study. The study is about the Internet of Things (IoT) and how it can enhance data-driven decision-making in higher education.

Over the next forty-five minutes, I will ask you a series of questions about yourself and this will segue to questions focused on your experience with Internet of things (IoT) technologies as faculty and/or administrator or as a student.

This interview will be audio recorded and if you do not like the interview to be recorded, please let me know before we can start the interview. While this interview is estimated to last for forty-five minutes, if you would like more time to elaborate, please let me know at the end of our first interview session. If you need to leave at any time during our interview session, let me know and we can conclude and continue at another time.

I would also like to remind you that all information you provide will be kept confidential. The recorded interview will be saved on OneDrive cloud storage that meets the HIPPA compliance (Health Insurance Portability and Accountability) and it will only be accessible to the researcher. The audio file will be deleted after three years leaving no discernable files from the recorded interview.

During the interview, I will ask you a series of general questions where you are encouraged to do most of the talking.

In the context of this study, the IoT refers to any technology that interconnects everyday objects (devices) to each other and to the Internet to enable “anytime, anywhere” access to information.

While data-driven decision-making (D3M) refers to making decisions backed up by empirical evidence.

Do you have any questions for me before we begin?

Then, let's begin. Date: ____________________

Participant's ID: ___________

RQ1: How have you as faculty or administrators or student at Ohio University engaged with IoT technology to enhance D3M?

To understand how IoT technologies might impact education, first I would like you to help me definition what IoT is about.

1. What is your definition of IoT?
2. How many years of teaching experience do you have as a faculty?
3. Describe your experience(s) using IoT related technology to enhance the teaching and learning process.
4. List ways you are using IoT devices for instruction.
5. When you reflect on your teaching experience before and after the IoT era, what are some of the positive/negative things that you have experienced in using IoT technology in supporting you as an instructor?
6. How are you being supported using IoT technologies in your classroom?
    a. Give examples of specific supports.
    b. Describe how support is made available to you
7. Describe the support that you may need to meet your specific needs in terms of using IoT technology for instruction.

8. What training opportunities have you had to equip you for effective use of IoT technology as an instructor?
    a. What types of professional development is offered in your college as training for integrating this technology in your pedagogy?
    b. Do you feel that you received adequate training to incorporate the IoT technology in your instruction?

RQ2: What are the perceived advantages and disadvantages of IoT technology among administrators, faculty, and student in D3M?

1. What concerns do you have regarding the use of IoT technology in the teaching and learning process as an instructor?
2. What encouraged you to integrated IoT related technology in your class curricula?
3. How does IoT related technology enhance your teaching experience?
4. What is your experience with using IoT technology with you students?
5. What types of IoT related technologies do you use in the course of your work?
6. Can you describe how you use IoT technology to enhance the teaching and learning process?
    a. How has this changed your view in designing instructions for your students?
7. Do you know of any other faculty, administrator, or study using IoT related technology?
    a. If so, how?
    b. Can you refer me to another faculty, administrator or student who maybe a resourceful participant for this study?

8. What factors are affecting the adoption of IoT related technologies in the teaching and learning process?
9. From your perspective, how can other faculty be supported to integrate IoT technology in their pedagogy?

RQ3: What beliefs and perceptions are affecting the adoption of IoT technology in higher education?

1. Please share your thought on how IoT related technology affects your life.
2. Do you have concerns regarding your experience using IoT related technologies? If so, what are they?
3. What are some of the disadvantages that you have experienced as an instructor while using IoT related technology in your courses?

CONCLUSION

Thank you for taking time to participate in this interview. Your response will be insightful to my dissertation research and hopefully the findings from the study will support the integration of IoT technologies in higher education to enhance data-drive decision-making.

Appendix B - IRB Approval

Project Number	17-E-178
Project Status	APPROVED
Committee:	Office of Research Compliance
Compliance Contact:	Rebecca Cale (cale@ohio.edu)
Primary Investigator:	Godfrey Ogallo
Project Title:	IoT Enhancing Data-driven Decision-making in Higher Ed. Case Study of Ohio University
Level of Review:	EXEMPT

The Ohio University Office of Research Compliance reviewed and approved by exempt review the above referenced research. The Office of Research Compliance was able to provide exempt approval under 45 CFR 46.101(b) because the research meets the applicability criteria and one or more categories of research eligible for exempt review, as indicated below.

IRB Approval:	06/05/2017 09:03:09 AM
Review Category:	2,4

Waivers: N/A

If applicable, informed consent (and HIPAA research authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. In addition, FERPA, PPRA, and other authorizations must be obtained, if needed. The IRB-approved consent form and process must be used. Any changes in the research (e.g., recruitment procedures, advertisements, enrollment numbers, etc.) or informed consent process must be approved by the IRB before they are implemented (except where necessary to eliminate apparent immediate hazards to subjects).

It is the responsibility of all investigators and research staff to promptly report to the Office of Research Compliance / IRB any serious, unexpected and related adverse and potential unanticipated problems involving risks to subjects or others.

This approval is issued under the Ohio University OHRP Federalwide Assurance #00000095. Please feel free to contact the Office of Research Compliance staff contact listed above with any questions or concerns.

Research Compliance
117 Research and Technology Center 740.593.0664
compliance@ohio.edu

Appendix C - Informed Consent

Ohio University Adult Consent Form without Signature

Title of Research: Internet of Things (IoT): Enhancing Data-drive Decision-making in Higher Education: Case Study of Ohio University

Researcher:
Godfrey Ogallo
go990311@ohio.edu

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to participate in this study. You should receive a copy of this document to take with you.

Explanation of Study

As data-driven decision-making become a new normal in higher education, this approach of decision has become essential in enhancing teaching and learning processes, supporting student-centered learning experience, facilitating customized instructions that address individual student learning needs, reducing the cost of education, maintaining campus security, and improving operational efficiency among others. The BYOD policy has supported the increased connection to the campus network from personal smart devices brought to campus by students, faculty, and administrators. Most of these devices are embedded with sensing, identifying and data transmission capabilities. Given that these devices generate a plethora of data, institutions of higher education can leverage data generated from these to enhance data-driven decision-making. Your participation in the study will last 45 minutes

Risks and Discomforts

No risks or discomforts are anticipated

Confidentiality and Records

Your response will be kept confidential by assigning an anonymous code to your recorded interview. The interviews will be transcribed. After the transcription, the recorded conversations will be deleted leaving no discernible files. The transcripts will be securely uploaded to OneDrive cloud storage that meets the HIPAA compliance (Health Insurance Portability and Accountability), and this data will only be accessible to the researcher.

Contact Information

If you have any questions regarding this study, please contact -

The investigator:

Godfrey Ogallo

go990311@ohio.edu
OR
The investigator's advisor
Dr. Greg Kessler
kessler@ohio.edu
740.593.2748

If you have any questions regarding your rights as a research participant, please contact Dr. Chris Hayhow, Director of Research Compliance, Ohio University, (740)593-0664 or hayhow@ohio.edu.

By agreeing to participate in this study, you are agreeing that:

- You have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered;
- You have been informed of potential risks and they have been explained to your satisfaction;
- You understand Ohio University has no funds set aside for any injuries you might receive as a result of participating in this study;
- You are 18 years of age or older;
- Your participation in this research is completely voluntary;
- You may leave the study at any time; if you decide to stop participating in the study, there will be no penalty to you and you will not lose any benefits to which you are otherwise entitled.

Version Date: [05/30/17]

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