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Review Article

Internet of Things (IoT) Implementation in Learning Institutions: A Systematic Literature Review

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ABSTRACT

Internet of Things (IoT) is a computing concept facilitating the management of collaborative activities from one central area. Millennial learners, growth in enrolment numbers in universities, and the need for equity and quality learning necessitate the use of IoT technologies in education. The focus of this paper is to examine IoT implementations in learning institutes, their application areas, the themes presented, the models and methodologies used, and the benefits. This study concentrated on publications from 2008 to 2017. The outcomes revealed that the utilization of IoT for tracking and tracing a learner's attendance had been one of the application areas of IoT in education. This study further categorized the papers and presents novel research opportunities based on concentrated themes and areas that had not been fully exhausted. Most research studies employed qualitative methods, with a few utilizing a quantitative approach with surveys. Research themes exhibited a shortcoming in other important themes, such as the models and methodologies used for implementing IoT. Finally, the results of this study agree that IoT implementation could help solve some issues in learning institutions like equity and quality learning. The results from this research also provide a base for future research works on the successful implementation of IoT in learning institutions.

Keywords: Adoption, information technology, intention, IoT, learning institutions

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INTRODUCTION

Integrating information and communication technologies in education has altered the learning environment (Albion et al., 2015), resulting in several changes and various improvements (Uzelac et al., 2015). The advancement of new technologies is as a result of the Industrial Revolution (IR) 4.0 (Hussin, 2018). The expansion is guided by the advent of artificial intelligence, the internet of things, and robotics, among others. The aim is to align people and technologies for any upcoming possibilities.

Internet of Things (IoT) utilization has taken root in several aspects of life including smart homes, factories, cities and learning surroundings (Chin & Callaghan, 2013; Marquez et al., 2016; Uskov et al., 2016). More citations are in Appendix A. IoT projects have been embarked upon to expand technologies like social networking and email, among others (Want et al., 2015). This has been made possible by enabling IoT in objects to disseminate information (French & Shim, 2016). As users' needs grow, innovative applications are being presented to track, control and automate peoples' activities everywhere (Asghari et al., 2019). For learners and instructors, the aim is to provide personalized services in pedagogy to create an intelligent environment (Bagheri & Movahed, 2016; Bandara & Ioras, 2016; Kamar et al., 2016).

IoT utilizes numerous subcomponents from different gadgets to attain the intelligent surrounding (Uzelac et al., 2015). It also employs diversified gadgets to provide consistent data dissemination (Kamar et al., 2016). Being an internetwork, IoT is significant technologically, physically, and largely in the socioeconomic surroundings (Krotov, 2017). Furthermore, the outfitting of a Wi-Fi facility, connected lecture halls, telecasting conference amenities, online repository, and several improved applications are for educating better leaners (ur Rahman et al., 2016).

In the current world, the educational climate revolution has led to an introduction of various modern kinds of learning and innovations (Bandara & Ioras, 2016). This has inspired the learning institutions to establish methods that can support learners and their growth using the current instruction techniques (Njeru et al., 2017). With the implementation of IoT in various environments, the main focus is to reshape every organization's operations, its objectives and policies (Onyalo et al., 2015). IoT aims to use heterogeneous networks to permit millions of people, places and things to participate (Hsu & Lin, 2018). In learning, the main objective is permitting physical space interactivity, to allow transmission of information or to enable learning (Veeramanickam & Mohanapriya, 2017). Hence, IoT needs to provide learner support in areas of personalized learning, interactivity, mobility, and also accessibility (Bagheri & Movahed, 2016; Farhan et al., 2017; Moreira et al., 2018). It can also lower the education costs and provision for quality education resources as compared to the existing channels (Bagheri & Movahed, 2016; Roy et al., 2016).

The most significant trial in education is the implementation of open, cheaper and quality guided global training environments (Jeffords et al., 2014). This comes amidst several hindrances in education that, if eliminated, would provision for access and immensely reduce the education costs (Aldowah et al., 2017). Hence, for the survival of institutions in the present era, there is a need for significant tools to impart better pedagogical actions to technology-savvy learners (Baker et al., 2016).

The key concentration areas of IoT applications have been smart cities, smart living, smart homes, smart health, smart security, and other approaches. For instance, the use of IoT in Smart homes (Stojkoska & Trivodaliev, 2017), IoT applications in Agriculture (Gómez-Chabla et al., 2019) for a clear perspective on IoT innovations, IoT in agro-industrial and environmental fields (Talavera et al., 2017) showing IoT utilization (monitoring, control, prediction, and logistics), IoT applications in healthcare (Ahmadi et al., 2019) showing various directions of IoT architecture in healthcare, IoT utilization in food safety (Bouzembrak et al., 2019), IoT for smart cities (Mijac et al., 2017) which reveals the infancy of IoT, and finally, IoT and supply chain management (Ben-Daya et al., 2019), which indicate gaps in frameworks and models in the supply chain. Apart from the mentioned, IoT has been speculated to enhance learning beyond the classroom area (Aldowah et al., 2017; Roy et al., 2016).

Nowadays, learners need to access education in a cheaper way while they are away from their study environments. Using gadgets that can allow anywhere and anytime access for learners can somehow overcome the aforementioned difficulties. IoT technologies, by supporting the learning process, can lower the cost for institutions (Bagheri & Movahed, 2016), ease resource sharing and also expand the quality of teaching (Farhan et al., 2017).

Looking at this area, there are several papers that have evaluated aspects of IoT in education, the significance and benefits, and correlated technologies. To the best of the researcher's knowledge as per this study, there is a lack of reviews addressing models and methodologies for implementing IoT in education. Hence, this paper presents a complete review of IoT models and theories in the context of learning from 2008 to 2017. In execution of the objective of this research, three research inquiries are presented below:

i. What are the predominant investigations on IoT, and the research concepts already described?
ii. What are the dominant models and theories employed in the study?
iii. What key constraints and omissions are found in IoT investigation?

For this exploration, the review is organized as follows: Section 2 studies the method employed for review including the protocol used, and the inclusion and exclusion criteria. Section 3 illustrates the data synthesis and extraction, and highlights publication sources.

Additionally, the distribution of articles as per publication year is presented. Section 4 demonstrates the results, including the benefits and methodologies. Lastly, section 5 discusses the conclusion.

RELATED STUDIES

This subsection cross-examines similar reviews in IoT implementation in learning environments. The objective is also to bring out the importance of IoT in learning environments. Additionally, it purposes to show the extent of IoT implementation in the learning context.

An exploration was conducted on IoT in education by Ramlowat and Pattanayak (2019). It examined benefits of IoT and its implementation in different areas of education, for instance distance studies, medical studies, computer science studies, among others. The paper also discussed the application areas of IoT apart from education. Another study was undertaken to review IoT smart campuses and their implementation (Zhamanov et al., 2017). The study brought out the significance of IoT in flipped classes and gave a comparison of it with the traditional methods. A different research looked at IoT and Big Data (Kusuma & Viswanath, 2018). The researcher examined the significance of IoT and Big Data in eLearning environments, and various eLearning procedures. A review on IoT in education was done by (Kassab et al., 2020), concentrating on benefits and challenges of incorporating IoT in educational areas and the curriculum. It also highlighted the challenges hindering deployment of IoT, which were security, human issues, and scalability.

Incorporating IoT in learning environments is a promising solution to overcome difficulties linked with high enrolment numbers and attaining equity. Accordingly, designing a university campus with the incorporation of technology boosts the learner experience (Aldowah et al., 2017). For instance, IoT has been utilized as a base for lifelong learning with Radio Frequency Identification (RFID and Near Field Communication (NFC) (Gómez et al., 2013) and also through learning analytics (Cheng & Liao, 2012). IoT has also been employed for underprivileged students in rural areas with sensors and wireless connections (Pruet et al., 2015). The outcome was an improved learner experience.

IoT has been incorporated in teaching and learning through pervasive technology (Chin & Callaghan, 2013). This contributed to an enhancement in the governing of campuses, while providing an effective delivery system for learning materials. IoT has been employed to enhance learning through data mining for efficient and effective online teaching and learning (Njeru et al., 2017). IoT has been applied to educational business models (Bagheri & Movahed, 2016), leading to minimizing the cost of firms, lowering time wastage, and bringing comfort to learners and educators. It eliminates the need for dedicated security

personnel by utilizing sensors and mobile gadgets. Finally, IoT has also been employed in vocational and university education due to its many benefits (Kortuem et al., 2013).

Hence, regarding the previous studies, this research explores uncovered areas through a comprehensive review. For instance, from the reviews undertaken, models and methodologies for adoption are minimally explored. Besides, implementations of IoT in learning have been maximally utilized.

REVIEW METHOD

Systematic literature inquiry is a methodical thorough analysis (Brereton et al., 2007). It is not about the aggregation of every available affirmation on a research inquiry. However, it aims to aid the creation of evidence-based suggestions for professionals. Research conducted by Kitchenham (2004) brought out the below mentioned points for performing similar evaluations:

- To give a summary of the already available evidence about technology. For instance, summarize pragmatic indicators of the advantages, inclusive of shortcomings of some definite procedure.
- To bring out any omissions in the latest explorations and to give suggestions for any supplemental investigations.
- For the provision of background to correctly place emerging research activities.

Conducting systematic literature reviews entails several discrete activities undertaken in three phases: planning, conducting the review, and reporting the review (Brereton et al., 2007). Furthermore, the steps mentioned are broken down into specific processes. They include: one, affirming the research inquiry; two, establishing a review protocol; three, validating the review protocol; four, identifying the appropriate research; five, determining paramount studies; six, evaluating the quality of the investigation; seven, extraction of required data; and eight, synthesizing the data.

Review Protocol

A review protocol outlines how a specific systematic review will take place to minimize researcher biases. It encompasses the rationale for the survey, investigation inquiries to be reported by the reviewer, the procedure to search the primary studies, procedures including the criteria for the study selection, quality assessments checklists for individual studies assessment, data extraction, and extracted data synthesis (Kitchenham, 2004). Figure 1 shows the selection process utilized in this research.

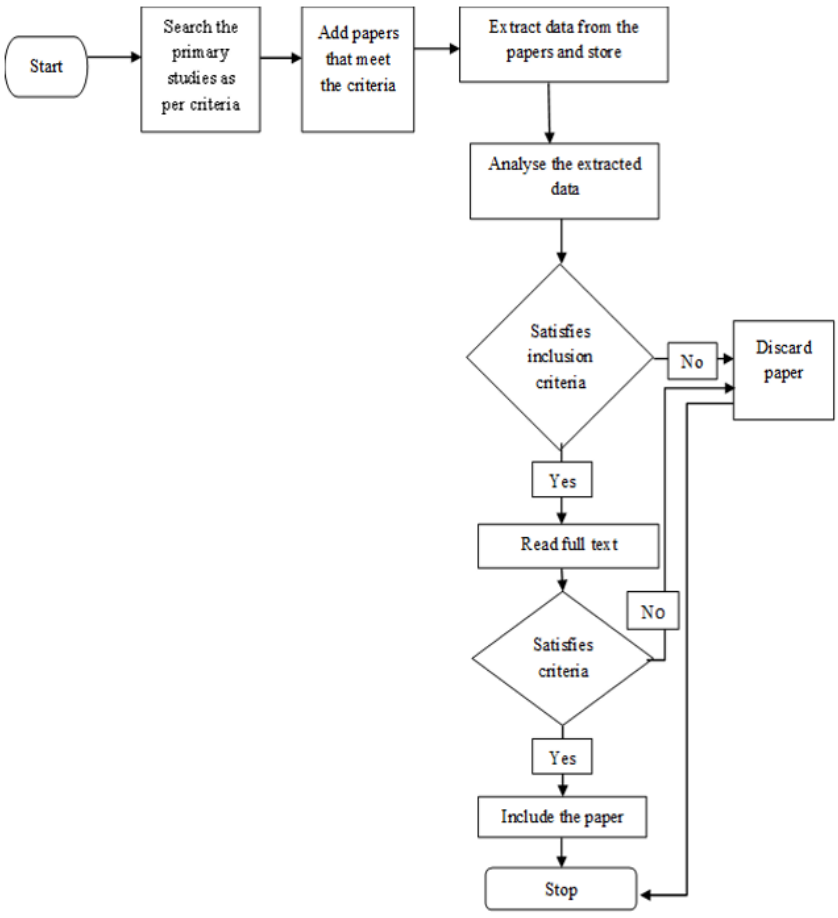

Figure 1. Paper selection process

Inclusion and Exclusion Criteria

This section ensures that the applicable analyses are utilized in the review procedure. To cover most of the relevant studies, papers were searched by querying different digital libraries. The purpose of this study is to understand the status of IoT in learning institutions. The procedure details examining published articles with future directions on the trends in this research area. Full papers written in English, published from 2008 to 2017 from peer-scrutinized reports, journals, book chapters, conference proceedings, and symposia reports were well-reviewed. The aim was to disqualify insignificant papers. A total of 200 journals were searched. A sum of 148 research papers was selected from the journals, conference proceedings, white papers, and articles. Table 1 recaps the basis.

Table 1

Inclusion and exclusion measure

Inclusion measure	Exclusion measure
Published from 2008 to 2017	External to IS research field
Papers that can be accessed full text	Papers with no access to the full text
Written in English	Not in English
Directly or indirectly answers the research question	Lacks the relationship to the defined research inquiries of the study
Papers with no direct term IoT but should address smart learning, smart education, IoT technologies used and focus on ubiquitous computing	Papers representing at least one key concepts (IoT, IoT adoption, IoT in learning, smart learning, smart education, IoT technologies among others) but not considering the term adoption
Papers proposing a model, a method, or methodology for adopting IoT and proposing practice mechanism	Papers with at least one of the concepts (method, model, methodology) but not considering learning domain
Published in the selected database	Publications that lacked a link to the inclusion criteria

Search Strategy

An orderly search starts with deducing keywords and search terms built from the study scope, literature, and discussions by the review team (Tranfield et al., 2003). The relevant strings for the search are then decided upon. The search strategy is thereafter relayed exhaustively to allow for future replication of the exploration. The examination procedure consists of manual and automatic stages. The automatic stages recognized studies related to IoT. In this study, the review was done from Scopus, Science direct, Taylor & Francis Online, Springer, and Web of Science journals like Computer Communications journal, International Journal of Development Research, Ad Hoc Networks and Wireless personal communications, Future generation computer systems, IEEE transactions on Industrial Informatics journal and others. Moreover, studies from conferences were also included (for instance ACM International Conference on Advances in Social Networks, enabling technologies: infrastructure for collaborative enterprises, Annual computer software and Applications conference, Applied System Innovation (ICASI)) for the study. Besides these, unpublished studies, conference proceedings, industry trials and even the internet material were considered. However, the key output of the research was a whole list of articles and papers where the review was grounded. Hence, the manual search process detailed the specific conference proceedings and journal papers from the year 2008.

Chosen journals encompassed either literature surveys or empirical research experiments. They also needed prior utilization as sources for other similar studies linked to information systems. Every journal or conference proceeding underwent review. Studies with a concentration on different literature surveys were recognized to be possibly applicable. All the papers were searched by applying the inclusion and exclusion criteria. The study was performed based on the following keywords: "IoT", "Internet of Things", "smart learning", "WSNs", RFIDs", "smart education" and "Internet of Things adoption" in the electronic journal databases.

Study Selection Process

At this stage, the choice of the suitable material for this literature review was done, as shown in Figure 2. The main search was performed via the search stream. It yielded 148 research papers using an automatic search method. Then, based on the inclusion and exclusion measure from the abstract and the close section of every paper, 64 papers were disqualified. A further manual scan was done, eliminating 18 more papers outside the specified criteria. Following this, a full scan was performed for the rest of the studies founded on the exclusion criteria. Manual steps were utilized to check any missing reports. Finally, a total of 49 papers were selected as the primary data. Thereafter, the classification by year and type of publication (journal article, conference proceedings) was done.

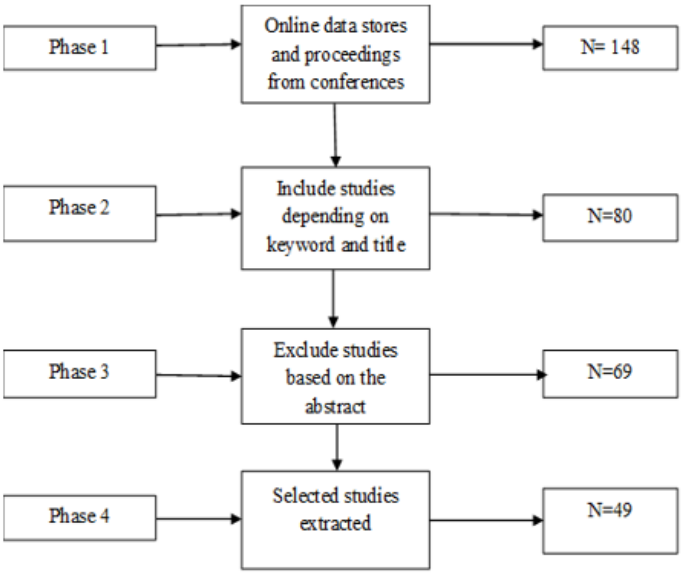

Figure 2. Study selection procedure

Quality Assessment

The quality assessment procedure outlines how to attain minimal biases with maximum internal and external validation (Brereton et al., 2007). This section aims to check the universal quality of the identified research articles. The full quality measure is in Appendix C. The four criteria about this study are:

QA1: Whether the topic in this article is related to IoT

QA2: If the research methodology is well outlined in this article

QA3: Whether enough illustration is provisioned for the setting where the study took place

QA4: If there is comprehensible information about the research intents

Each paper was assessed and later allocated a score of either high, medium, or low-quality level. A mark of 2 was allocated to the articles that attained the measure. A mark of 1 was given to those that partially satisfied the criteria while a mark of 0 was allocated to those that did not satisfy the criteria. High-quality papers scored a value of at least 5 and above, a score of 4 was given to a medium rated paper, and low to those whose score was below 4. As a result, 14 papers that did not meet the full criteria were removed from the list. Overall, the study chose 49 papers. From Figure 3, it can be seen that a good number of papers (62%) got a high score following these criteria, with 30% getting a medium score and 8% getting a low score.

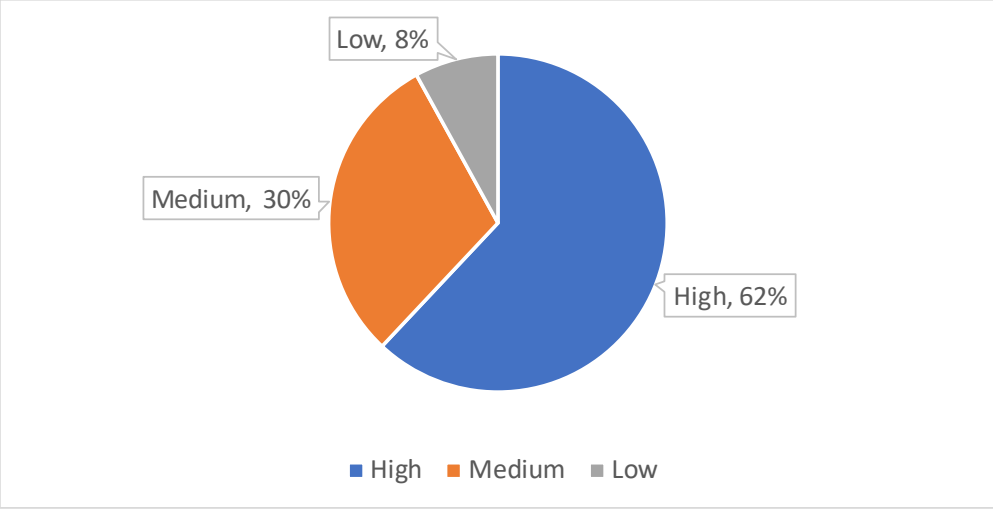

Figure 3. How studies are distributed

DATA EXTRACTION AND SYNTHESIS

To minimize errors and biases, data extraction forms are used in systematic reviews (Tranfield et al., 2003). They specify the general information, study aspects with other definite details, and emerging themes together with details of synthesis. Research synthesis entails making a summary, integrating, and accruing the outcomes of various studies on a concern. Here the main objective was getting a data extraction form to accurately record information from preliminary studies. The required details were extricated via endnote and Microsoft Excel spreadsheets. The extracted details are as shown in Table 2.

Table 2
Extraction of data from main studies

Extracted data	Detail
Article ID	Unique paper recognition
Writer and publishing Date	Author names and the publication year (2008-2017)
Article title	Paper name during a search
Article Subject	Objectives a paper address
Theory/Framework	Adopted theory/framework
Data gathering technique	Like a survey, experiment, observation, among others.
Data analysis process	A qualitative, quantitative, or mixed method
Group Origin	A description like benefits, adoption, strategies, among others Journal, book chapter, conference proceedings, among others

Publication Source Overview

Overall, 49 papers were chosen for the study (Appendix B), which included 45 articles from journal studies and 4 from conference studies. The earliest report was produced in 2010. Figure 4 shows the chosen articles from 2008 to 2017 by category type.

Temporal Outlook of the Publication

As per Figure 4, the extracted items concentrated on internet, things, IoT, learning, management, computing, education, technology, innovation adoption and learning, among others. Figure 5 shows how the articles were distributed. This study found little research on IoT adoption, more specifically centred on education from 2008 to 2010, with more

publications from 2014 to 2017. This shows that the concept of IoT began recently, and it is still not fully exhausted.

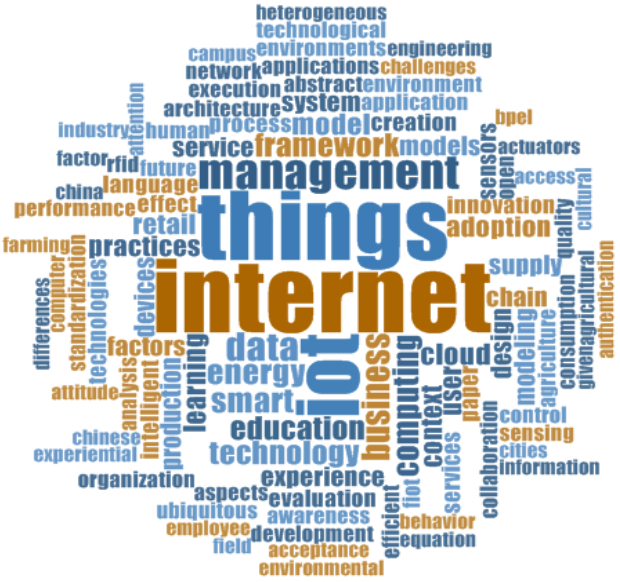

Figure 4. Weighted focus

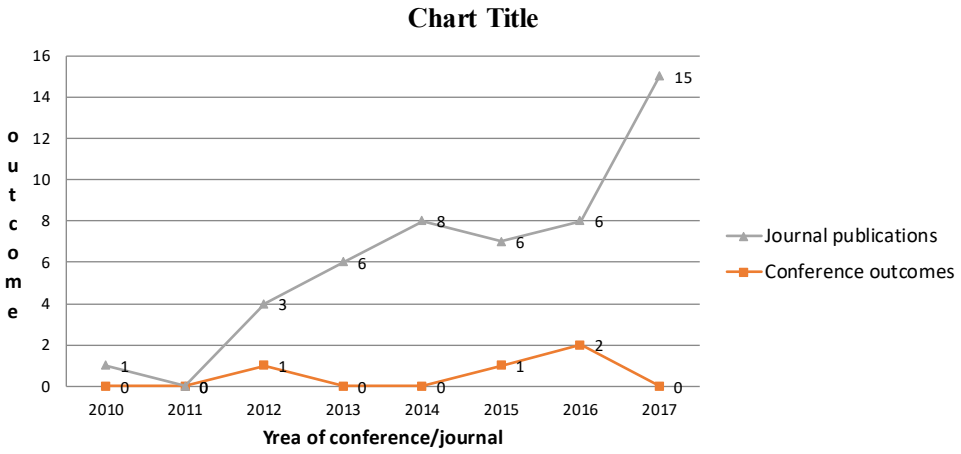

Figure 5. Distribution of articles

Citation Count

Table 3 shows that some of the chosen studies exhibited an elevated impact and some, a low impact. The statistics were obtained from Google Scholar and they show rough evidence on the paper citations. Likewise, there are not many studies that have been done on IoT in learning institutions before 2017. There are low rates in terms of adoption for learning institutions. About 12 studies have a citation count of more than 100, with the rest falling below 100. As low as 10 articles were cited as low as 10 times. One study lacked a citation. Conversely, as per this study, most of the papers have been published from 2015 and it is expected of them to have low citation count.

Table 3
Citation count

STUDY_ID	Study Title	Citations
I2	The Internet of Things: A survey	9826
I14	IoT: A perception, structural facets, and future requirements	57962
I23	The Internet of things vision: Key features, applications, and open issues	2362
I36	An authentication model for Internet of things clouds	1739
I41	Context aware computing for the Internet of Things: A survey	1731
I17	IoT: utilization, investments, and issues for enterprises	590
I10	A recap of IoT for individuals having impairment	380
I7	A vision of IoT: Applications, challenges, and opportunities with China perspective	304
I33	Enabling the internet of things	297
I46	Upcoming Internet of Things: open pitfalls and trials	138
I45	A blended view on the elements affecting consumer acceptance of IoT technology	121
I15	Educating the Internet-of-Things generation	111
I19	Developing a theoretical framework of strategic decision, to support ability and details dissemination under Internet of Things	96
I42	Why are not organizations adopting virtual worlds	92
I37	IoT grounded Smart environments: state of the Art, Taxonomy, and open investigations problems	85

Table 3 *(Continued)*

STUDY_ID	Study Title	Citations
I13	Interaction structure grounded on IoT as a pillar for Education	75
I43	A socio-technical structure for IoT blueprint: An individual engrossed blueprint for IoT	75
I12	An evaluation on Internet-of-Things	74
I35	A research structure for smart education	71
I38	Opportunistic IoT: Exploring the social side of IoT	55
I48	A study of the institutional forces influencing the adoption intention of RFID by suppliers	54
I6	Evolution is not enough: Revolutionizing current learning environments to smart learning environments	40
I49	Aspects of RFID adoption level with identified value	38
I27	IoT: being prepared for what is coming	38
I8	Smarter Universities: A vision for the fast-changing digital era	37
I25	A strategical process using IoT Smart data pricing models	36
I29	Conceptualizing and measuring quality of experience of the internet of things: Exploring how quality is perceived by users	33
I32	The growth of next generation bar code-RFID embrace	32
I40	Building trust in the Human-Internet of Things relationship	26
I44	IoT Business models	26
I24	Adoption of Internet of Things in India: a test of competing models using SEM	25
I16	The Internet of Things plus current business opportunities	25
I34	An integrated framework for RFID adoption and diffusion	22
I3	The result of IoT on Educational Business design	22
I11	IoT based student's interaction framework employing attention scoring assessment in e-learning	16
I30	Understanding the Internet of Things ecosystem: multi-level analysis of users, society, and ecology	14
I21	Establishing a unified model for RFID expansion	13

Table 3 *(Continued)*

STUDY_ID	Study Title	Citations
I18	Details about learning IoT: Research direction and upcoming trends from social science viewpoint	13
I1	IoTFLiP: IoT-based flipped learning platform for medical education	8
I26	Disrupting objects: a design to enable acquisition of IoT-based innovations by the urban poor	5
I28	The upcoming Technological and Theoretical models in Education: linking Cloud Computing (CC), Connectivism plus IoT	5
I22	The Application of WSNs and wearable technologies for education	2
I4	Benefits of "IoT" on E-learning in the Smart Cities	2
I20	Internet-of-Things-based Learning Framework to enable STEM Undergraduate Education	2
I39	Remote laboratory: using Internet of Things	2
I9	Investigating the Educational capability of IoT in Seamless instruction.	1
I31	The Internet of Things as an accelerator of progressing broadband networks in Thailand	1
I5	Democratizing AmI and the IoT: The Power and Influence of Social Innovation and Participative and Humanistic Design	0

Methodologies of Research

Figure 6 exhibits all the study methodologies employed in the initial exploration. It shows that most of the studies found in literature employed the qualitative methodology. Few studies employed the quantitative method. Besides, those that employed quantitative methodology utilized the survey method. Appendix D also gives the full details of the methodologies and methods.

OUTCOMES

R-Q1: What are the predominant investigations on IoT, and are the research concepts already described?

As from literature, there are three main categories of IoT: monitoring and control, big data and business analytics, and information sharing and collaboration (Lee & Lee, 2015). The detailed analysis of the selected studies was based on their similarities. This

is in terms of factors that influence IoT adoption or its related technologies in learning institutions. As per the evaluated publications and for feedback to the research inquiries, the investigation brings out five main categories of articles related to the subject of study, as shown in Figure 7.

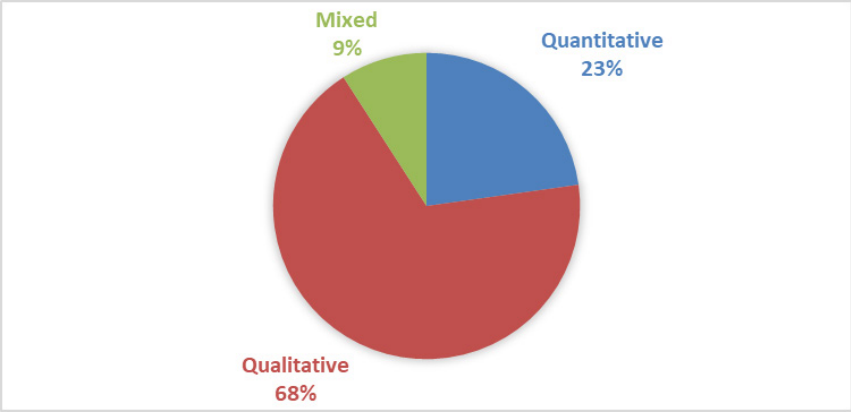

Figure 6. Research methodologies distribution chart

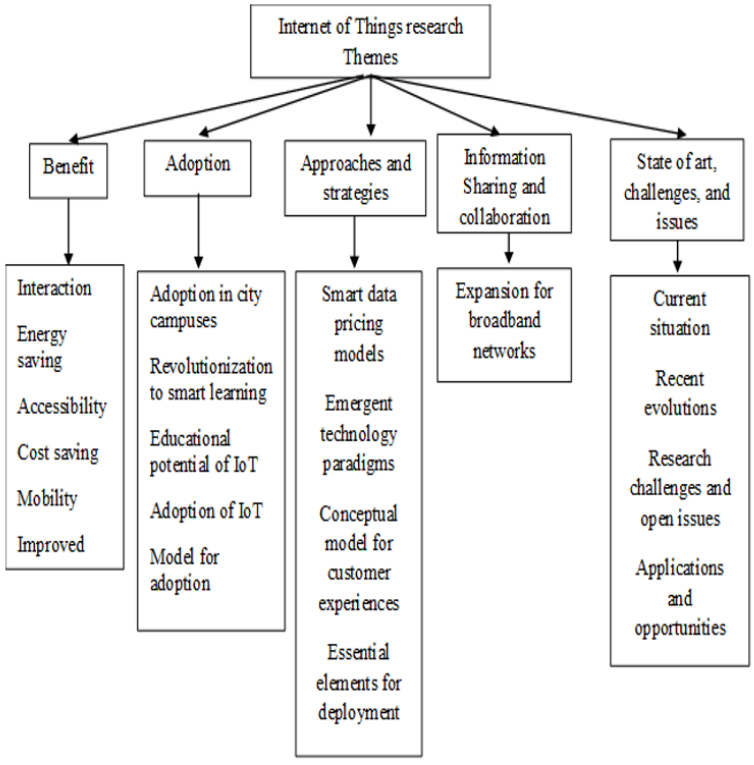

Figure 7. Themes for research and topics mentioned

Information Sharing and Collaboration

Most of the research conducted on IoT which was identified in this study detailed out a few things: the positive elements of utilizing IoT in limited resources environments, advantages of IoT in learning, the technical issues of IoT, tracking students' attendance using RFID technology, comparing outcomes of IoT learning platforms with traditional learning methods, use of IoT to stimulate learners' motivation, IoT as a subject of study in higher learning, and the important role of a teacher in using these applications. IoT brings in greater accessibility because of the high internet speed and lower gadget costs (Sarıtaş, 2015). This means better learning resources and immersive learning experiences with greater interaction. Accordingly then, IoT has a chance of lowering the education costs and expanding education material past the study rooms (Roy et al., 2016). It can facilitate quality educational resources at a fraction of the price of the prevailing mechanisms. Furthermore, IoT can be used to accelerate the expansion of broadband networks to reach out to many learners (Sudtasan & Mitomo, 2017).

Adoption

At the onset, we include studies with details on the adoption and inclusion of IoT in learning. Selected studies discuss elements that may impact the utilization of IoT. Few studies in this research have examined the adoption of IoT through models and frameworks, while highlighting important factors for successful implementation (Barreto et al., 2015; Kalashnikov et al., 2017; Li et al., 2012). However, research by Moreira et al. (2018) suggests that successful acceptance and introduction of IoT in learning institutions depends on the perception and inclination of educators, politicians, and society.

Benefits

Few studies have shown how to achieve benefits from IoT. Hence, IoT has attracted many in recent years, changing the landscape of disseminating information in the virtual world, interchanging details, convenience, and practicality (Ali et al., 2017). In global higher education, IoT is explicitly linked to the betterment of economic development, new research, and innovation (Bandara & Ioras, 2016). For example, IoT provides ways in which new opportunities can be utilized to merge various smart devices for learning (Niyato et al., 2016). The outcome is an advanced computing environment. Following this, system efficiency, safety, and security, upgraded trading opportunities and an income stream will be achieved. For instance, a study was done on developing a design to incorporate IoT-linked revolutions by the suburban poor (Roy et al., 2016). The result showed that IoT could improve the quality of education. This is through the acquisition of enhanced educational resources and the provision and availability of massively online open courses. Chen et al., (2014) in contrast looked at the benefits of IoT in terms of opportunities available for IoT.

Accordingly, IoT is believed to offer communication through existing technologies and new communication modes. The incorporation of IoT with the virtual and physical world will help realize utilization of various concepts and technical components.

Approaches and Strategies

Studies under this area outlined techniques and procedures used by IoT. They indicated the necessity to understand the users' connection between the social and technical perspectives for sustainability (Shin & Park, 2017; Shin, 2014). However, there is a need to address social innovation roles and the human approach participation (Bibri, 2015). Another research suggested the stimulation of people's thinking, creativity, and much of entrepreneurship.

State of art, Challenges, and Issues

Studies in this section bring out the modern state of IoT and any problems that need attention. For instance, universities confront challenges from the traditional learning systems (Coccoli et al., 2014). The outcome has resulted in recent evolutions in technology and networking, dramatically changing the way of life and knowledge accession. Hence, IoT can boost the role of technology as an innovation promoter in different markets of utilization (Miorandi et al., 2012). The IoT scenario and its facilitating technologies are also studied (Farooq et al., 2015). The human-centric perspective of IoT is also explained (Guo et al., 2012). Additionally, there are details on how data mining can be utilized with computational intelligence for future IoT applications (Tsai et al., 2014).

In summary, of the 148 articles on IoT revealed, only 49 that focused on the study area were retained. The 49 retained papers investigated IoT adoption and use in learning. However, most concentrated on the organizational level of adoption, and few on individual perception and preparedness. From the advantage category, most of the studies focussed on the benefit of IoT, issues, challenges, and future directions. Few studies focussed on the use of IoT to measure performance, track or monitor attendance and capture data.

R-Q2: What are the dominant models and theories employed in the study?

Most of the theories and models employed were grounded on the organizational level. However, some articles utilized individual-level theories. Many theories were related to technology adoption, entailing the incorporation of more than one single theory (Hameed et al., 2012). However, in this study, few researchers had utilized theories and theoretical models to expound on the adoption of IoT. A few theories that were employed included the Theory of Planned Behavior (TPB), Diffusion of Innovation (DOI), Technology Readiness Index (TRI), and Technology, Organization and Environment (TOE).

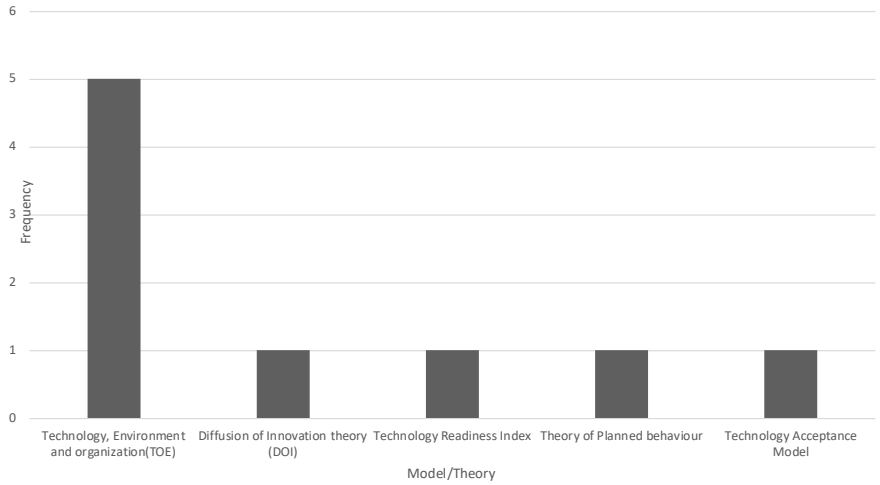

Figure 8. Theoretical frameworks and models used in selected studies

From Figure 8, TOE was found to be the most widely used theory in institutions planning, to adopt and use IoT. TOE by Tornatzky and Fleischer (1990) was developed to evaluate and analyse the present organization's conditions concerning the adoption and implementation of innovations. For instance, Aboelmaged (2014) mentioned that the TOE framework was strong theoretically and empirically, and hence helpful in the study of readiness, adoption, and implementation of various applications. The next theory is the DOI theory by Rogers (2003), that describes the willingness or non-willingness to adopt a new technology. Rogers (2003) argued that faster innovations to adopt were those that offered more relative advantage, compatibility, simplicity, trialability and observability. DOI tries to predict an innovation's adoption behaviour according to the personal characteristics related to the innovation (Samiee & Rezaei-Moghaddam, 2017).

TRI describes people's tendency to accept and use new technologies to achieve goals in home life and work (Parasuraman & Colby, 2015). The model assesses an individual's willingness to grab and utilize innovations at his quarters and duty (Parasuraman, 2000). Studies have applied TRI in assessing important factors for the successful implementation of technologies. For instance, Al-Shareem et al., (2015) emphasized on external reasons influencing preparedness to adopt public and private partnerships, Lin and Hsieh (2007) emphasized the role of technology readiness in self-service technology acceptance, and Thakur and Srivastava (2014) emphasized on readiness to adopt through TRI. TPB developed by Ajzen (1991) has been used to predict human behaviour in different fields. It hypothesizes that a person's conduct is as a result of three elements; a person's mentality toward behaviour, subjective standards, and perceived behavioural control (Cheon et al., 2012). TPB can be used to study wide areas of acceptance of technology (Oye et al., 2014).

The significant expectation of TPB is to catch those motivational variables and intentions, to speculate an individual effort (Ho et al., 2017).

R-Q3: What key constraints and omissions are found in the IoT investigation?

This study examined a sum of 148 papers to gather more knowledge and insight on IoT adoption in learning. However, it can be seen that the higher learning institutions have not fully utilized the technology. Only 49 papers were deemed relevant for this study. Therefore, there is a need for a better understanding of the technology to prepare organizations for its adoption. Possibly, the quantitative design approach would provide more insight into this analysis area.

Despite several articles on the adoption of IoT, recent academic literature on IoT adoption for learning institutions has shown a gap in models for readiness to adopt and use IoT. Researchers (Bourrie et al., 2015) argued that organizational readiness was reflected in the beliefs, attitudes, and intentions of members of an organization. Hence, much effort and detail are required to improve the impression and arrangements in institutions (Moreira et al., 2018). Sabi et al. (2016) also ascertained that consideration of the existing social and cultural conditions needed evaluation to avoid failure in the technology adoption process. Additionally, some studies pointed out the need to address privacy and security difficulties (Atzori et al., 2010; Bagheri & Movahed, 2016; Bibri, 2015). Very little research concentrated on the significance of user behaviour in IoT implementation; while other studies focused on the benefits, general discussion on IoT (including challenges, factors, technologies, and future directions), adoption and actual usage by organizations, and significance of the technology.

DISCUSSION AND CONCLUSION

This study has evaluated the implementation of IoT in learning. The study has examined the low usage of IoT in learning, and how only a few models have been used for adopting IoT. For greater insights, the few models and methodologies that have been used were brought out. It also exhibits the gaps in the literature to highlight the potential of IoT in helping tackle learning-related challenges. Amidst several benefits of IoT, innovations that handle learning and pedagogical issues are not fully in place. As highlighted in the introduction, IoT has numerous benefits for the educational environments to enable the tracking of learner activities. Hence, IoT can allow learning institutions to quickly address learner challenges through the study activities. Finally, this study shows the benefits and issues of utilizing IoT in learning.

The SLR method identified 49 primary studies published between 2008 and 2017. In addition, this study was to determine the utilization of IoT in other areas in learning with the themes and benefits. From the study, there has been noted a tremendous rise in the

number of papers in this field because of the significance of this subject in learning. It was noted that most studies were linked to monitoring learning activities. The rise in student population and need for quality learning requires the transition from traditional learning to personalized study. The level of device connectivity furnished by IoT necessitates an enriched learning process for students around the globe (Mrabet & Moussa, 2017). Besides, IoT technologies extend learning by generating sources of data for gathering and inspecting learners' studies individually (French & Shim, 2016). This is one way to transform the traditional pedagogy to the current learning methods through IoT. Another application of IoT is outdoor learning through RFID (Tan et al., 2007). Educators can design varying educational applications in areas with low capacity to relay information. The outcome is enhanced student creativity and improved skills from new knowledge.

Achieving quality learning in the face of continuous expansion is critical. As the learner's requirements have been altered with the evolvement of new technologies, using the best tools for strong pedagogy to the technology savvy population is important. Moreover, having the best decisions to improve the success of learners and institutions is also crucial. Hence, the need to utilize IoT, as per this study can help get valuable insights. There is a need for more research in learning environments.

From the review, the universal quality of the identified research articles yielded that 62% of the papers had a high score, 30% had a medium score, and 8% had a low score. Furthermore, most studies did not use any method, while majority (68%) used the qualitative technique. According to this study, very few authors used the quantitative method (23%), hence this is something that needs further exploration. This study may have failed to examine every existing literature item. Nevertheless, the aim is to furnish information on this growing technology to both, stakeholders, and practitioners. Based on this study's categorization of literature, it can be seen that using IoT for tracking and tracing objects and people has been the norm. Hence, the benefits and improvements resulting from IoT have still not been fully utilized in learning.

Concerning the predominant models and methodologies, this study found few utilizations. Since IoT can improve the society, making learners more linked while having independent control is key in the future eLearning vision. IoT can provision for improved infrastructure robustness, scalability, continuous communication and can save on learner costs. Furthermore, using IoT will create learner flexibility, expand learning materials, upgrade teaching and learning, and bring agility. It is crucial that stakeholders consider this evolving technology and actively deploy it in learning environments. With the continuous enrolment of learners in educational institutions, a major issue is extending learning services to a wider location. Implementing IoT has significant benefits that make it preferable for expanding teaching and learning. Therefore, selecting a good model and methodology for implementing IoT is crucial. Major issues like security and privacy need to be handled,

as they inhibit the spread of IoT. This study did research comprehensively on IoT for learning institutions through more than 120 authors and various studies. However, it was not possible to capture every research.

There are gaps identified concerning IoT in learning from this review, which are further elaborated on as follows:

- There is a miss on the models that provide direction on IoT adoption in education with defined guidelines. The aim is to help learning institutions in deploying IoT. IoT will impact planning, quality learning and decision making, among other issues.
- There are many barriers to implementing IoT in learning from the people and organizational context. There is a need to clearly understand the peoples' perspective and their preparedness. Research by Moreira et al. (2018) suggests the need for preparedness from stakeholders and educators. There are not many studies addressing the issue of preparedness among other challenges.

Overall, after all the analysis was done, the study concludes that the use of IoT can be of great benefit if more research is undertaken. The findings from this review will assist university policy makers to make better decisions regarding implementation and deployment of IoT. IoT is among the technologies that can play an important role in enhancing quality learning, increasing knowledge acquisition, and lowering study costs. IoT is expected to improve learning, enhance quality education, and save on costs while overcoming learning inequities. More study can be done on the technologies used in various IoT implementations in learning, with a comparison on which one suits best. This study acts as a basis for researchers in getting more research ideas on IoT in learning.

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Appendix A

Defining Internet of Things

Concept	Definition	Author
Internet of Things	The interconnectedness of numerous gadgets that have possibility of report, screen, or give other esteem or administrations that are of incentive to end clients	Atabekov et al. (2016)
Internet of Things	formation of inventive alternatives for learning and this is conceivable because of the expansion of concepts from ubiquitous computing and technologies as mobile, Radio Frequency Identification amidst the rest	Gonzalez et al. (2008)
Internet of Things	IoT involves interaction with heterogeneous devices along with seamless sharing of data with a specific end goal to give personalized services to the learners and instructors	Kamar et al. (2016)
Internet of Things	a dynamic worldwide system foundation that has the capability of self-conFigureuration based on standards and interoperable protocols where there is identification of physical and virtual things, physical attributes and virtual personalities to use intelligent interfaces by being coherently being part of the data network	Xu et al. (2014); Uzelac et al. (2015); Moreira et al. (2018)
Internet of Things	the enabling of internet presence for any person, place, or thing on the planet	Want et al. (2015)
Internet of Things	It comprises various gadgets part of the technological, physical, and broad socioeconomic environments. The physical surrounding has human and nonhuman objects connected by ubiquitous wireless network. They empower programmed correspondence and association among the items and the physical condition, and the mechanical condition contained equipment, programming, organizing advances, information, incorporated stages, and specialized benchmarks empower collaborations in the physical condition.	Krotov (2017)

Appendix B

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Appendix C

Quality evaluation measure

QAF: "QUALITY ASSESSMENT FACTORS"					
S/ID	Q-A1	Q-A2	Q-A3	Q-A4	SCORE
11	2	2	2	2	8
I2	2	0	0	2	4
I3	2	1	0	2	5
I4	2	0	2	1	5
I5	2	0	1	2	5
I6	2	0	0	2	4
I7	2	0	2	2	6
I8	2	0	2	1	5
I9	2	0	1	2	5
I10	2	0	1	2	5
I11	2	1	1	1	5
I12	1	1	1	1	4
I13	2	2	2	2	8
I14	2	0	2	1	5
I15	2	0	2	1	5
I16	2	0	1	1	4
I17	2	0	1	1	5
I19	2	0	2	2	6
I20	2	0	2	1	5
I21	2	2	1	1	6
I22	2	0	2	1	5
I23	1	1	1	1	4
I24	2	2	2	2	8
I25	2	1	2	2	7
I26	2	2	1	1	6
I27	2	0	1	1	4
I28	2	0	1	1	4
I29	2	2	2	2	8
I30	2	2	1	2	7
I32	2	2	2	2	8
I33	2	0	1	1	4

Appendix C *(Continued)*

QAF: "QUALITY ASSESSMENT FACTORS"					
S/ID	Q-A1	Q-A2	Q-A3	Q-A4	SCORE
I34	2	1	1	1	5
I35	2	0	1	1	4
I36	2	0	0	2	4
I37	2	1	0	1	4
I38	2	0	0	1	3
I39	2	1	0	1	4
I40	2	0	1	1	4
I41	2	0	1	1	4
I42	1	2	1	1	5
I43	2	2	1	1	6
I44	2	2	1	1	6
I45	1	2	1	1	5
I46	2	0	0	2	4
I47	2	2	1	2	7
I48	2	2	1	2	7
I49	2	2	2	2	8

Appendix D

Distribution of research methodologies

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
1	Dijkman et al. (2015)	Business models for internet of things	Presenting a framework for developing business models for IoT application	none	mixed	Interviews and Surveys

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
2	Farhan et al. (2017)	IoT based student's interaction framework using attention scoring assessment in e-learning	To develop IoT-based interaction framework and analysis of the student experience of electronic learning (eLearning).	none	quantitative	experiment
3	Ali et al. (2017)	IoTFLiP: IoT-based flipped learning platform for medical education	Developing of an IoT flipped learning for improved learning	none	qualitative	none
4	Coccoli et al. (2014)	Smarter Insitutions: A vision for the quick digital era	Analyze the current situation of education in universities, with particular reference to the European scenario. Specifically, we observe that recent evolutions, such as pervasive networking and other enabling technologies, have been dramatically changing human life, knowledge acquisition, and the way works are performed, and people learn	none	qualitative	none

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
5	Thiesse et al. (2011)	The rise of next generation bar code-RFID adoption	To find the causals of adopting RFID within initial standards adopters	TOE	quantitative	survey
6	Adhiarna et al. (2013)	An integrated framework for RFID adoption and diffusion	The main concern in this study is stages of adoption which covers tree phases in respect of the maturity of the RFID project and the sophisticated business applications and RFID technology	TOE	qualitative	none
7	Iyawa et al. (2017)	Utilizing WSNz and wearable technologies for education	To perform a scoping evaluation on utilizing WSNs and wearable innovations for instruction	none	qualitative	none
8	Reyes et al. (2016)	Determinants of RFID adoption stage and perceived benefits	This study identifies the determinants of radio frequency identification (RFID) adoption stage and explores the perceived benefits from RFID adoption	TOE	quantitative	survey

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
9	Hossain and Quaddus (2015)	Development of an integrated model for RFID extension	To develop an integrated model that explains the adoption, continuance, and extension of a technological innovation – taking radio frequency identification (RFID) as the case.	TOE	quantitative	survey
10	Yoon and George (2013)	Why arent organizations adopting virtual worlds	To comprehend reasons for slowness in firm incorporation of virtual worlds than required, through empirical determination of elements significant for organizational need to incorporate virtual worlds	TOE	quantitative	survey
11	Gómez et al. (2013)	Interaction System Based on Internet of Things as Support for Education	The education field, where Internet of Things can be used to create more significant learning spaces.	none	qualitative	none
12	Gao and Bai (2014)	A unified perspective on the factors influencing consumer acceptance of internet of things technology	To develop and test an integrative model of factors determining consumers' acceptance of IoT technology.	TAM	quantitative	survey

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
13	He et al. (2017)	Instruction founded on Internet of Things (IoT) Framework to ease STEM Undergraduate instruction	Implementation of an IoT-based learning model that enables STEM undergraduate instruction	none	qualitative	none
14	Mital et al. (2018)	Adoption of Internet of Things in India: a test of competing models using SEM	To satisfy a clear gap in the main field of research by proposing a Structured Equation Model (SEM) approach to test three competing models in the context of Internet of Things in India.	SEM	quantitative	survey
15	Roy et al. (2016)	Disruption of things: a model to facilitate adoption of IoT-based innovations by the urban poor	This study examines the adoption of the Internet of Things (IoT) based innovations by urban poor communities.	none	quantitative	survey
16	Shin and Park (2017)	Understanding the Internet of Things ecosystem: multi-level analysis of users, society, and ecology	To conduct socio-technical analysis of the rapidly evolving Internet of Things (IoT) ecosystem and industry, including such factors as market growth and user experiences, policy, and the impact of IoT on various areas.	none	Mixed	interview and survey

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
17	Zhu et al. (2016)	A research framework for smart education	The definition of smart education and presents a conceptual framework.	none	qualitative	none
18	Tsai et al. (2014)	Future Internet of Things: open issues and challenges	An overview of IoT and FIoT, followed by discussions on how to apply data mining and computational intelligence to FIoT.	none	qualitative	none
19	Sudtasan and Mitomo (2017)	The Internet of Things as an accelerator of advancement of broadband networks: A case of Thailand	Illustrates effect of consumer decisions influenced by Internet of Things applications	none	qualitative	none
20	Shin (2014)	A socio-technical framework for Internet of Things design centered on humans	How Internet of Things will evolve and stabilize in a smart environment, relation linking social and technical elements of Internet of Things and challenges in design, deploying, and sustaining diverse components of IoT	none	Mixed methods	Interviews and Surveys

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
21	Barreto et al. (2015)	An authentication model for Internet of things clouds	Present an architectural model and several use cases that allow different types of users to access IoT devices	none	qualitative	none
22	Perera et al. (2014)	Context aware computing for the Internet of Things	Context awareness from an IoT perspective.	none	qualitative	none
23	Kounelis et al. (2014)	Human-IoT relationship	Agency as a driver in building trusted human Internet of Things	none	qualitative	none
24	Kalashnikov et al. (2017)	Remote laboratory: via Internet of Things	Remote laboratory project for video streaming	none	qualitative	none
25	Guo et al. (2012)	Opportunistic IoT: Exploring the social side of	To present the IoT from the human-centric perspective	none	qualitative	none
26	Gubbi et al. (2013)	Internet of Things: A vision, architectural components, and future guidelines	A cloud centric vision for worldwide implementation of IoT	none	qualitative	none

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
27	Farooq et al. (2015)	A review on Internet of things	A detailed examination of the IoT notion with its enabling innovations and the sensor networks	none	qualitative	none
28	Chen et al. (2014)	IoT perception in China: Applications, challenges, and opportunities	The status of IoT development in China, plus standards, R&D plans, applications, and standardization	none	qualitative	none
29	Miorandi et al. (2012)	The Internet of things vision: Key elements, uses, and open issues	Research challenges and open issues to be faced for the IoT realization in the real world	none	qualitative	none
30	Ahmed et al. (2016)	Internet-of-Things-Based Smart environments: state of the Art, Taxonomy, and open research challenges	Status on evaluation efforts to permit IoT based smart environments	none	qualitative	none
31	Bagheri and Movahed (2016)	The effect of the Internet of Things (IoT) on Educational Business model	To investigate and analyze change of IoT platform regarding education business model	none	qualitative	literature

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
32	Atzori et al. (2010)	The Internet of Things: A survey	Allow the reader to understanding what has been done and what remains to be addressed, as well as which are the enabling factors of this evolutionary process and what are its weaknesses and risk factors.	none	qualitative	none
33	Bayani et al. (2017)	Internet of Things (IoT) Advantages on E-learning in the Smart Cities	The need of adopting IoT technologies in smart city campuses, analyzing the predictable advantages of the e-learning.	none	qualitative	none
34	Bibri (2015)	Democratizing AmI and the IoT: The power and Influence of Social Innovation and Participative and Humanistic Design	To explore the power and seminal role of social innovation and participative and humanistic design—as one holistic approach—in sustaining the success of AmI and the IoT technologies, and to identify and address the great challenges involved in the process of embracing this approach	none	qualitative	none
35	Chen et al. (2016)	Evolution is not enough: Revolutionizing present instruction environments to smart learning area	Challenges with a view towards revolutionizing current learning environments to smart learning environments and provides new suggestions for technological solutions	none	qualitative	none

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
36	Demirer et al. (2017)	Exploring the Educational Potential of Internet of Things (IoT) in Seamless Learning.	Introduction of IoT technology pus its potentiality in seamless instruction.	none	qualitative	none
37	Domingo (2012)	An overview of the Internet of Things for people with disabilities	Overview of the Internet of Things for people with disabilities is provided	none	qualitative	none
38	Kortuem et al. (2013)	Educating the Internet-of-Things generation	To place the IoT at the core of the first-year computing curriculum and to prime students from the beginning to meet the coming changes in society and technology	none	qualitative	none
39	Krotov (2017)	The Internet of Things and upcoming business opportunities	To stimulate thinking, creativity, and entrepreneurship in relation to the IoT	none	qualitative	none
40	Lee and Lee (2015)	IoT Applications, investments, and challenges for enterprises	Essential IoT technologies for the deployment of IoT-based products and services and IoT categories for enterprise applications	none	qualitative	none

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
41	Lee et al. (2017)	How and what to study about IoT: Research trends and future directions from the perspective of social science	Examines the status of scholarly discourse on IoT.	none	qualitative	none
42	Li et at. (2012)	Towards a theoretical framework of strategic decision, supporting capability and information sharing under the context of Internet of Things	That groups IoT into perspective of managers' strategic need and industrial driving force, and suggest that market-based exploratory necessities impact companies incorporating get-ahead strategy, and market-based exploitative possibilities are significant for organizations incorporating catch-up strategy in market	none	qualitative	none
43	Niyato et al. (2016)	Smart data pricing models for the Internet of Things: A bundling strategy approach	Suggest an improved pricing structure for IoT service providers to choose the sensory details initial cost and IoT service subscription price given to sensor owners and service individuals, separately	none	qualitative	none
44	Saariko et al. (2017)	The Internet of Things: Are you prepared for what is coming?	Reviewing the complexity of IoT, the issues in linked environments, plus the rising necessity to create links for innovative outcomes	none	qualitative	none

Appendix D *(Continued)*

Distribution of research methodologies						
ID	Instigator(s)	Article Name	Intent	Theory/ Framework	Method	Details collection process
45	Sarıtaş (2015)	The Emergent Technological and Theoretical Paradigms in Education: The Interrelations of Cloud Computing (CC), Connectivism and IoT	Background and fundamentals about emerging technology paradigms – Cloud Computing (CC) and Internet of Things (IoT), and an emerging learning theory – Connectivism.	none	qualitative	none
46	Shin (2017)	Conceptualizing and measuring quality of experience of the internet of things: Exploring how quality is perceived by users	Relationship between consumer experiences, the quality perception of IoT, and develops a conceptual model for QoE in personal informatics	TRA and TPB	Mixed method	Focus groups, brainstorming
47	Sudtasan and Mitomo (2017)	The Internet of Things as an accelerator of advancement of broadband networks: A case of Thailand	Show influence of consumer decisions on choices of advanced Internet access by the emergence of IoT applications	Bivariate probit model	quantitative	Survey
48	Want et al. (2015)	Enabling the internet of things	Benefits of IoT, future directions and challenges	none	qualitative	none
49	Tsai et al. (2013)	Examining institutional pressure for incorporating RFID by suppliers	How different institutional forces experienced by retailer's suppliers were related to their relational investment on inter-organizational information sharing	DOI	quantitative	survey

Appendix E

Additional article (Book Chapter)

ID	References	Name	Aspiration
81	Bibri (2015)	The Shaping of Ambient Intelligence and the Internet of Things	The book explains how Ambient Intelligence (AMI) and IoT utilizations of scientific discovery merge with various implementations in the spheres of the European society. It positions AmI and the IoT developments and innovations as modernist science–based innovation enterprises in a volatile and tense relationship.