

Critical Factors Influencing Pre-Service Teachers' Use of the Internet of Things (IoT) in Classrooms

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Abstract—

In order to improve teaching and learning, this research sought to understand the elements that pre-service teachers consider when deciding whether to employ the Internet of Things (IoT) in the classroom. The implications of employing the IoT in an e-learning environment on pre-service instructors' perceptions of utility, convenience of use, attitudes toward using the IoT, and the influence of such attitudes on students' behavior were examined using the technology acceptance model (TAM). By using deliberate sampling, 47 final-year pre-service teachers were chosen to take part. Regression analysis was used to assess the data gathered in a quantitative manner. The findings demonstrated that pre-service teachers' views on deploying IoT in the classroom were highly influenced by TAM-related aspects of the IoT's perceived utility and simplicity of use. Their view regarding IoT, however, had little bearing on whether or not they intended to adopt it. On the other hand, the pre-service participants' desire to use or continue to use the IoT in the future was most strongly influenced by its perceived utility. As a result, many pedagogical implications are presented for the creation of teacher training programs. The findings of this study give suggestions for further research.

Keywords—internet of things, IoT, critical factors, pre-service teachers, e-learning, technology acceptance model

Introduction

The next generation of Internet technology, known as the Internet of Things (IoT), employs intelligent gadgets to link the real world and the internet [1]. IoT systems are growing increasingly prevalent, and in only a few years, their broad acceptance has significantly changed all facets of life for billions of people [2]. The Internet of Things is referred to as "the global infrastructure for the information society that can facilitate interconnecting all types of objects, such as physical and virtual things based on the presented telecommunication protocols and technologies" [3] (Global Standards Initiative on the Internet of Things, p. 914). The Internet of Things (IoT) is regarded as an automation and analytics system since it leverages big data, artificial intelligence, networks, sensors, and other technologies to develop faultless service systems [4]. The pervasiveness of IoT streamlines everyday activities, deepens interactions with the environment, and improves social connections with both people and things [5]. Our children's digital and technological environment is being transformed and reshaped by the IoT [6]. Over 75 billion IoT-capable gadgets will be deployed worldwide by 2025 [7]. The IoT swiftly transforms the conventional educational system into one that is more adaptable, flexible, and effective [3]. IoT technology will thus inevitably have an impact on our educational institutions. IoT technology has a great deal of promise to enhance the teaching and learning process and make "anytime, anywhere" a reality [8]. However, the IoT's use in education is still in its infancy [3], and very few publications have concentrated on doing so, especially in the context of underdeveloped nations [9]. For instance, a recent systematic analysis [10] found that adoption and potential use of the IoT in education are still uncommon, particularly in developing nations (such as Saudi Arabia). This provides enough opportunity for research into the problems affecting IoT implementations in education, especially in underdeveloped nations. This field has little and just recently undergone research. Finding Saudi preservice teachers who are prepared, technologically accepting, and want to employ technology (like IoT) in their future classrooms is crucial to Saudi Arabia's digital transformation. Therefore, by addressing this requirement, the present research seeks to add to the body of knowledge.

It is crucial to prepare pre-service teachers to incorporate emerging technologies since the Internet of Things cannot be ignored [11] [12] [13]. To prepare students, it is vital to identify the variables affecting their desire to use IoT technology in classroom and learning settings. By identifying the elements that influence pre-service teachers' behavioral intentions to utilize IoT technology in their future teaching and learning, this research investigates the crucial aspects affecting their intents to use the IoT in their classrooms. The results of this study may help us better understand the important variables that affect pre-service teachers' aspirations to utilize IoT and, therefore, their actual usage of IoT in their future careers. The results of the present research might have a number of pedagogical ramifications for creating, implementing, and assessing teacher training programs that use IoT technology into their practices. The rest of this research is divided into the following sections. The literature review is discussed in the second portion, while the third section presents the theoretical framework and hypothesis construction. The technique (covering the sample and context, instrument, data collection, and analysis) is covered in the fourth part. The fifth part contains a presentation of the study's findings. The sixth portion presents the discussions and implications, while the seventh section presents the findings and restrictions.

Literature review

The IoT in education

The use of the IoT in education is growing quickly and is helpful in teaching and connecting students [10] [14]. Implementing the IoT in any educational environment may help students learn more quickly and teachers teach more effectively [14] [15]. One of the main advantages of the IoT in education has been noted as enabling personalised and distinctive contact with learners. Additionally, the classroom's physical and virtual resources, as well as interactions between students and teachers, may also be improved [8] [11]. As a result, IoT-based learning environments may have a big impact on the duties and activities of both students and teachers [3]. The favorable effects of integrating the IoT in an educational setting on teaching and learning outcomes have been recognised by several research in the literature.

For instance, [16] carried out an experimental research with 50 engineering students and discovered that the IoT was utilized to help the teaching process and improve student academic progress. They discovered that by connecting natural things to virtual ones through the IoT, more information may be obtained and meaningful learning is facilitated. Another example is the experimental distant learning platform for architecture that [17] built and put into use. It was based on the IoT. The findings showed that IoT technology may boost students' academic performance and enhance instructors' capacity to give courses. An IoT-based teaching management system developed by [18] helped instructors monitor student attendance and boost interest in learning; it was discovered to have a positive impact on students' learning processes for higher education. Additionally, [9] carried out a research in Thailand with 244 pupils and four instructors to look at how sensor-based IoT affects kids' interest in learning. The results demonstrated that the learning outcomes and engagement of students who utilized sensor-based IoT to study were much higher than those of those who did not.

A research on the potential of Google Lens as an IoT tool in biology classrooms in Ukrainian schools was just completed by [19]. They discovered that Google Lens produced excellent results and ought to be employed in the classroom. Additionally, [20] investigated the efficacy of Voca-Lens using a mixed-method research with 56 students from three Malaysian schools and discovered that it had a favorable influence on fostering students' motivation and learning results. Other recent research on the benefits of IoT-based learning environments on students' academic performance focus on promoting learning creativity [21], improving software design and production [22], and enhancing language proficiency [23].

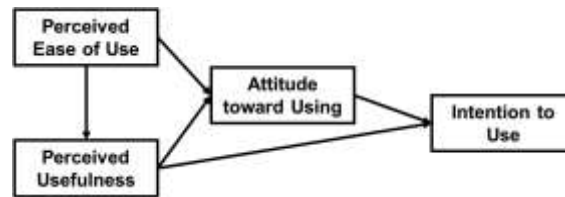
Pre-service teachers in the Saudi context

Future development in Saudi Arabia is significantly facilitated and driven by technology [24]. As a result, the technical proficiency of instructors is highly regarded, and the Saudi educational system has progressively incorporated technology into the teaching-learning process [25]. As a consequence, Saudi instructors at all educational levels are now required to be proficient in digital technologies in order to enhance and revolutionize teaching and learning [26]. Because they guarantee that new teachers are prepared for their future classrooms, teacher preparation programs (pre-service training) are regarded as the foundation of teacher education [27]. Pre-service teachers should get extensive digital literacy instruction from colleges and institutions [28]. Education preparation programs need to be overhauled comprehensively across all subject areas if pre-service teachers are to be more responsive to the possibilities and difficulties presented by increasing technology integration [29]. [30] underlined the need for creating programs in education faculties to educate them while examining the technical acceptability of the IoT in mathematics pre-service instructors. There is a dearth of proper training for teachers to use IoT technology in their classrooms, according to several research examining pre-service teachers' attitudes on utilizing the IoT in teaching and learning [31] [32]. This research, which focuses on pre-service teachers in Saudi Arabia, attempts to explore the planned usage of the IoT based on the technological acceptance model (TAM). The TAM, which is described in more detail in the next section, is used for this inquiry.

Theoretical framework and hypothesis

The TAM model, which was first put out by [33], is one of the most widely used models for analyzing people's attitudes toward technology. To predict or explain the elements that affected how a person used any information technology (IT) system, [33] suggested the TAM [34]. [35]. Users' adoption of an IT system is determined by their

behavioral intention to utilize the system, according to the TAM (illustrated in Figure 1) [36]. The TAM states that perceived utility and simplicity of use are the two key elements that determine whether a technology application is accepted or rejected [37]. Perceived usefulness is described as "the degree to which a person feels that utilizing a specific system would boost his or her work performance, whilst perceived ease of use refers to "the degree to which a person believes that using a particular system would be devoid of effort" [33] (p. 320). In other words, the degree of preparedness and desire to utilize such technology is significantly and fundamentally influenced by the degree of user acceptance of the characteristics and functions of the technology [38].



Both perceived usefulness and ease of use positively influence users' attitudes toward utilizing the technology and their intention, which, in turn, affects the actual usage of technology [39]. Attitude refers to a "user's evaluation regarding the usage of the system" [36] (p. 194). According to [40], TAM factors "appear to be able to account for 40 percent to 50 percent of user acceptance" (p. 152). By adopting the TAM, this study attempts to elucidate what influences pre-service teachers to accept or reject using the IoT in a learning environment based on the factors of perceived usefulness and perceived ease of use.

In summary, both perceived usefulness and perceived ease of use were found to positively impact behavioral intention toward using a system, and perceived ease of use was reported to impact perceived usefulness [41] positively. Therefore, the following research questions and hypotheses (Hs) were formulated based on the four TAM factors of technology use: perceived ease of use, perceived usefulness, user attitude, and a user's behavioral intention to use technology.

Research question 1: What is the relationship between pre-service teachers' perceptions of IoT ease of use and their perceptions of its usefulness?

H1: There is a significant relationship between pre-service teachers' perceptions of IoT ease of use and its usefulness.

Research question 2: What is the relationship between pre-service teachers' perceptions of IoT ease of use and their attitude toward its use?

H2: There is a significant relationship between pre-service teachers' perceptions of IoT ease of use and their attitude toward its use.

Research question 3: What is the relationship between pre-service teachers' perceptions of IoT usefulness and their attitude toward its use?

H3: There is a significant relationship between pre-service teachers' perceptions of IoT usefulness and their attitude toward its use.

Research question 4: What is the relationship between pre-service teachers' perceptions of IoT usefulness and their intention to use it?

H4: There is a significant relationship between pre-service teachers' perceptions of IoT usefulness and their intention to use it.

Research question 5: What is the relationship between pre-service teachers' attitudes toward using IoT and their intention to use it?

H5: There is a significant relationship between pre-service teachers' attitudes toward using IoT and their intention.

Methodology

A descriptive research design using a quantitative approach was implemented in this study to examine the TAM factors that determine pre-service teachers' decision to use (adopt) the IoT for teaching and learning in their future classrooms.

Sample and context

To attain the aim of this study, a purposive sample [42] was used with a total of 47 pre-service teachers from the faculty of education, including final-year undergraduate male and female students studying a Bachelor of Computer

Teacher program. Participants were enrolled in an Instructional Software Design course and were required to complete a set of assignments related to the topic of the weekly lecture over 14 weeks.

In each of these assignments, the students were asked to select one IoT application (e.g., Google Lens, Goggle Assistant, etc.) and utilize its functions for several purposes, such as researching, reporting, or obtaining practical design skills. For example, students were asked to perform direct searches (typing into the search engine via the application), translate, or read specific text on the display screen (scanning a barcode or recognizing text through the application). The assignments were consistent with the course outcomes in equipping the students with the skills and competencies necessary for their future profession as a teacher.

Instrument

A survey questionnaire was employed in this study to investigate pre-service teachers’ perceptions of the use of the IoT in the classroom. The self-report questionnaire was adopted from Davis [33], based on the four validated constructs of perceived ease of use, perceived usefulness, user’s attitude, and IoT intention to use. A 5-point Likert scale (from 1 = ‘strongly agree’ to 5 = ‘strongly disagree’) was used to measure all survey items. Table 1 shows the survey constructs and items.

Table 3. Reliability and validity coefficients of the survey

Construct	Item	M (SD)	Cronbach's Alpha (if Item Deleted)	Item-Total Correlation	Corrected Item-Total Correlation	Cronbach's Alpha
Perceived ease of use (6) items	PEU1	3.99 (.50)	.796	.848*	.741*	.854
	PEU2		.817	.753*	.653*	
	PEU3		.800	.821*	.733*	
	PEU4		.813	.780*	.659*	
	PEU5		.807	.660*	.480*	
	PEU6		.803	.814*	.707*	
Perceived usefulness (6) items	PU1	3.74 (.76)	.893	.734*	.599*	.893
	PU2		.866	.844*	.734*	
	PU3		.880	.786*	.678*	
	PU4		.853	.897*	.839*	
	PU5		.869	.830*	.747*	
	PU6		.881	.765*	.667*	
Attitude toward use (4) items	AU1	3.79 (.74)	.856	.742*	.549*	.844
	AU2		.774	.864*	.744*	
	AU3		.748	.899*	.794*	
	AU4		.816	.795*	.646*	
Intention to use (3) items	IU1	3.74 (.72)	.905	.809*	.626*	.863
	IU2		.711	.937*	.837*	
	IU3		.772	.986*	.777*	

Note: *Correlation is significant at the 0.01 level.

Correlation and descriptive analysis

As shown in Table 3, the mean of four study constructs ranged from 3.74 to 3.99, demonstrating that pre-service teacher participants’ perceptions of the IoT were slightly high in terms of these four factors.

Table 4. Correlations between independent and dependent variables

Hypothesis	Dependent Variable	Independent Variable	Pearson Correlation	p-Value
H1	Perceived usefulness	Perceived ease of use	.690	.000*
H2	Attitude	Perceived ease of use	.742	.000*
H3	Attitude	Perceived usefulness	.668	.000*
H4	Intention of use	Perceived usefulness	.656	.000*
H5	Intention of use	Attitude	.545	.000*

Note: *Correlation is significant at the 0.01 level.

Before regression analysis, for each hypothesis, Pearson’s correlation coefficient was calculated between the dependent and independent variables. All correlations (shown in Table 4) were statistically significant and positive between every pair of variables: perceived ease of use and perceived usefulness (r=.690, p<.001), perceived ease of use and attitude (r=.742, p<.001), perceived usefulness and attitude (r=.668, p<.001), the intention of use and perceived usefulness (r=.656, p<.001), and intention of use and attitude (r=.545, p<.001).

Simple regression analysis

To answer research question 1: “What is the relationship between pre-service teachers’ perceptions of IoT ease of use and their perceptions of its usefulness?” a simple regression analysis was conducted to test hypothesis 1. The result is presented in Table 5 and shows that the value of R2 is .476, which indicates that perceived ease of use accounts for 47.6% of the variation in perceived usefulness

Table 5. Results of the simple regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	p-Value	R ²
	B	Std. Error	Beta			
Perceived ease of use	.753	.118	.690	6.400	.000*	.476

Note: *Indicates significance at the .05 level.

A statistically significant and positive relationship was detected between perceived usefulness and perceived ease of use (Beta=.690, p=.000), which means that increasing one unit of perceived ease of use will increase .690 units of perceived usefulness. Therefore, hypothesis 1 was supported, indicating that pre-service teachers' perceptions of the IoT usefulness are positively and significantly affected by their perceptions of ease of use.

Multiple linear regression analysis

In this study, two multiple linear regressions were performed. The first was conducted to answer research question 2: "What is the relationship between pre-service teachers' perceptions of IoT ease of use and their attitude toward its use?", and therefore test hypothesis 2. In addition, it was conducted to answer research question 3: "what is the relationship between pre-service teachers' perceptions of IoT usefulness and their attitude toward its use?" and therefore test hypothesis 3; the results are presented in Table 6. Overall, the value of R² is .597, which indicates that the model accounts for 59.7% of the variation in attitude. A statistically significant positive relationship was found between perceived ease of use and attitude (Beta=.536, p=.029) and between perceived usefulness and attitude (Beta=.299, p=.000). This means that perceived ease of use and usefulness have significantly and proportionally influenced participants' attitudes; however, perceived ease of use had a more substantial influence (.536) than perceived usefulness (.299). Therefore, there was enough evidence to support hypotheses 2 and 3. In particular, pre-service teachers' attitudes toward the use of the IoT in classrooms is positively and significantly affected by their perceptions of its ease of use (hypothesis 2), and pre-service teachers' attitudes toward using the IoT in classrooms is positively and significantly affected by their perceptions of its usefulness (hypothesis 3).

Table 6. Results of the multiple regression analysis (attitude as dependent variable)

Model	Unstandardized Coefficients		Standardized Coefficients	t	p-Value	R ²
	B	Std. Error	Beta			
Perceived ease of use	.568	.141	.554	4.048	.029*	.597
Perceived usefulness	.291	.129	.299	2.257	.000*	

Note: *Indicates significance at the .05 level.

The second multiple linear regression analysis was performed to answer research question 4: "What is the relationship between pre-service teachers' perceptions of IoT usefulness and their intention to use it?" and therefore test hypothesis 4. In addition, it was conducted to answer research question 5: "What is the relationship between pre-service teachers' attitudes toward using IoT and their intention to use it?" and, therefore, to test hypothesis 5, the results are presented in Table 7. Overall, the value of R² is .451, which indicates that the model accounts for 45.1% of the variation in the intention to use. A statistically significant positive relationship was found between the intention to use and perceived usefulness (Beta=.528, p=.001), but the relationship between intention and attitude was not statistically significant (Beta=.192, p=.207). This means that intention to use was proportionally and significantly influenced by perceived usefulness but not attitude toward it. Therefore, hypothesis 4 was supported but there was insufficient evidence to support hypothesis 5. In particular, pre-service teachers' intentions to use the IoT in classrooms were positively and significantly affected by their perceptions of its usefulness (hypothesis 4). However, pre-service teachers' intentions to use the IoT in classrooms were not significantly affected by their attitudes toward its use (hypothesis 5).

Table 7. Results of multiple regression analysis (to use as the dependent variable)

Model	Unstandardized Coefficients		Standardized Coefficients	t	p-Value	R ²
	B	Std. Error	Beta			
Perceived usefulness	.506	.144	.528	3.515	.001*	.451
Attitude	.189	.148	.192	1.281	.207	

Note: *Indicates significance at the .05 level.

The summary results of all three regressions are shown in Figure 2. For all test results, p-value<.05, and the arrows represent the coefficient (path analysis).

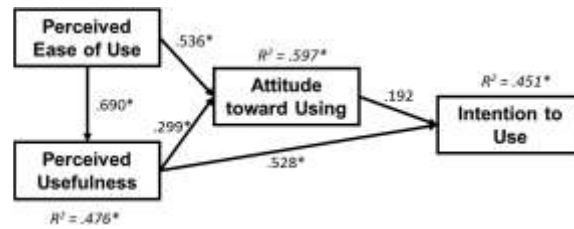


Fig. 2. Summary of research results

Discussion and implications

This study shows that pre-service teachers' evaluations of the utility of IoT technology had a favorable and substantial impact on their plans to employ it. The participants' preference for using IoT technology in their upcoming classrooms was mostly influenced by how well it helped the teaching-learning process. This finding is backed by relevant work that emphasizes how incorporating IoT technology for instructors has improved educational methods. These procedures include boosting participation and interaction [5, making the learning environment more adaptable and effective [14], and encouraging students' drive to meet their learning objectives [20].

Participants in the research assessed IoT ease of use to be positively and substantially related to perceived usefulness. This finding supports that which [34] and [35] found in their studies on the intentions of instructors to employ technology (such as multimedia and smartphone clicker apps). The findings [33] are also supported by the TAM literature, which shows that perceived utility and ease of use are two important criteria that either favorably or unfavorably affect a user's behavioral intention to embrace the technology.

The participants were final-year students majoring in educational technology, so they dealt with various technological applications in their courses and might not have had any problems utilizing various IoT applications in their learning tasks and activities. This result could also be explained by the fact that participants were final-year students who were also majoring in educational technology. This supports the hypothesis made by [45] that user familiarity with technology is positively correlated with how concerned they are about its utility.

The findings also show that perceived usefulness and reported simplicity of use had a beneficial influence on the pre-service teacher participants' opinions. These results are in line with earlier studies, such as [45] [46]. According to [36], an individual's attitude toward adopting a certain technology depends greatly on their degree of confidence while utilizing that technology. In light of this, participants' first-hand exposure to IoT applications in this research may have made them less confident in adopting IoT. Another explanation, according to [47], might be linked to attitude's little influence as a mediating element between users' perceptions of utility, usability, and behavioral intention.

In conclusion, a significant result from the data analysis is that pre-service teacher participants' opinions of the usefulness of IoT technology are generally influencing their choices of or usage of any digital application. Participants typically choose to pick or use any digital application depending on the benefit (usefulness) desired from it. The perceived utility of the IoT is thus the most important element in determining whether or not pre-service participants intend to utilize it or do so in the future, according to the study's results. A significant pedagogical consequence of such a finding is that university professors and course designers should think about incorporating more IoT technology into the course curricula of programs that prepare teachers. Students enrolling in such programs as pre-service instructors should get acquainted with and gain expertise with various IoT apps for educational duties and activities. Instructors should make it simpler to deploy IoT technology and provide support for students to produce materials, complete tasks, and conduct activities in order to increase the IoT's utility. To ensure that students' views about utilizing the IoT in future classrooms are good and that they plan to utilize it, it is important to stress the benefits of using the IoT to facilitate the teaching-learning process, such as flexibility, adaptability, efficiency, and boosting academic achievement [48].

In order to guarantee that younger teachers are prepared for their future careers, instructors and program creators in education institutions should pay greater attention to pre-service training in integrating the IoT. Particularly when taking into account new and emerging technologies, training is a deciding element in instructors' performance [12] [13]. To stay up with the fast digital revolution, educational institutions should think about redesigning teacher preparation programs to put an emphasis on pre-service teachers' technology knowledge and abilities [27].

Conclusion and limitations

This research looked at the important elements influencing pre-service teachers' plans to use IoT technology into their future instruction in Saudi Arabia. Therefore, TAM-related variables were presented and investigated, including perceived usability, utility, user attitude, and pre-service teachers' plans to utilize IoT.

Because of their opinions of the ease of use and utility of IoT technologies, we hypothesized that pre-service teachers taking part in this study would develop a favorable attitude toward using them in their future careers. This, in turn, would help to increase their level of intention to use IoT technologies in the future. To determine the parameters predicting participants' intents to adopt the IoT, one simple regression and two multiple linear regression analyses were performed. The findings showed that pre-service teachers' opinions of the Internet of Things' utility are favorably impacted by their opinions of the technology's simplicity. Attitude was considerably impacted by perceived ease of use and perceived utility of the IoT, although the latter had a stronger impact than the former. Pre-service teachers' opinions on the utility of the IoT had a favorable and substantial impact on their intents to employ it in the classroom. Their opinions regarding adopting the IoT, however, had no impact on their intents to utilize it in the classroom. In conclusion, the findings showed that, in predicting participants' intentions to utilize IoT in future classrooms, participants' perceptions of its value and perceived ease of use were the most important determinants. The results of this study suggest that IoT technologies should be more fully integrated into the course materials and curricula of teacher preparation programs, and that pre-service teachers should receive more training in how to use IoT technology as a useful tool for teaching and learning.

There were some restrictions on this research. First, according to data analysts, structural equation modeling (SEM) is the best technique for data analysis. SEM was not taken into account in this research, however, owing to the small sample size ($n=47$), while SEM analysis calls for 15-20 respondents for each aspect [44]. Another constraint on the generalizability of the results is that a particular sample of pre-service instructors from King Faisal University in Alahssa, in the Eastern Province of Saudi Arabia, was chosen for sampling convenience. Therefore, future study may examine a more extensive sample of pre-service teachers from various institutions that are situated in various Saudi Arabian regions. Third, the research was carried out among future instructors enrolled in a specific degree (Instructional Software Design). Studies conducted in various settings can provide different findings. Future studies should thus be carried out in other contexts (such as various institutions) to assess the validity of the results. Fourth, the TAM concept's components formed the foundation for this study's findings. In other words, future study could think about looking at external characteristics like pre-service teachers' self-efficacy, technical aptitude, and institutional support via an expanded TAM. These elements could influence the IoT technology adoption theory for the teaching-learning process. Fifth, since this study relied heavily on quantitative data collection, future studies may use a mixed-methods strategy to better understand how pre-service teachers perceive their desire to utilize the Internet of Things. Sixth, data for this research was gathered immediately before to the Saudi Arabian Ministry of Education's formal notification of school closures due to COVID-19 pandemic limitations. The landscape of teaching and learning has been significantly impacted by the quick move to distant learning [49] [50] [51]. As a result, given the nature of remote learning, several variables may impact pre-service teachers' usage of the IoT. Future research may thus examine these issues while taking remote learning features into account. The study concludes by recommending further research into the TAM-related factors for a variety of other new technological applications, such as robotics and artificial intelligence [52], among pre-service teachers. This is because pre-service teachers' behavioral intention to use modern technologies is significant and has an impact on how that intention is actually used in the future [27].

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