A Framework of Internet of Things (IoT) as an ICT Strategy to Facilitate Information and Communication Sharing in UK Universities

Mohammed Ali,
mohammed.ali@manchester.ac.uk
University of Manchester
Manchester Institute of Innovation Research
Innovation Management and Policy Division

Trevor Wood-Harper,
atwh@manchester.ac.uk
University of Manchester
Manchester Institute of Innovation Research
Innovation Management and Policy Division

Bob Wood,
bob.wood@manchester.ac.uk
University of Manchester
Manchester Business School

Michael Newman,
mike.newman@manchester.ac.uk
University of Manchester
Alliance Manchester Business School
Accounting and Finance division

Abstract: The Internet of Things (IoT) has become a growing trend in the current technological panorama. In Education, the IoT is a vastly developing technologically driven information and communication environment for researchers, students, and administrators. We review the benefits and challenges of the IoT to determine a potential communication and information sharing culture in HEIs. Although the results indicate that stakeholders demand a better collaborative learning environment, improved information sharing and productive efficiency, IoT is burdened with privacy, data security and interoperability concerns that dissuade stakeholders from embracing IoT. IoT as an ICT strategy has the potential to meet HEIs system expectations, yet stakeholders are still undecided about their willingness to embrace the IoT. This prompts future research to explore the reasons why stakeholders are resistant towards the IoT.

Keywords: Internet of Things, Higher Education, Actor Network Theory, ICT Strategy, Communication, Information Sharing

Introduction

Modern Information and Communication Technology (ICT) solutions and strategies have transformed the traditional educational process resulting in better quality education systems at various levels of learning (Maksimović, 2018). There are currently seven known categories of technologies, tools, and strategies have been a potential game changer in the education sector: visualization technologies, social media technologies, learning technologies, Internet technologies, enabling technologies, digital strategies and consumer technologies (Rushby & Surry, 2016). The Internet of Things (IoT), for example, is an internet technology that has enabled small devices to become connected to the Internet, which in turn provides an opportunity to make remarkable developments in many facets of life (Majeed & Ali, 2018). IoT in the education domain has successfully bridged the gap between the requirements needed for both traditional education systems and contemporary education systems through the transformation of an interconnected sharing and collaborative environment. This has been brought together by internet based information and communication tools and strategies that form this sharing culture.

Kevin Ashton first coined the term "Internet of Things" in 1999, which describes a unique set of interoperable objects connected via radio-frequency identification (RFID) technology (Gawali & Deshmukh, 2019). Similarly, Oberländer et al. (2018, p. 488) states that IoT facilitates the connectivity of physical objects that include sensors and actuators in the form of data communication technologies that are powered by the internet. These definitions suggest that the significant growth and ubiquitous penetration of the IoT can be attributed to the rapid increase in smart device usage within the past decade.

The advanced development and ubiquitous nature of internet technology has led to a world where devices are able to be interconnected to the internet, thus providing anytime anywhere access to information. The IoT are a technological innovation of pervasive computing that is developing a worldwide network of the information society, which facilitates novel and complex services (Patel & Cassou, 2015). For example, Universities are currently using the IoT, such as campus-wide Wi-Fi that allow students and staff to use their mobile devices to access information regarding the campus according to their location e.g. guiding lost students using interactive map data or even check the availability of study rooms. By 2023, the size of the IoT in Education market is expected to grow to $11.3B due to the increased use of connected devices in educational institutions (Petrov, 2019).

Various supporting technologies are responsible for the IoT growth, such as developments in smart devices, broadband availability, reduced cost of connected devices and energy efficient systems (Talari et al., 2017). Similarly, a 2015 report about the IoT found that the rise of other technologies, such as cloud computing and big data (Ali, 2020; Ali, 2019a; Ali, 2019b) has influenced the technological ecosystem that has facilitated the emergence of the IoT (Rose, Eldridge, & Chapin, 2015). With the proliferation of smart technologies, the IoT is a new wave of ubiquitous connectivity. Moreover, Gómez et al. (2013) asserted that developments in nanotechnology (small technologies used mainly in the scientific field) have facilitated the manufacturing of miniature devices that can be inserted into various systems with additional functionality of efficiently connecting to the Internet.

Although the IoT is an emerging technology that brings together both virtual and physical devices based on existing ICTs, there are several limitations such as a lack of security, privacy and trust in the IoT, which may dissuade stakeholders from embracing the technology (Hsu & Lin, 2018). For those reasons, this research explores the benefits and challenges pertaining to the IoT as an ICT strategy to facilitate communication and information sharing among stakeholders associated with Higher Education Institutions (HEIs).

Related Work

The IoT today are fostering new technological innovations that are changing the face of industry. This growing trend has been fostered because of the convergence pertaining to wireless technologies and the developments in the internet. This makes any object a smart device that is able to communicate unobtrusively. Although the IoT provides opportunities to enhancing information and communication driven decision-making (ICD) (Krotov, 2017; Pauget & Dammak, 2018; Wei & Zhou, 2018), there are a number of key issues that could potentially affect the integration of the IoT into Higher Education (HE) regarding information sharing and collaboration.

Zhu, Yu, and Riezebos (2016) found that the ubiquitous nature of improved access to information facilitates the development of connected communities where educational stakeholders, particularly students can share ideas with their peers and other stakeholders such as their tutors/teachers. For example, the IoT devices can facilitate live streaming of other classrooms situated in schools in different parts of the world. This provides the potential use of the IoT in distance learning scenarios in which learners can view recorded lectures via a virtual learning space or view a live lecture outside of the University (Kassab et al., 2018). In the same vein, the IoT-enabled learning spaces uniquely facilitate the ubiquitous access to information, as well as contexts that connect people, processes, data and things on demand via smart devices (Middleton et al., 2014; Whitmore et al., 2015).

The application of digital technology as a strategy or tool to share and distribute information have become favourable targets in data mining (Njeru, Omar, Yi, Paracha, & Wannous, 2017). Njeru et al. (2017) found that the benefits retained from using visualization tools is improved collaboration/information sharing. Despite information sharing not being a new paradigm, the indelible nature of the digital footprint resulting from the information that is shared online is a concern, particularly regarding the sharing of individuals' information without their consent (Whitmore et al., 2015).

Research by Hansen and Reich (2015) found that the different access levels to information resources and technologies influence stakeholder success, particularly among students (stakeholder success in the student context would be improved learning outcomes, better access to information for research purposes and improved collaboration with other stakeholders such as teachers). The authors argue that there is concern about the equal access to online information since stakeholders do not have the same level of access to technological resources. Similarly, poorer students are more likely to have limited access to ubiquitous learning platforms, thereby restricting their success. In the same vein, Fraga-Lamas et al. (2016) argued there is limited access to information resources and secure communications for defence and public safety, which indicates the need to integrate the IoT in sectors such as public safety and education. This will help to improve the rate of access to important online information.

Du et al. (2018) discovered that although information disclosure is a privacy related issue, which could be argued as a technical challenge related to The IoT technology, it has a direct impact on users' personal information and not only the system itself. The authors go on to mention that the information exchanged among users and The IoT vendors could be disclosed by these human actors and not the result of a system exploit or attack. Therefore, this creates not only a technical issue, but also a personal issue in the potential disclosure of information that is exchanged between human actors on a personal level.

Dery et al. (2014) found that mobile communication technology practices have considerably evolved within a relatively short period in both work and non-work contexts. With respect to IoT, this type of mobile communication technology has also rapidly evolved through a seamless platform communication that not only facilitates knowledge management and knowledge availability, but it also provides stakeholders with a sense of engagement via unique value-added learning experiences across varying distances using the IoT enabled tools or strategies (Zhu et al., 2016). The ubiquitous nature of communication facilitated by The IoT renders itself as a platform that supports collaborative research in which students and faculty can work together and share ideas anytime anywhere in one centralised space. Likewise, Demirer, Aydın, and Çelik (2017) state that owing to the pervasive nature of smart devices, The IoT technologies are a potential game changer in the provision of seamless learning in both informal and formal communication spaces in education settings.

Concerning a lack of support, the IoT have become a standard in various industries, where data ownership is questioned by organisations, particularly when comping to regulatory policies related to sharing data with third parties. This issue is pertinent given the limited support surrounding the ownership of the IoT data (Janeček, 2018). For HE, data ownership is even more pertinent owing to the large quantities data produced by the IoT in Universities is accessed by third party vendors offering services to them. Berman and Cerf (2017) questioned about the social and ethical behaviour of the IoT. The authors argued while technological innovation should not be limited, developing effective models for governing the IoT is needed to guide social behaviour and ethical use of the IoT technologies that promote efficiency.

According to Harwood & Gerry (2017), a lack of knowledge and/or understanding of or familiarity with the IoT can result in user resistance among human actors or system users. Confidence in the IoT therefore becomes critical, as organisations have to build users' trust in using the IoT. Despite this important issue, the nature of trust in a system can vary based on the agency of human actors and machine objects that operate within a network. Therefore, it is vital for actors and objects to work collectively or collaboratively owing to the complex adaptive socio-technical nature of the IoT, which comprise of various benefits that come from interdependencies situated in networked systems.

The interoperability of the IoT presents series of security challenges, such as cyber-attacks and authorised access to data. Noura, Atiquzzaman, and Gaedke (2018) found that despite industry proposals to overcome the IoT interoperability problem, there is still very little ground that can address these issues. The authors found that the lack of standards and limited cutting-edge technologies hinders the development of the IoT.

Hsu and Lin (2018) found that when sharing information using the IoT, there is a growing threat regarding the perceived privacy risk related to the application of these smart technologies. Given the likely increase in the IoT driven data sharing for the education system, data security becomes a matter of security and risk. The vendors who provide support for the processes within the IoT ecosystem further influence such vulnerability (Fraile, Tagawa, Poler, & Ortiz, 2018). To further support the claim of vulnerability in the IoT, a report compiled by Arxan, IBM and the Ponrmon Institute found that 80% of the IoT devices were not tested for any vulnerabilities owing to the quick deployment of these applications in order to meet user demands (Forrest, 2017). This confirms the security concerns associated with the IoT platforms, which in turn can compromise its sharing and communicative potentials. Strategies or tools that could avert potential security threats that originate from the IoT devices because of their varying privacy and security requirements are limited (Islam, Kwak, Kabir, Hossain, & Kwak, 2015). Despite regulations of data privacy and security that aim to protect the confidentiality and integrity of data, such as the General Data Protection Regulation (GDPR), the lack of standards and legal restrictions on data sharing could in turn thwart the application of the IoT in other contexts (Yorkstone, 2019). This is particularly important for higher education, where security would be a high priority given the security standards required to protect stakeholders' personal information.

Although the IoT is a potential game-changer to different sectors, the technology itself can be a potential threat towards not only individuals' roles, but also to the entire information sharing and communication ethos. This is because individuals can communicate and share information with each other on a social level, but the introduction of the IoT could instil fear in potential users and be a threat to not only their job position, but also their social interactions with others. This may result in potential users to reject the technology or fear it as it could be a personal threat to their social life and career. From the related work, several key issues have been identified: information issues, communication issues and technology issues in the IoT. Information refers to the data issues in the IoT devices used in HEIs, communication refers to the collaborative and communicative issues between HEI stakeholders, which are generated from the IoT devices, and technology refers to the hardware/software side of the IoT devices or the technical issues that can arise from using the IoT devices in HEIs. In short, the key issues derived from the literature have been summarised in Table 1. This facilitates the development of the proposed model.

Table 1: The IoT Integration Issues from Several Perspectives

Category	Key Issues		Reference
	Benefits	**Challenges**	
Information	Better access to information resources Promote information sharing	Limited access to information Information Disclosure	Du et al. (2018) Fraga-Lamas et al. (2016) Hansen and Reich (2015) Njeru et al. (2017) Whitmore et al. (2015) Zhu et al. (2016)

Communication	Enhance collaboration Encouraging Learner Engagement Lack of Trust	Lack of support Limited Understanding of the IoT	Berman and Cerf (2017) Demirer et al. (2017) Harwood & Gerry (2017) Janeček (2018) Zhu et al. (2016)
Technological	Highly accessible Scalable/Flexible Ubiquitous technology	Interoperability issues Security issues Privacy issues Technophobia	Forrest (2017) Fraile et al. (2018) Hsu and Lin (2018) Islam et al. (2015) Noura et al. (2018) Mani & Chouk (2018)

Theoretical Framework: Actor Network Theory (ANT)

Actor-network theory (ANT) refers to an analytical method that is used to analyse various sociotechnical contexts from a conceptual perspective (Lee & Chen, 2011). ANT describes and explores socio-technical processes in a heterogeneous network with focus on the interactions among various human and nonhuman actors. In particular, Latour (1987) and Callon (1991) in Lee & Chen (2011) explains that ANT describes how relationships are developed between human and nonhuman actors and their mutual benefits via the network. In our paper, human actors refer to HE stakeholders or potential the IoT users, such as teachers, students, and administrators, whereas non-human actors refer to the technological artefact, namely the IoT to support the human actors (Sarker, Sarker, & Sidorova, 2006). Since ANT has been widely applied to IS studies in fields such as business (Guilloux et al., 2013), healthcare (Cho et al., 2008), e-government (Heeks & Stanforth, 2007) and information security (Tsohou et al., 2015) to explore the role of actors in a given technological scenario, such as implementation, makes ANT an ideal for the paper.

ANT concepts related to our paper include: **Punctualisation**, which refers to looking at a technology as a whole. For example, looking at the IoT tools and strategies from a holistic point of view. **Inscription**, which refers to aligning actors with actants. For example, aligning users or stakeholders, such as students, teachers and admins with IT artefacts to facilitate institutional practices, namely the IoT. **Storytelling**, which refers to the successful experience of integrating and using technological artefacts. For example, can the integration the IoT as an IT tool/strategy for HE facilitate institutional practices, such as teaching and research, as well as promoting information sharing and collaboration among HE stakeholders. **Translation**, which is linked to effectiveness and efficiency of an innovation based on four sub-concepts, including Problematisation, Interessement, Enrolment and Mobilization. For example, can the aforementioned sub-concepts improve the efficiency and effectiveness of the IoT to enhance institutional practices, as well as promote information sharing and collaboration. And **Black boxing**, which refers to aligning the interests of many actors. For example, can the IoT cater to the needs held by HE stakeholders?

Despite the plethora of research on the IoT in organisational contexts, there is still an underlying problem concerning the wider aspects that affect the application of the IoT in higher education (Qin, Li, Zhang, Gao, & He, 2014). This prompts the need to explore this problem to address communication and sharing information issues in the HE domain. Figure 1 illustrates the proposed framework:

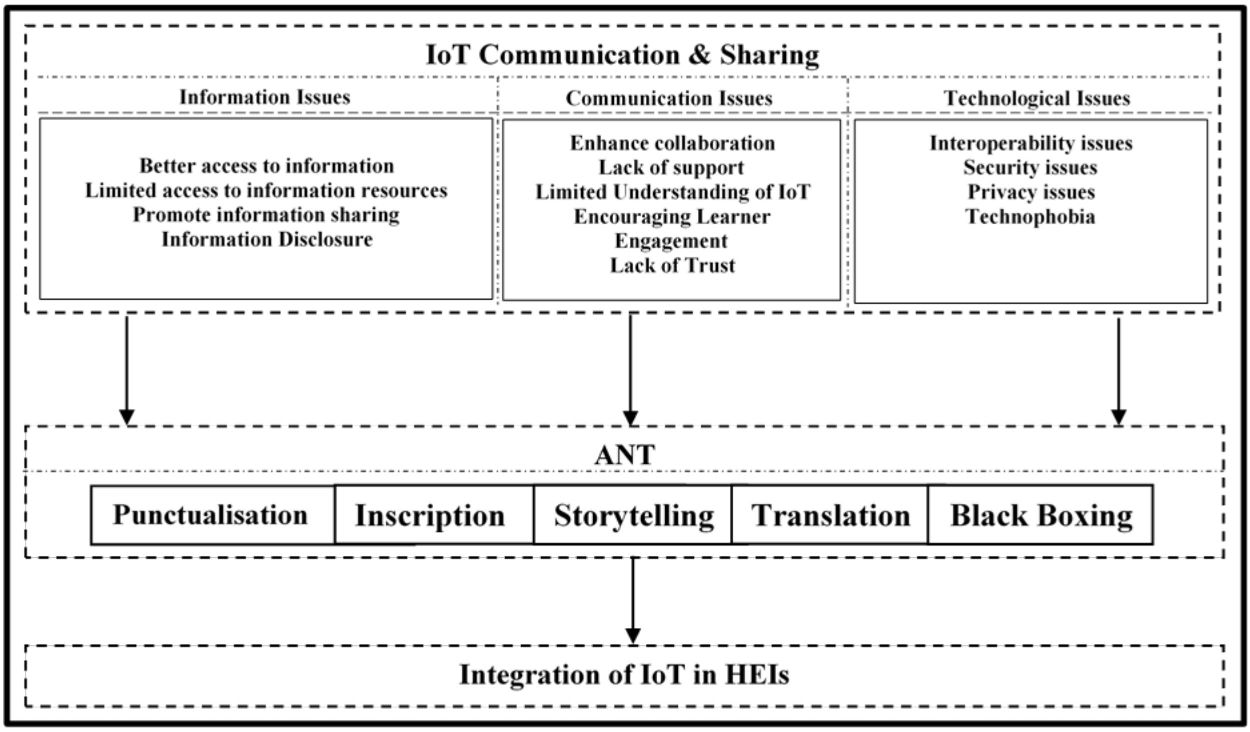

Figure 1: Research Framework Drawing Upon the IoT and ANT Concepts from an ICT Perspective

Research Method

A qualitative research method was used to address the following "how" question:

> *How can the integration of an ICT strategy through the IoT technology meet the informational, communication and system needs of University stakeholders?*

The unit of analysis or research population are University stakeholders comprising of students, teachers and administrators. A case study was carried out on two high-ranking University situated in North-West England. For the sample size and categories of participants, 40 participants made up of undergraduate/postgraduate students and lecturers and admins across the two Universities were interviewed (see Table 2). These particular participant groups were chosen because these are potential users of the IoT in HE and their perception of the benefits and challenges of this innovation could influence their decision to use the IoT to support their institutional practices. To protect participants' personal identities, pseudonyms replaced their real names.

Table 2: Summary of Key Stakeholders (participants) from UK Universities

No.	**Participant**	**Code**	**No.**	**Participant**	**Code**
University A			**University B**		
UA1	Student	S1A	**UB1**	Student	S1B
UA2	Student	S2A	**UB2**	Student	S2B
UA3	Student	S3A	**UB3**	Student	S3B
UA4	Student	S4A	**UB4**	Student	S4B
UA5	Student	S5A	**UB5**	Student	S5B
UA6	Student	S6A	**UB6**	Student	S6B
UA7	Student	S7A	**UB7**	Student	S7B
UA8	Student	S8A	**UB8**	Student	S8B
UA9	Admin	A1A	**UB9**	Admin	A1B
UA10	Admin	A2A	**UB10**	Admin	A2B
UA11	Admin	A3A	**UB11**	Admin	A3B
UA12	Admin	A4A	**UB12**	Admin	A4B
UA13	Admin	A5A	**UB13**	Admin	A5B
UA14	Teacher	T1A	**UB14**	Teacher	T1B
UA15	Teacher	T2A	**UB15**	Teacher	T2B
UA16	Teacher	T3A	**UB16**	Teacher	T3B
UA17	Teacher	T4A	**UB17**	Teacher	T4B
UA18	Teacher	T5A	**UB18**	Teacher	T5B
UA19	Teacher	T6A	**UB19**	Teacher	T6B
UA20	Teacher	T7A	**UB20**	Teacher	T7B

For data collection, individual interviews and focus groups with supporting documentation were conducted. Participants were recruited by contacting several Universities via email upon which receiving a response, would proceed to send a plain language statement for consent. Interview and focus group questions were designed as means to contextually frame participants' responses within the ANT framework. In particular, a semi-structured interview protocol was developed comprising of various questions and sub-questions aligned to the research questions. Semi structured interviews were used as a set of specific pre-defined questions needed to be asked about the topic in order to collect the most accurate and relevant data. Semi-structured interviews also created the opportunity to improvise during the interview process (Myers & Newman, 2007) in order to collect supplementary data that was not collected from the main narrative of the interview sessions, but would be equally as relevant and interesting as the main narrative data.

The structure of the interview protocol comprised of open-ended questions that captured the participants' responses that aligned with the research questions, which in turn enabled the participants to elaborate on their responses. For the focus groups, similar questions were asked in an open-ended discussion among a selected sample of the participants. Two focus groups were held. The first comprised of eight students, five admins and seven teachers from University A's population and a further two from each respected participant group was selected for University B. The interviews and focus groups took place over a three-month period between September and December 2018.

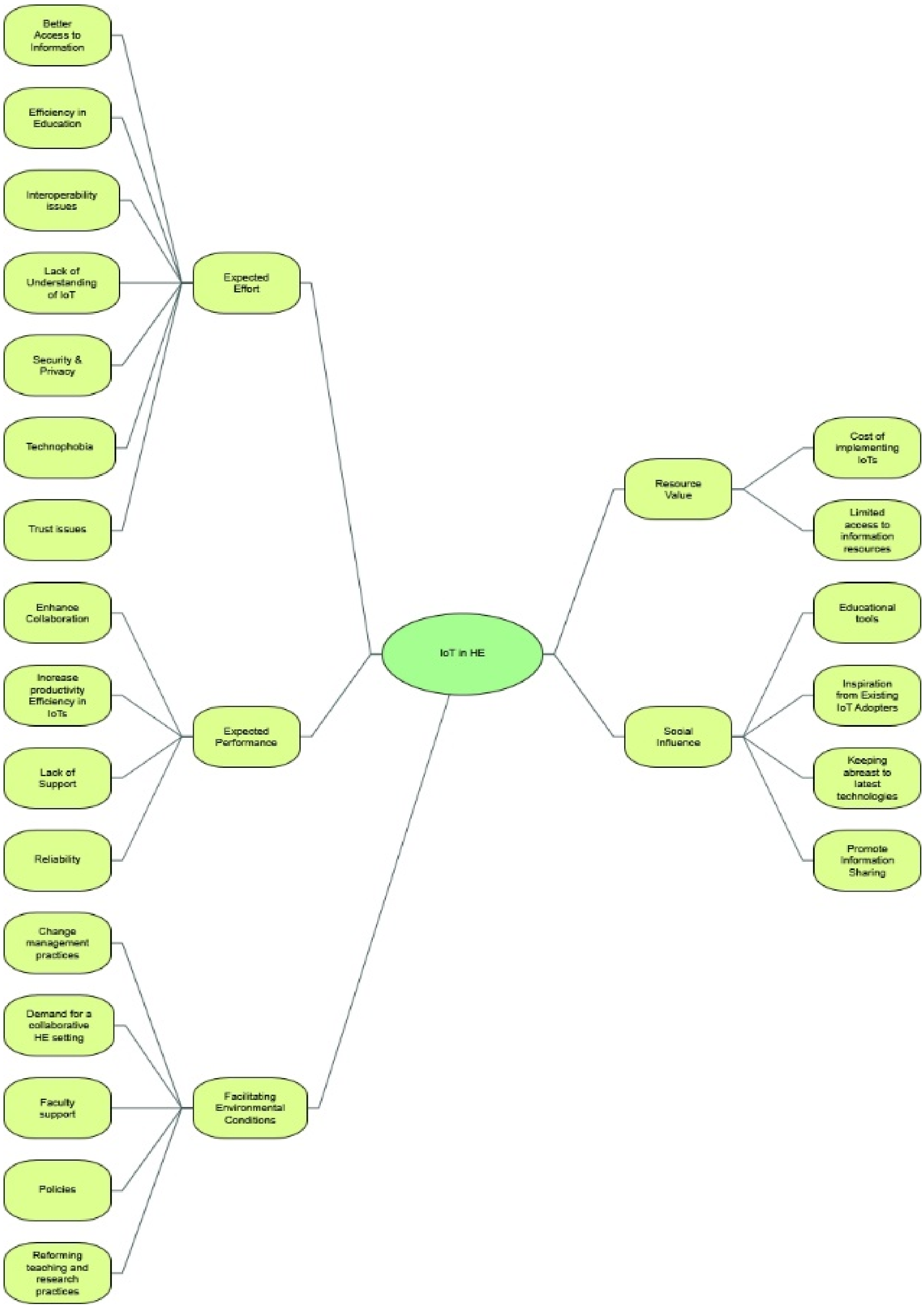

Figure 2: Coded Themes from Data Analysis using Nvivo

Finally, the interview and focus group transcripts were transcribed and were imported to a qualitative analysis tool known as Nvivo. The main themes and sub-themes were coded by applying nodes to each of them. This helped to unearth new concepts from the data and categorise them based on ANT theory. This contributed towards the validity of the research findings. Theme diagrams were created to highlight the main themes. Figure 2 illustrates the coded themes from the data analysis process using Nvivo.

Findings & Analysis

The key components of the ANT framework helped to determine the potential integration of strategic innovation in the form of a novel technology (IoT). The following ANT predictors or concepts in the context of this research are defined below:

- **Punctualisation**: Looking at the IoT tools and strategies from a holistic point of view.
- **Inscription**: Aligning users or stakeholders, such as students, teachers and admins with IT artefacts to facilitate institutional practices, namely the IoT.
- **Storytelling**: the integration the IoT as an IT tool/strategy for HE to potentially facilitate institutional practices, such as teaching and research, as well as promoting information sharing and collaboration among HE stakeholders.
- **Translation**: the effectiveness and efficiency of the IoT based on four sub-concepts, including Problematisation, Interessement, Enrolment and Mobilization to enhance institutional practices, as well as promote information sharing and collaboration.
- **Black boxing**: the IoT to potentially cater to the similar benefits held by HE stakeholders.

The participants' beliefs and perceptions towards a potential the IoT technology converged around five central themes that reflected the proposition of the ANT framework as shown in Figure 3. These include Expected Performance, Expected Effort, Social Influence, Facilitating Environmental Conditions and Resource value, in addition the ANT concepts mentioned above. Moreover, the key themes were mapped to the appropriate ANT theme. These themes were born out of the concepts sharing similar characteristics, which were then categorised accordingly.

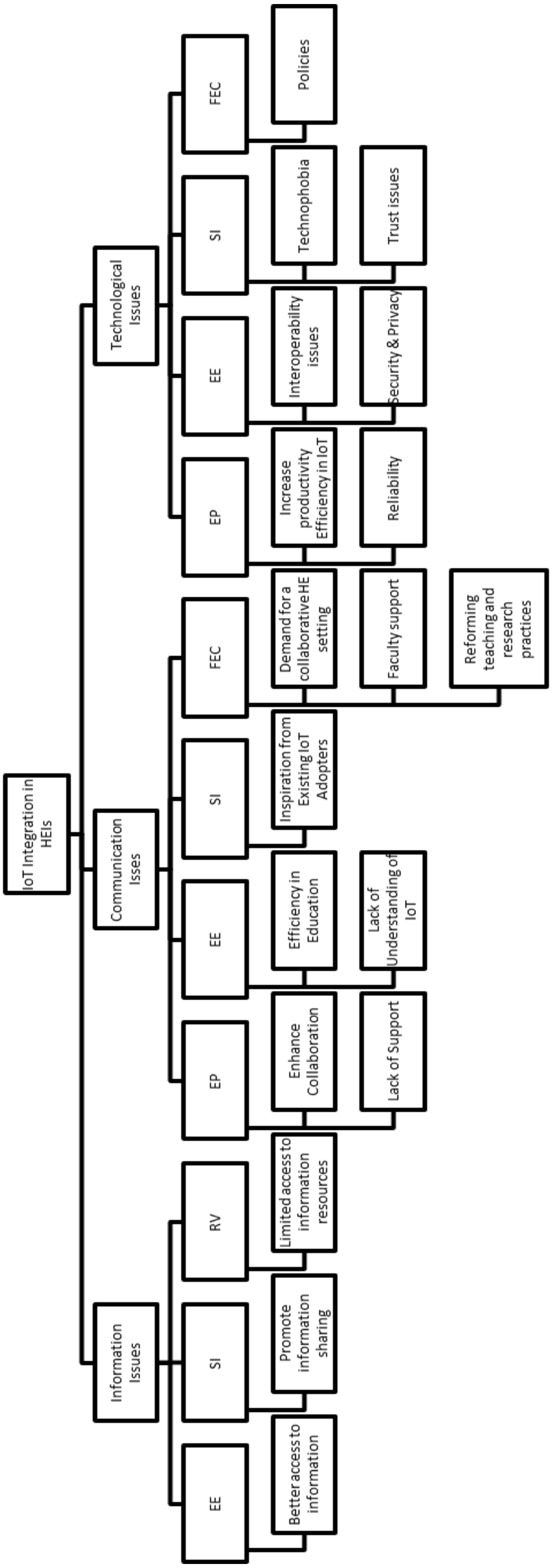

Figure 3: The IoT Themes & Concepts in HE from an ICT and ANT Perspective

Performance Expectancy (PE)

"Performance expectancy" emerged strongly amongst the admin side. They noted that the ability to integrate the IoT technology as a strategy to enhance productivity and efficiency were most prominent in influencing their potential use of the technology. The admins noted that the IoT could potentially help "*untether researchers from the field using sensor technology*" as they collect, as well as autonomously transmit, share and communicate data from remote locations (A1A, A2B and A4B). This capability makes this technology ideal for enhancing institutional practices, such as information sharing and communication.

Students emphasised a need for a reliable integrated system or platform like the IoT to enable cross-departmental access to information (S1A and S8B). The "*inefficiency and unreliability of using paper-based methods*" while registering for some courses was also highlighted (S2A and S4B). The IoT was perceived as an efficient and reliable integrated system that can bring all university departments within a shared working environment.

The performance expectancy also emerged as a substantial enabler that influences the potential integration of the IoT technology amongst the admins. The reliability of the IoT technology is an essential issue in determining its integration to enhance communication/collaboration and information sharing. The admins mentioned about the "*lack of support from vendors*" hindering the potential acceptance of the IoT owing to trust issues between the University and the vendors (A3A, A4A and A5B).

Expected Effort (EE)

"Expected effort" emerged thematically across the participant responses. Most of the teachers expressed excitement about the potential use of the IoT technology owing to potential opportunities that this technology is likely to play in the teaching and learning process. They explained that the IoT is expected to make their "*job processes more manageable*", enhance their "*collaboration with students*", and provide "*better access to course materials*" (T1A).

The IoT would also be used in the teaching and learning process if there are guaranteed efficiencies such as better engagement with their students and promote more efficient education practices (T1A, T2B and T7B). Similarly, there is likely to be an increased desire to apply the IoT as an educational tool/strategy if it can intuitively be used to accomplish specific tasks. For example, the lecturers stated that if "*the IoT were compatible with pedagogy ethos of the University, it would influence their acceptance of the technology*" (T3B and T5B). It was argued by the admins that "*technophobia*", "*interoperability issues*", a "*lack of understanding*" of the IoT and "*security and privacy*" influence the acceptance of the technology (A4A, A1B and A3B). A lack of trust in the IoT, as well as having a lack of knowledge of the IoT would more than likely lead to a rejection of the technology (A2A, A5A and A5B).

Similarly, a potential dilemma could occur from the integration of the IoT if there is an ongoing "*level of interruption in the classroom*" when a student is struggling with the technology, as well as other students being distracted when attempting to help them (T6A and T4B). The efficiency that the IoT are set out to create, thus presents greater disruption.

The participants also mentioned that having an understanding of the IoT-enabled education is a key determinant to potential the IoT integration. If the IoT were to be embraced in HE, both teachers and students have to perceive the technology as being useful in order to promote collaboration and information sharing between them. The challenge with the IoT is the technology's ability to "*maintain the effective management of information*", which in turn hinders collaboration and information sharing capabilities (S3A and S6B).

The response from the teacher and student participants showed that they have a high preference for digital content. They emphasised that they are more likely to use The IoT in the event of reducing the amount of effort in their ability to conduct institutional activities such as enhancing ubiquitous access to information and untethering them from physical learning spaces.

Social Influence (SI)

"Social influence" was found to be a high predictor of the potential integration of the IoT technology amongst the participants. Admins noted that the desire to keep abreast of trending technology could influence their choice to use The IoT. Participant A5B noted that they moved towards working with the IoT devices owing to the "*influence from collaborative projects*" they had worked on with their technically minded colleagues.

A community of members including admins, students and teachers have established research camps that aim to promote information sharing and collaboration via the IoT. Technically driven research spaces influenced their decision to use the IoT devices (S4A and S5B).

The student participants emphasised that it is essential to keep well informed of emergent technologies such as the IoT. An understanding of the IoT affords them with the skills applicable in today's digital economy (S7A and S2B). Further, the student participants explained that they have opted to adopt the 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 (S5B and S6A).

Facilitating Environmental Conditions (FEC)

In terms of "facilitating environmental conditions", the administrators noted that despite the effort by HEIs 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 (A4B and A5A).

Education policies are paramount when it comes to adopting new technologies (T2B and T7B). The participant further reiterated that policies that encourage and explicitly support the integration of the IoT into collaborative teaching and learning. Teachers noted that it is essential to have strategies that foster change management practices to "*reduce barriers to the IoT integration*" (T3A and T7A). Teachers also mentioned the need for professional development programs that should incorporate the IoT tools/strategies to encourage early adoption of these technologies (T4A and T2B). They noted that this would help educators "*develop innovative methodologies and appropriate pedagogies*" that "*reshape classroom experiences*" (T1B, T2A and T3B). One student argued that embracing a particular educational tool requires faculty to support the IoT enabled learning environment (S7A and S8B).

It was also noted 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 (A3A and A2B). The students pointed out that the role of faculty is paramount in influencing students to adopt the IoT (S7B and S8B). 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 (S7A and S8B).

Resource Value (RV)

In terms of "resource value", while the cost of adopting the IoT was not an outstanding factor in influencing the use of the technology amongst faculty, both students and administrators mentioned that despite the positive reputation the IoT has received from other sectors, the costs and inadequate institutional resources to support effective technology integration had influenced its use (S1B, A4B and T1B).

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 the IoT*" in their University (A2B and A4A). Despite the proliferation of educational technology, Universities fully adopt the IoT as an educational tool (T4B). The integration of the IoT into the education system is a gradual process due to the cost and challenges of implementation (A3B and T2A).

Relevance to ANT

Information Issues

Information issues relate to the themes EE, SI and RV, and the ANT concepts of storytelling, translation, black boxing and punctualisation. Translation in the sense that mobilisation of the IoT allows for better information sharing capabilities. Black boxing because the concept of better information access is a shared benefit among students, teachers and admins. Punctualisation in the sense that the wider issues of the IoT in HEIs limited information resources present a wider impediment of the IoT non-adoption in HEIs. Inscription in the sense that students, admins and teachers can use the same the IoT to support institutional practices such as the concept of promoting information sharing.

Communication Issues

Communication issues relate to the themes EP, EE, SI and FEC, and the ANT concepts of black boxing, storytelling, punctualisation and inscription. Black boxing in the sense that the concept of enhanced communication is a shared benefit among students, teachers and admins. Storytelling in the sense that the IoT integration can facilitate the concept of enhanced collaboration and increased productivity efficiency in the IoT, as well as provide support for faculty and a means to reform teaching and research practices. Similarly, translation in the sense that mobilisation of the IoT facilities collaboration among HEI stakeholders. In terms of punctualisation, the wider issues of the IoT in HEIs such as concepts like, inspiration from existing the IoT adopters that present a wider opportunity of the IoT adoption in HEIs, as well as the wider barriers to the IoT adoption such as a lack of understanding of the IoT.

Technological Issues

Technological issues relate to the themes EP, EE, SI and FEC, and the ANT concepts of storytelling, punctualisation and inscription. In terms of punctualisation, the wider technical issues of the IoT in HEIs such as concepts like reliability issues interoperability issues, security and privacy issues, trust issues and technophobia that present a wider impediment of the IoT non-adoption in HEIs. Storytelling in the sense that the IoT integration can help HEIs to introduce new policies to include the IoT as part of HEIs' ICT strategy to facilitate collaboration and information sharing capabilities.

In summary, the themes and concepts deduced from the above analysis in relation to ANT theory are summarised in Table 3. This was achieved by first categorising the concepts taken from the empirical findings into the key themes. This facilitated the categorisation of the themes into the three main perspectives covered in this paper, namely the informational, communicative and technological perspectives. Categorising the themes according to the relevant perspective then facilitated the categorisation of which ANT theme each perspective belonged to in order to highlight a relationship between the perspectives and the ANT themes. The adapted framework in Figure 4 highlights this process based on Table 3.

Table 3: Summary of Key the IoT & ANT Themes & Concepts in HE from an ICT Perspective Drawn from the Empirical Study

Themes		**Concepts**	**ANT Concepts**	**Stakeholder(s)**
Information Issues	Expected Effort (EE)	Better access to information	Black boxing Punctualisation Storytelling Translation	A1B, A2A, A2B, A3B, A4A, A4B, A5A, A5B, S1B, S2B, S3A, S4A, S5B, S6A, S6B, S7A, T1A, T1B, T2A, T2B, T3B, T4B, T5B, T6A, T7B
	Social Influence (SI)	Promote information sharing		
	Resource value (RV)	Limited access to information resources Information Disclosure		
Communication Issues	Expected Performance (EP)	Enhanced Collaboration Lack of Support		

<table>
<tr><td rowspan="4"></td><td></td><td>Increase productivity
Efficiency</td><td rowspan="4">Black boxing
Inscription
Punctualisation
Storytelling</td><td rowspan="4">A1A, A1B, A2A, A2B, A3A, A3B, A4A, A4B, A5A, A5B, S1A, S2A, S2B, S3A, S4A, S5B, S6A, S7A, S7B, S8A, S8B, T1A, T1B, T2A, T2B, T3A, T4A, T3B, T3B, T4B, T7A, T7B</td></tr>
<tr><td>Expected Effort (EE)</td><td>Efficiency in Education
Lack of Understanding of the IoT</td></tr>
<tr><td>Social Influence (SI)</td><td>Inspiration from Existing the IoT Adopters
Limited Understanding of the IoT
Encouraging Learner Engagement</td></tr>
<tr><td>Facilitating Environmental Conductions (FEC)</td><td>Demand for a collaborative HE setting
Faculty support
Reforming teaching and research practices</td></tr>
<tr><td rowspan="4">Technological Issues</td><td>Expected Performance (EP)</td><td>Reliability issues</td><td rowspan="4">Punctualisation
Storytelling</td><td rowspan="4">A1A, A1B, A2A, A2B, A3A, A3B, A4A, A4B, A5A, A5B, S1A, S2A, S2B, S3A, S4A, S5B, S6A, S7A, S7B, S8A, S8B, T1A, T1B, T2A, T2B, T3A, T4A, T3B, T3B, T4B, T7A, T7B</td></tr>
<tr><td>Expected Effort (EE)</td><td>Interoperability issues
Security issues
Privacy issues</td></tr>
<tr><td>Social Influence (SI)</td><td>Technophobia
Trust issues</td></tr>
<tr><td>Facilitating Environmental Conductions (FEC)</td><td>Policies</td></tr>
</table>

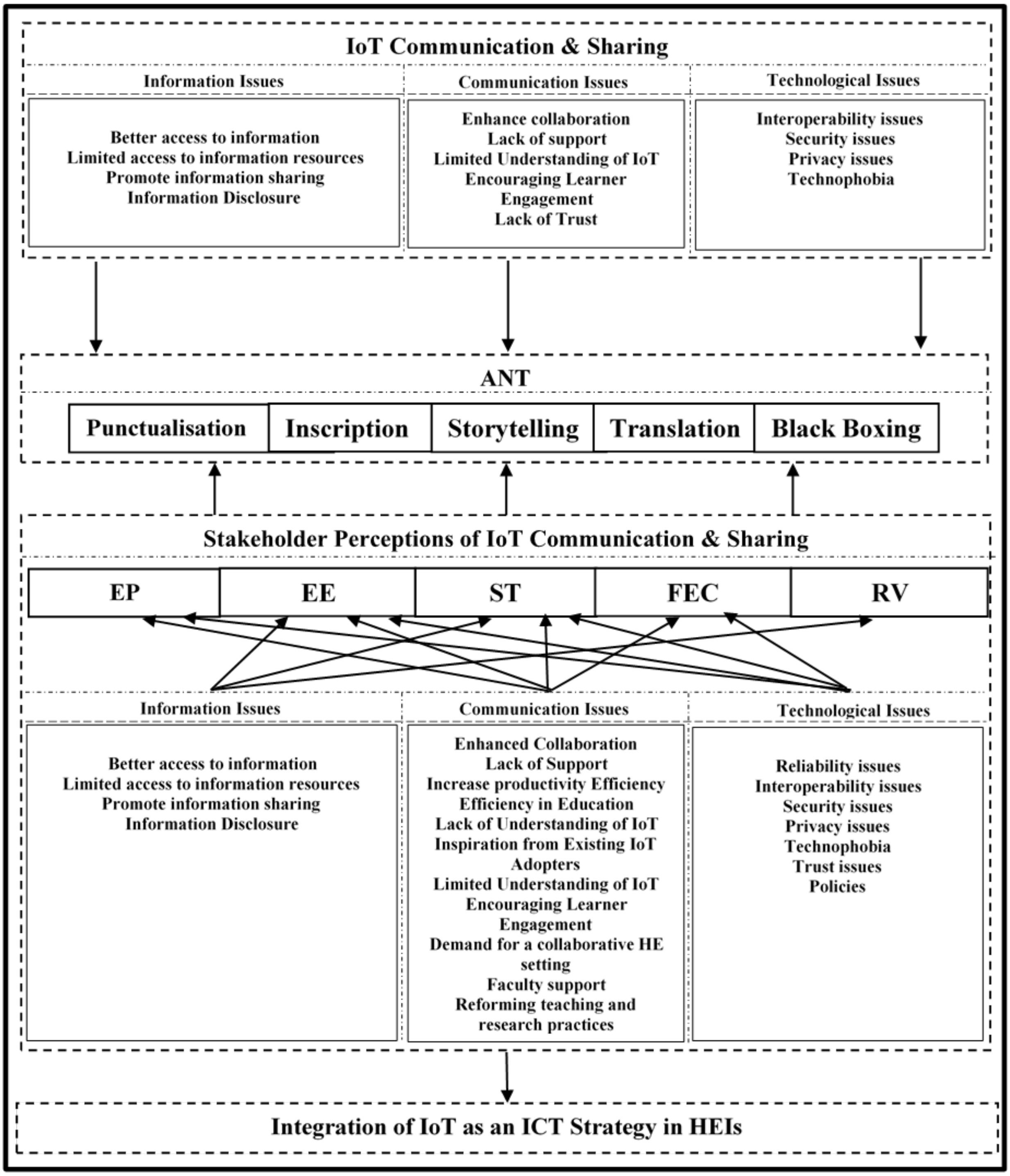

Figure 4: Adapted Framework Drawn upon the IoT and ANT Concepts from an ICT Perspective

Discussion

This descriptive case study design allowed participants to share their perceptions of the IoT technology. The discussion aligns to the research questions of the study. The findings provided insight into how insight into how a potential the IoT strategy can facilitate communication and information sharing within HE.

As the IoT becomes a new normal in HEIs, stakeholders are looking for new strategies to enhance performance, engagement, and behaviour. Integrating the IoT into HE provides the opportunity to store, analyse, and share data. Data could potentially be used to personalise instructions tailored to match the needs and expectations of HEI stakeholders, such as admins, teachers and students. This data can then be leveraged to create new strategies that enhance collaboration and information sharing in HE settings.

The beliefs and perceptions reported to influence the IoT integration in HEIs include expected performance, expected effort, social influence, facilitating environmental conductions and resource value. The key themes were guided by the propositions of the Actor Network Theory (ANT) and the ICT topology adopted throughout this paper.

PE had a significant impact on the potential integration of the IoT technology among the HEI stakeholders. It became more apparent that the IoT as an IT strategy to could potentially create a shared working space that promotes collaboration and work productivity. Relatedly, teachers could embrace the IoT as an IT strategy to improve efficiency in their teaching research practices, such as grading and preparing course materials. Stakeholders highlighted that they would only accept the IoT for teaching and learning if it aligned with their individual needs and efficiencies. Despite this, there is a need for professional development in order to raise awareness about the IoT and how this aligns with existing curricula. Therefore, ongoing training about the IoT and its integration into the teaching and learning process is vital to raise such awareness.

Other themes that were deduced from the findings were EE, SI and FEC, which were perceived as benefits to the IoT integration to promote collaboration and information sharing (Njeru et al., 2017). For example, teachers appear to be convinced by the idea that the IoT can only be realised through training and support to increase the uptake of the IoT in HEIs. To improve the buy-in into integrating the IoT, administrators are required to increase teachers' awareness about why the IoT cannot only improve their efficiency but can also act as an IT strategy that can facilitate and promote collaboration and information sharing to increase efficiency and provide a better teaching and learning experience.

Despite the significant costs of integrating technologies like the IoT, this had very little impact on teachers' behaviour towards integrating the IoT in that teachers and students would utilise the technology availed to them by administrators. Cost can be perceived as key barrier to administrators while efficiency was more of a concern for teachers. Nevertheless, to promote efficiency among teachers with the availed technology, administrators are expected to draft policies as part of its IT strategy that support professional development to raise awareness of the IoT and how this can promote collaboration and information sharing to enhance HEI practices.

Information issues were found to relate to the ANT concepts of storytelling, translation, black boxing and punctualisation. This included the mobilisation of the IoT for better information sharing capabilities, better information access as a shared benefit among students, teachers and admins and limited information resources as a wider impediment of the IoT non-adoption. These findings represent a link between the sociotechnical aspect of ANT and the information component the ICT topology in a sense that the integration of the IoT as a potential information-sharing tool can help to meet or hinder stakeholders' informational needs.

Communication issues were found to relate to the ANT concepts of storytelling, punctualisation and inscription. This included enhanced communication as a shared benefit among students, teachers and admins, enhanced collaboration, increased productivity efficiency, provision of support for faculty, reforming teaching and research practices, mobilisation of the IoT, facilitating collaboration among HEI stakeholders, inspiration from existing the IoT adopters and a lack of understanding of the IoT. These findings represent a link between the sociotechnical aspect of ANT and the communication component the ICT topology in a sense that the integration of the IoT as a potential collaboration tool can help to meet or hinder stakeholders' informational needs.

Technological issues were found to relate to the ANT concepts of storytelling, punctualisation and inscription. This included the wider technical issues of the IoT in HEIs such as reliability issues, interoperability issues, security and privacy issues, trust issues and technophobia that present a wider impediment of the IoT non-adoption in HEIs. This also includes the introduction of new policies to include the IoT as part of HEIs' ICT strategy to facilitate collaboration and information sharing capabilities. These findings represent a link between the sociotechnical aspect of ANT and the technological component the ICT topology in a sense that the integration of the IoT as a potential innovative technology can help to meet or hinder stakeholders' system needs.

In short, HEIs are potential incubators of the IoT if integrated into the education system. HEIs are expected to facilitate its use as collaborative and sharing tools on a management platform across various educational institutions. If the IoT are to gain traction across HE, it is crucial to understand where different stakeholders are positioned in the spectrum of technological awareness.

Conclusion & Future Work

With the current education system transitioning from a traditional to a data-driven education process, the uptake of the IoT within HEIs is slowly gaining traction. The integration of the IoT in HEIs can offer potential affordances to institutional practices. Opportunities include better collaborative learning, improved information sharing and productive efficiency that is driven by ubiquitous tools that can used as a potential ICT strategy to facilitate these practices for HEI stakeholders. With the increased integration of the IoT to the teaching and learning process, the HE sector is very likely to transition to competency based learning driven by IT tools.

Despite the IoT highlighting several potential opportunities in the teaching and learning process, it is equally important to regard the barriers to the IoT integration in HEIs. This paper found that the IoT as a potential IT strategy could come with potential risks such as privacy concerns, data security and interoperability issues.

Information, communication and technological issues were found to relate to the ANT concepts and findings highlighted a link between the sociotechnical aspect of ANT and the information, communication and technological components of the ICT topology. Despite the opportunities the IoT can bring to HEIs, stakeholders have contrasting perceptions of the IoT as a potential information sharing and communication strategy to meet their system expectations, and therefore are undecided about their willingness to embrace the IoT.

The research findings drawn on recommendations for future research. Considerations for future research are required to determine the best practices or strategies to integrate the IoT in HEIs. The low level of awareness of IoT technology amongst the HEI stakeholders' prompts further additional research to explore the reasons why HEI stakeholders are reluctant to embrace the IoT. This also includes how pedagogical strategies can be developed to implement the IoT as a potential IT strategy that can facilitate institutional practices, as well as promote information sharing and collaboration amongst HEI stakeholders. Further research could also draw on developing best practices from a faculty perspective who are likely to be early adopters of the IoT in HEIs, and thus could be a persuading factor for faculty to adopt the IoT into their pedagogy. This could help to develop a network of faculty members to promote the potentials of the IoT to persuade other potential adopters. For security and privacy, future research could draw on how HEIs could address cyber-attacks in the event of integrating the IoT into their curricula.

References

Ali, M. (2019a). Cloud Computing at a Cross Road: Quality and Risks in Higher Education. *Advances in Internet of Things*, *9*(3), 33-49.

Ali, M. (2020). *Multi-Perspectives of Cloud Computing Service Adoption Quality and Risks in Higher Education*. In D. B. A. Mehdi Khosrow-Pour (Ed.), Handbook of Research on Modern Educational Technologies, Applications, and Management (2nd Ed ed.). IGI Global.

Ali, M. B. (2019b). Multiple Perspective of Cloud Computing Adoption Determinants in Higher Education a Systematic Review. *International Journal of Cloud Applications and Computing (IJCAC)*, *9*(3), 89-109.

Berman, F., & Cerf, V. G. (2017). Social and ethical behavior in the internet of things. *Communications of the ACM, 60*(2), 6-7.

Cho, S., Mathiassen, L. & Nilsson, A. (2008). Contextual dynamics during health information systems implementation: an event-based actor-network approach, *European Journal of Information Systems*, *17*(6), 614-630, DOI: 10.1057/ejis.2008.49

Demirer, V., Aydın, B., & Çelik, Ş. B. (2017). Exploring the educational potential of Internet of Things (IoT) in seamless learning *The Internet of Things: Breakthroughs in Research and Practice* (pp. 1-15): IGI Global.

Dery, K., Kolb, D. & MacCormick, J. (2014). Working with connective flow: how smartphone use is evolving in practice, *European Journal of Information Systems*, *23*(5), 558-570, DOI: 10.1057/ejis.2014.13.

Du, J., Jiang, C., Gelenbe, E., Xu, L., Li, J., & Ren, Y. (2018). Distributed Data Privacy Preservation in IoT Applications. *IEEE Wireless Communications*, *25*(6), 68-76.

Forrest, C. (2017). 80% of IoT apps not tested for vulnerabilities, report says. Retrieved 24th Feb 2019 from https://www.techrepublic.com/article/80-of-IoT-apps-not-tested-for-vulnerabilities-report-says/

Fraga-Lamas, P., Fernández-Caramés, T. M., Suárez-Albela, M., Castedo, L., & González-López, M. (2016). A Review on Internet of Things for Defense and Public Safety. *Sensors (Basel, Switzerland), 16*(10), 1644. doi:10.3390/s16101644

Fraile, F., Tagawa, T., Poler, R. and Ortiz, A. (2018). Trustworthy industrial IoT gateways for interoperability platforms and ecosystems. *IEEE Internet of Things Journal*, *5*(6), 4506-4514.

Gawali, S. K., & Deshmukh, M. K. (2019). Energy Autonomy in IoT Technologies. *Energy Procedia, 156*, 222-226. doi:https://doi.org/10.1016/j.egypro.2018.11.132

Gómez, J., Huete, J. F., Hoyos, O., Perez, L., & Grigori, D. (2013). Interaction system based on internet of things as support for education. *Procedia Computer Science, 21*, 132-139.

Guilloux, V., Locke, J. & Lowe, A. (2013). Digital business reporting standards: mapping the battle in France, *European Journal of Information Systems*, *22*(3), 257-277, DOI: 10.1057/ejis.2012.5

Hansen, J. D., & Reich, J. (2015). Democratizing education? Examining access and usage patterns in massive open online courses. *Science, 350*(6265), 1245. doi:10.1126/science.aab3782

Harwood, T., & Garry, T. (2017). Internet of Things: understanding trust in techno-service systems. *Journal of Service Management*, *28*(3), 442-475.

Heeks, R & Stanforth, C. (2007) Understanding e-Government project trajectories from an actor-network perspective, *European Journal of Information Systems*, *16*(2), 165-177, DOI: 10.1057/palgrave.ejis.3000676

Hsu, C.-L., & Lin, J. C.-C. (2018). Exploring factors affecting the adoption of Internet of Things services. *Journal of Computer Information Systems, 58*(1), 49-57.

Islam, S. M. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. (2015). The Internet of Things for Health Care: A Comprehensive Survey. *IEEE Access, 3*, 678-708. doi:10.1109/ACCESS.2015.2437951

Janeček, V. (2018). Ownership of personal data in the Internet of Things. *Computer law & security review, 34*(5), 1039-1052.

Kassab, M., DeFranco, J., & Laplante, P. (2020). A systematic literature review on Internet of things in education: Benefits and challenges. Journal of Computer Assisted Learning, 36(2), 115-127.

Krieger, D. J., & Belliger, A. (2014). *Interpreting Networks: Hermeneutics, Actor-Network Theory & New Media*: transcript.

Krotov, V. (2017). The Internet of Things and new business opportunities. *Business horizons, 60*(6), 831-841.

Lee, S. M., & Chen, L. (2011). An integrative research framework for the online social network service. *Service Business, 5*(3), 259.

Majeed, A., & Ali, M. (2018). *How Internet-of-Things (IoT) making the university campuses smart? QA higher education (QAHE) perspective.* Paper presented at the Computing and Communication Workshop and Conference (CCWC), 2018 IEEE 8th Annual.

Maksimović, M. (2018). IoT concept application in educational sector using collaboration. *Facta Universitatis, Series: Teaching, Learning and Teacher Education, 1*(2), 137-150.

Mani, Z., & Chouk, I. (2018). Consumer Resistance to Innovation in Services: Challenges and Barriers in the Internet of Things Era. *Journal of Product Innovation Management*, *35*(5), 780-807.

Manwaring, K., & Clarke, R. (2015). Surfing the third wave of computing: a framework for research into eObjects. *Computer law & security review, 31*(5), 586-603.

Middleton, C., Scheepers, R. & Kristiina, V.T. (2014) When mobile is the norm: researching mobile information systems and mobility as post-adoption phenomena, *European Journal of Information Systems*. *23*(5), 503-512, DOI: 10.1057/ejis.2014.21

Myers, M.D. and Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and organization*, *17*(1), 2-26.

Nimmo, R. (2011). Actor-network theory and methodology: Social research in a more-than-human world. *Methodological Innovations Online, 6*(3), 108-119.

Njeru, A. M., Omar, M. S., Yi, S., Paracha, S., & Wannous, M. (2017). *Using IoT technology to improve online education through data mining.* Paper presented at the 2017 International Conference on Applied System Innovation (ICASI).

Noura, M., Atiquzzaman, M., & Gaedke, M. (2018). Interoperability in Internet of Things: Taxonomies and Open Challenges. *Mobile Networks and Applications*. doi:10.1007/s11036-018-1089-9

Oberländer, A.M., Röglinger, M., Rosemann, M, Kees, A., Ågerfalk, P & Tuunainen, V. (2018). Conceptualizing business-to-thing interactions – A sociomaterial perspective on the Internet of Things, *European Journal of Information Systems*. *27*(4), 486-502, DOI: 10.1080/0960085X.2017.1387714

Patel, P., & Cassou, D. (2015). Enabling high-level application development for the Internet of Things. *Journal of Systems and Software, 103*, 62-84. doi:https://doi.org/10.1016/j.jss.2015.01.027

Pauget, B. & Dammak, A. (2019). The implementation of the Internet of Things: What impact on organizations?. *Technological Forecasting and Social Change*, 140, 140-146.

Petrov, C. (2019). *Internet Of Things Statistics 2020 [The Rise Of IoT]* [Online]. Available: https://techjury.net/stats-about/internet-of-things-statistics/ [Accessed 26th Feb 2020].

Qin, W., Li, B., Zhang, J., Gao, S., & He, Y. (2014). *Design and Implementation of IoT Security System Towards Campus Safety.* Paper presented at the Advanced Technologies in Ad Hoc and Sensor Networks, Berlin, Heidelberg.

Rose, K., Eldridge, S., & Chapin, L. (2015). The internet of things: An overview. *The Internet Society (ISOC)*, 1-50. Rushby, N., & Surry, D. (2016). *The Wiley Handbook of Learning Technology*: Wiley.

Sarker, S., Sarker, S., & Sidorova, A. (2006). Understanding Business Process Change Failure: An Actor-Network Perspective. *Journal of Management Information Systems, 23*(1), 51-86. doi:10.2753/MIS0742-1222230102

Talari, S., Shafie-Khah, M., Siano, P., Loia, V., Tommasetti, A., & Catalão, J. (2017). A review of smart cities based on the internet of things concept. *Energies, 10*(4), 421.

Tsohou, A., Karyda, M., Kokolakis, S & Kiountouzis, E. (2015). Managing the introduction of information security awareness programmes in organisations, *European Journal of Information Systems*, *24*(1), 38-58, DOI: 10.1057/ejis.2013.27

Wei, P., & Zhou, Z. (2018). Research on security of information sharing in Internet of Things based on key algorithm. *Future Generation Computer Systems, 88*, 599-605.

Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. *Information Systems Frontiers, 17*(2), 261-274.

Xia, F., Yang, L. T., Wang, L., & Vinel, A. (2012). Internet of Things. *International Journal of Communication Systems, 25*(9), 1101-1102. doi:doi:10.1002/dac.2417

Yorkstone, S. (Ed.). (2019). Global Lean for Higher Education: A Themed Anthology of Case Studies, Approaches, and Tools. CRC Press.

Zhu, Z.-T., Yu, M.-H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments, 3*(1), 4. doi:10.1186/s40561-016-0026-2.