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EDITED BY
Lucas Kohnke,
The Education University
of Hong Kong, Hong Kong SAR, China

REVIEWED BY
David Mark D. Weiss,
University of Miami, United States
Di Zou,
The Education University
of Hong Kong, Hong Kong SAR, China
Adrian Ting,
Hong Kong Polytechnic University,
Hong Kong SAR, China

*CORRESPONDENCE
Hira Batool
drbatoolhira@gmail.com

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Augmented reality applications as a digital learning innovation in response to the pandemic

Hira Batool*

College of Graduate Studies, Walailak University, Tha Sala, Thailand

Augmented reality applications are digital learning innovations that can rapidly improve the learning of college and university students in the virtual setting. Ever since the beginning of the pandemic, on-site teaching has been pushed back to limit the spread of disease. This paper examines the attitudes and subjective and behavioral norms of 100 college students in Thailand toward digital learning innovations accessed through augmented reality applications. The study offers a theoretical model established through the theory of planned behavior (TPB) and uses it to investigate students' choices of augmented reality applications as digital learning innovations in their courses. The data were analyzed through structural equation modeling. The findings showed that students' acceptance of digital learning innovations through augmented reality applications could be explained through TPB wherever attitudinal and subjective factors showed significant influence; meanwhile, perceived behavioral control did not demonstrate a significant influence on college students. The findings acknowledge the positive effects of augmented reality applications as experienced by college students in Thailand.

KEYWORDS

digital, learning, innovation, augmented, Thailand

Introduction

The worldwide spread of COVID-19 is causing a great amount of devastation across many aspects of our society, especially education. The World Health Organization has confirmed COVID-19 as a global pandemic. The daily news reports highlight the ever-growing list of problems the pandemic is causing around the world, including its economic impacts (Rajmil et al., 2021). Educational institutions, in particular, are working to reduce the spread of COVID-19 and limit its effects on students' lives.

Despite the widespread diffusion of COVID-19, Thailand is comparatively affected by the pandemic (Ali et al., 2021). In response to the pandemic, Thai colleges and universities imposed a lockdown on face-to-face learning and announced learning and teaching would take place through several virtual channels (Hussain et al., 2022). However, due to the highly innovative nature of digital learning, numerous students face difficulties with participating in these environments (Tolentino et al., 2022). Both students and instructors have encountered significant challenges with the practical portions of many courses. For example, engineering and medical students

have experienced difficulties with online replacements for lab sessions that previously required in-person instruction (Mseleku, 2020).

Various authors have emphasized that the pandemic presents an opportunity for institutions to substantially revise their learning systems and, in doing so, re-center themselves and prepare for future change (Saleem et al., 2021). Maqableh and Alia (2021) recommended that learning institutions should implement innovative approaches to promote digital learning while eliminating the gaps that learners may encounter in accessing and using these environments. In this regard, information and communication technologies (ICT), especially augmented reality, can play a significant role in enhancing the digital learning experience and allowing students to achieve practical skills through this medium. Augmented reality allows students to deepen their knowledge and understanding of virtual objects *via* collaborative three-dimensional features and enhances users' participation *via* smart tools such as tablets (Wang et al., 2021). Nevertheless, it has been observed that augmented reality applications have been neglected by educational institutions (Psotka, 2022).

This paper discusses the potential of augmented reality applications to significantly improve college students' learning abilities, and abilities to demonstrate practical understanding, in the context of the COVID-19 pandemic. This paper intends to address gaps in knowledge by assessing students' attitudes toward digital learning *via* augmented reality applications.

This study used Google Excursions augmented reality applications, built by Google in 2015, as online teaching sources during the pandemic outbreak. These apps are designed to offer a simulated reality *via* smartphones connected with the institution (Pret and Cogan, 2018; Bourdin et al., 2021).

The theory of planned behavior (TPB) was used to analyze students' attitudes toward digital learning *via* these applications. Various authors have also applied TPB and its components to examine students' intentions toward the use of these applications in their learning (Balyk et al., 2021).

Therefore, three main research questions were proposed:

> Q1: Do augmented reality applications have any impact on students' attitudes toward digital learning?

> Q2: Do augmented reality applications have an impact on students' subjective norms regarding digital learning?

> Q3: Do augmented reality applications have an impact on students' perceived behavioral control toward digital learning?

The current paper is innovative in that the theory of planned behavior has never before been used to assess attitudes toward augmented reality applications in Thailand. The results derived from this study add new insights to the literature on the challenges of conducting the practical portions of college courses within in the online domain.

Literature review

Augmented reality applications

In the current period of easily accessible advanced technology, the educational structure has become more varied. Novel tools, with their ability to facilitate interaction among learners and instructors, are now used in digital learning systems as empirical cognitive devices (Sudirman et al., 2020). Moreover, visualization delivered *via* intelligent devices, e.g., tablets, can perform important functions in many different situations and can be of use in overcoming the limitations of digital learning. Research has examined the influence of augmented reality applications on students' learning intentions (Wang et al., 2017) and has found that these applications can improve students' educational accomplishments and learning abilities as compared to conventional learning methods for all types of classes. For example, Shin (2018) claimed that several learners could not better understand their syllabus through traditional online systems. Thus, augmented reality applications play a significant role in constructing a strong link between students and instructors *via* 3D based applications for online learning.

Ozdimer et al. (2018) define augmented reality applications as those that create a three-dimensional reality that can present the digital world as a physical phenomenon. Collaborative technologies, i.e., augmented reality applications, enable students by offering solutions to the challenges they face. With these applications, students can enter the virtual setting, actively contribute, and relate to virtual things in the real world, increasing their three-dimensional abilities (Wang et al., 2021).

The hedonic value of augmented reality applications

Hedonic value, in simple terms, refers to the value perceived through real-time enjoyment and fun. Academic staff can ensure student satisfaction by providing real-time experiences through applications with hedonic value.

The hedonic value of an application involves providing digital experiences accompanied by real sensations that recall doing things in a physical setting. Doing lab experiments online, for example, can be just as enjoyable as digitally trying on makeup (Rab et al., 2013). The hedonic value itself allows these applications to provide real-time understanding to their users, improving playfulness (Zhong et al., 2021).

Wetzels et al. (2009) found that hedonic value is a highly significant part of augmented reality applications, triggering learners' rational and expressive approaches in a way that directly connects them with practical effects. Likewise, Iwanaga et al. (2021) examined students' logical- and emotional-based learning and understanding as significant factors in their intention to benefit from augmented reality–based education. Hedonic values promote real knowledge and the inspiration to gain it, including elements that affect students' commitment to the course (Haverila and Haverila, 2021). As an illustration from the literature, Arnold and Reynolds (2003) argued that hedonic value defines users' perceived behavioral control, which in turn influences their attitude and intention. It also improves the effectiveness of the course and maximizes students' understanding of it, thus defining the students' point of choice, such methods have been investigated with augmented reality systems by past author as well (Teo, 2011). This innovation looks at augmented reality applications offers a distinctive understanding level (Cheng, 2020). At the same time, a previous study reported that it offers stimulation, self-representation, pleasure, and hedonic practices (Chu et al., 2018). The hedonic aspect of augmented reality significantly influences students' behavioral intentions and attitudes toward digital learning (Khodadadi et al., 2020).

The utilitarian side of augmented reality applications

From a utilitarian perspective, augmented reality applications offer a logical and useful interaction with specific objects that can potentially influence the user's behavioral intentions (Novak et al., 2013). These applications hold strong potential as innovations in current or new digital learning systems (Hyde, 2019). It has been established that the utilitarian aspect can enhance objects' visibility and increase their recognition in a real-time environment, thus contributing to an optimistic attitude among users and their perceived intention to use the application (Novak et al., 2000). They can also improve the physical appearance of online courses, further engaging and inspiring students with regard to digital learning (Yimaz, 2016).

The pandemic has caused educational institutions around the world to shift to a digital-based education system. The utilitarian aspect of augmented reality increases the practicality of digital courses (Hyde, 2019) and therefore affects students' logical insights toward digital learning systems (Mi et al., 2020).

Numerous authors have analyzed the two aspects of augmented reality applications, i.e., the hedonic and the utilitarian, on users' behavioral intentions (Taipour et al., 2021).

Consequently, this study contends that the impact of augmented reality applications on students' behavioral intentions toward digital learning systems during the pandemic remains underexplored. The following hypotheses were therefore proposed, positing augmented reality applications as a single independent variable and students' attitudes, subjective norms, and perceived behavioral control as three separate dependent variables. Each hypothesis is linked, respectively, to the corresponding research question posed in Section 1 above.

> H1: Augmented reality applications have a positive impact on students' attitudes toward digital learning.

> H2: Augmented reality applications have a positive impact on students' subjective norms toward digital learning.

> H3: Augmented reality applications have a positive impact on students' perceived behavioral control with regard to digital learning.

Methodology

Data were collected from 100 college students in Thailand *via* convenience sampling. The minimum sample size was calculated through G*Power software, having three predictors with an effect size of 0.15 and a power of 0.95, with two tails that came to the minimum sample size of 89 (Faul et al., 2009). The sample size of this study is therefore above the minimum requirement. Students were contacted through a Facebook group set up by teachers to connect for assignments and lecture updates. A virtual survey form was distributed among the group members and voluntary contributions to the research were sought. Participants were instructed to install the Google Expeditions application on their tablets to experience online learning through augmented reality. A value check was employed in the form of an online survey that posed several appropriate questions about participants' familiarity with Google Expeditions and asked them to register their responses *via* a Likert scale. The question items were adapted from previous literature. The hedonic and utilitarian aspects were adapted from Khare et al. (2010) and Scholz and Duffy (2018). The TPB constructs, i.e., attitude, subjective norms, and perceived behavior control toward digital learning, were adapted from Khodadadi et al. (2020).

The data were analyzed through PLS(SEM) because of its potential to bootstrap the results into a larger sample size (Krishnan et al., 2011).

Results

To test the proposed hypothesis, the author first analyzed the collected data for demographic purposes. The results are

TABLE 1 Demographics of study participants.

		Frequency	Percent
Gender	Male	50	50%
	Female	50	50%
Age	18–25	50	50%
	26–34	50	50%
Study program	Undergraduate	50	50%
	Graduate	50	50%

presented in Table 1. As displayed in the table, the proportions of male and female participants were 50% each. Similarly, with regard to age, the two main groups were targeted in the university to cover both graduate- and undergraduate-level university students.

Reliability and validity

The items' convergent validity was assessed through Cronbach's Alpha, composite reliability (CR), and average variance extracted (AVE). Hair et al. (2010) stated that the value of an item should be 0.7 and above for the alpha, 0.8 and above for the composite reliability, and 0.5 and above for the AVE. The reliability values for the alpha, composite reliability, and AVE of the augmented reality application, as well as the utilitarian aspect, hedonic aspect, subjective norm, and perceived behavioral control, are presented in Table 2.

From Table 2, it can be seen that the augmented reality applications have an α of 0.755, a CR of 0.815, and an AVE of 0.656. The hedonic aspect has an α of 0.777, a CR of 0.965, and an AVE of 0.653. The subjective norm has an α of 0.762, a CR of 0.863, and an AVE of 0.679. Lastly, the perceived behavioral control has an α of 0.782, a CR of 0.780, and an AVE of 0.719. This means that the reliability standards of the adopted questionnaire have been satisfied and that it meets the standards of PLS for hypothesis testing.

To confirm the validity of the research questionnaire, it has been recommended to examine the diagonal and non-diagonal values in the correlational table of results; the non-diagonal values should be lower than the diagonal ones, or, put another way, the diagonal values should be higher than the non-diagonal values (Sarstedt et al., 2014). The validity aspects for the present study are reported in Table 3. The diagonal value for the attitude is 0.936; for the augmented application, 0.990; for the perceived behavioral control, 0.763; and for the subjective norm, 0.71. As all of these values are higher than the non-diagonal values, we can conclude that the adopted questionnaire was valid and reliable.

The results of the hypothesis testing are presented in Table 4. This study proposed three main research questions linked with three hypotheses, respectively. To answer these research

TABLE 2 Reliability values.

Measurement items	Loadings	α	CR	AVE
Augmented App Utilitarian aspect		0.755	0.815	0.656
UA1	0.782			
UA2	0.788			
UA3	0.758			
Hedonic Aspect				
HA1	0.828			
HA2	0.735			
HA3				
Attitude		0.777	0.965	0.653
ATU1	0.795			
ATU2	0.885			
ATU3	0.867			
Subjective Norm		0.762	0.863	0.679
SN1	0.862			
SN2	0.850			
SN3	0.843			
Perceived Behavioral Control		0.782	0.780	0.719
BC1	0.898			
BC2	0.771			
BC3	0.797			

α, Cronbach Alpha; CR, composite reliability; AVE, average variance extracted.

questions, there was a strong need to run bootstrapping tests on the collected data. As can be seen in Table 4, attitudes toward digital learning were tested within the context of augmented reality applications, and the *t*-value came out to 1.96 with a beta value of 0.725. Thus, hypothesis 1 has been confirmed; as the results demonstrate, augmented reality applications can play a positive role in changing students' attitudes toward digital learning. Similarly, the results support research question 2 and hypothesis 2, with a beta value of 0.729 and *t*-value of 1.99. We can therefore conclude that augmented reality applications play a positive role in changing students' subjective norms toward digital learning. However, the results did not support research question and hypothesis 3, because the *t*-value was lower than 1.96 and the beta value was also low. However, it was interesting to see that the existing relationship was positive, but at a very low intensity.

Discussion

This study intended to examine the characteristics of augmented reality applications in digital learning systems in Thailand during the pandemic by employing the theory of planned behavior. The findings showed that college students' attitudes and subjective norms influence digital learning through augmented reality applications. The beta value for

TABLE 3 Discriminant validity.

	1	2	3	4
1. Attitude toward digital learning	**0.936**			
2. Augmented reality applications	0.825	**0.990**		
3. Perceived behavioral control toward digital learning	0.745	0.753	**0.763**	
4. Subjective norms toward digital learning	0.481	0.769	0.442	**0.731**

It presents the discriminant validity of the proposed variables. The rule of thumb is that diagonal values should be greater than non-diagonal values. The bold values (i.e., those on the diagonal) are higher than the non-diagonal values. This confirms the convergent validity of the questionnaire.

TABLE 4 Hypothesis testing.

Hypothesis	β-values	*t*-values	Accept/Reject
AA → Attitude toward digital learning	0.725	1.96	H1 - yes
AA → Subjective norm toward digital learning	0.729	1.99	H2 - yes
AA → Perceived control toward digital learning	0.012	1.92	H3 - no

attitude came out to 0.725 with a *t*-value of 1.96, which means that there is a positive association between augmented reality applications and attitudes toward digital learning. This supports the first hypothesis and confirms the findings of previous authors (Chu et al., 2018; Chen, 2019). Similarly, the beta value for the second hypothesis comes out to 0.729, with a significant *t*-value of 1.99. The findings connected to this hypothesis are similar to the results of previous authors (Novak et al., 2000). However, perceived behavior control demonstrated a non-significant impact on digital learning through augmented reality applications, because the beta value (0.012) was lower, with an insignificant *t*-value of 1.92. A previous study by Yimaz (2016) had similar results for perceived behavioral control.

The integration of augmented reality applications into digital learning systems must be considered from a rational perspective. College students' use of augmented reality applications improves their knowledge, as these applications offer a three-dimensional presentation of the course. They also increase communication and improve outcomes, including maximizing students' knowledge. The present moment is thus an ideal time to entertain the idea of introducing this digital education method. Previous studies by Akçayır et al. (2016) and Chen (2019) highlighted the potential of digital learning approaches for improving the delivery of education. Cheon et al. (2012) suggested that augmented reality applications can improve the way students work with the course, as well as boost their confidence levels. However, these applications may not influence the students' perceived control.

As Yoo et al. (2021) discuss, most educational institutions have used conventional technologies (e.g., Zoom, Google Classroom) to operate online courses since the pandemic was declared. Classes held using these technologies most likely do not hold students' attention. Most people who matter to students are against the use of augmented software for digital learning. Further investigation *via* qualitative analyses is needed to better understand this phenomenon.

The significant capabilities offered by these applications improve students' level of knowledge and reduce the psychological challenges posed by digital learning. Several digital learning networks have been launched since the start of the pandemic. As Saidin et al. (2015) stated, augmented reality applications represent the core principles of coursework that effectively help students perform their practical work. Augmented reality applications, and the collaborative capabilities they offer, add a distinctive element: the ability to bring the presence of simulated objects into the real world, with significant effects on users' recognition and composition.

Moreover, research on augmented reality applications in the context of an ASEAN country could be quite valuable for the relevant literature. Thailand is currently considered an emerging country in the context of the use of augmented reality applications in online education systems. This study addresses the challenges of providing a realistic learning experience for students, which were quite significant during the height of the pandemic. The augmented reality applications used for this study were Quiver, Element 4D, and Domino World AR, as the trial version to test their impact on students' learning experiences. Each of these applications was designed to bring life and physical reality to the virtual classroom setting. Additionally, they were found to be more engaging and made difficult subject matter easier, as per the findings of the research study.

More precisely: Quiver is used more for subjects in the natural sciences, as it allows the use of interactive 4D images. Similarly, Element 4D facilitates conducting practical experiments in a virtual setting. Domino World AR allows the instructor to create the course in the virtual setting by adding

interesting props to turn a serious lecture into an interesting one.

Lastly, three research questions were raised in the introduction to the present study. To answer those questions: the results of this study found that, in the case of students in Thailand, augmented reality applications do have a positive effect on their attitudes and subjective norms toward digital learning, but not on their perceived behavioral control.

Conclusion

This study explores the role of students' attitudes, subjective norms, and perceived behavioral control in adopting augmented reality applications for digital learning. The findings have shown that students play a strong role in digital learning through these applications. Lecture delivery through an augmented application boosts students' confidence and influences their attitudes and subjective norms. As a result of the pandemic, many learners face difficulties in joining online courses through traditional resources. Moreover, for higher education institutions and students in both affluent and developing nations, digital learning remains both a cultural problem and a tough technical dilemma. This research is limited to data sampling from one country. The results are therefore not generalizable to all levels of educational institutions or to all students. As a result, paths are open for future qualitative and quantitative studies, or both, to investigate factors that restrict and encourage the use of augmented reality applications in the delivery of education at various levels and across geographic contexts.

Limitations and future research potential

Due to the lack of sufficient time and resources, only data from Thailand were available. The generalizability of this study to other country contexts is therefore limited. Other researchers may want to use this study as an example for testing augmented reality applications in the context of other countries. Future investigators could also test other applications apart from those used in this study.

Contribution to theory and practice

This study contributed to the theory of planned behavior in the context of the challenge of converting virtual learning into a real experience by extending its use *via* augmented reality applications. In practice, this study, and its findings of proof of the effectiveness of these applications among students, can serve as an example and a source of motivation for educational researchers and institutions to move from the use of conventional digital learning applications to augmented reality applications.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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