Actualizing the Affordance of Mobile Technology for Mobile Learning: A Main Path Analysis of Mobile Learning

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ABSTRACT: As the number of mobile device owners on university campuses grew over the past two decades, scholars specializing in digital education and its application versatility have taken a heightened interest in mobile learning programs and platforms. The nature of mobile learning is constantly evolving with the development of technology artifacts, and it brings the purpose of this article into sharper focus as we examine mobile learning from various perspectives, critical issues confronting distant education programs, and identify potential research directions for future studies. To that end, main path analysis, a citation-based systematic review method, is employed for this study in collecting and analyzing of 935 articles that address mobile learning in the higher education community. The results of the analysis identify several significant trajectories, which reveal four popular research clusters: mobile technology artifact, educator motivation approach, learner learning projection, and actualizing mobile learning and in turn identifies two mobile learning research derivatives: Mobile-technology affordance and actualizing mobile learning. This kind of discovery research has demonstrated that mobile learning will strengthen learning references.

Keywords: Mobile Learning, M-Learning, Affordance actualization, Main path analysis

1. Introduction

With the development of mobile technologies and wireless devices, mobile learning (m-learning) has been recognized as a trend in educational applications(Wu et al., 2012), which can be defined as information acquiring taking place while learner is not at a fixed location, or when the learner benefited from the adoption of mobile technologies to gain learning opportunities (O'Malley et al., 2003). As Ally and Prieto-Blázquez (2014)) stated, the availability of mobile technology enables educators to have the opportunity to access educational resources in an unfixed location. Mobile technology-enabled educational programs are now widely regarded as a development priority for many schools, as accessibility of handheld device hikes among university students. Despite the plethora of writings devoted to discussing the impact of mobile technology on formal education experiences, a more comprehensive exploration is imperative to scrutinize possible challenges and development direction since the m-learning concepts are organically and constantly evolving.

The developing mobile technology offers a more flexible, personalized and accessible learning experience (Yusri & Goodwin, 2013). In this domain, the role of technology component is growing with the development of digital technologies, and thus facilitating the changing of mobile learning concepts. More specifically, the studies on mobile learning have transformed from the design aspect into the usage aspect. Design aspect of mobile education indicates the importance of the nature and potential outcome of mobile technologies for educational purposes; On the other hand, the more recent researches show a growing attention to the approach of actualizing the unrealized capacity of mobile technologies, entails the interaction between learning context and technology adoption as a critical point.

It is worth noting that past reviews highlighted the importance of technology essence and practical usage, this study further embraced "affordance actualization" as a theoretical method to cope with the dynamic fabric of m-learning. Affordance actualization refers to actors through technology adoption to achieve immediate concrete outcomes in support of their goals (Strong et al., 2014). this study suggests appropriate affordance actualization from the Information System domain, to examine how to adopt technology artifacts in facilitating the attainment of educational goals, thus to deal with the changing concept of mobile learning. Also, the affordance actualization perspective provides this study a way to further the understanding of technology loopholes in the domain of digital education for following reasons: First, this perspective allows the study to explain the possibilities an object affords for action (Majchrzak, Faraj, Kane, & Azad, 2013; Tim, Hallikainen, Pan, & Tamm, 2020), rather than taking technological artifacts for granted. In doing so, digital educational researchers could capture the potential actions of technological artifacts in a learning environment. Second, the process of m-learning adoption is highly volatile and requires educators to constantly innovate and evolve with the fast

changing learning dynamic. Apart from understanding how to integrate mobile technologies into the essence of learning, it is very vital to consider two major points, affordance and actualization, when analyzing the learning outcome of m-learning. Therefore, this study aims to address the following research questions: How to make the affordances of mobile learning being realized in higher education in a changeable place?

Four research themes have been deliberately identified based on the previous literature in the realm of m-learning: mobile technology artifact, learner learning projection, education motivation approach, and actualizing m-learning. In an attempt to solidify m-learning results achieved through mobile technology applications, Strong's affordance actualization (2014) was applied as a theoretical lens to track existing research topics, and to conceptualize the deployment process of m-learning. Adding values to this research, an integrated model is developed to expedite our comprehension of actualizing m- learning for higher education.

2. Contextual background

The advent of digital technology has brought a series of innovative educational digital services. In addition, the ownership of mobile devices has also spread at an unprecedented rate. As of 2020, 93% of the world's population lives in areas covered by mobile cellular networks (Union, 2019). According to the literature (Center, 2017; Poushter, 2016), in the United States, the largest mobile device users are ordinary college students, aged between 18 and 29. In the same age group, 96% will use smartphones in 2020 (Center, 2020). More specifically, the growing maturity of mobile technology allows learners and educators to overcome the physical boundary, which accommodates better accessibility to education services.

Recent empirical evidence indicates that m-learning can be used to support students' learning in higher education settings (Ke & Hsu, 2015; Wu et al., 2012). However, research in m-learning has been fragmented and idiosyncratic, and based mostly on the understanding of the individual researcher (Alrasheedi, Capretz, & Raza, 2015). In addition, after more than 20 years of m-learning research, there is still relatively little systematic knowledge available, especially regarding the use of mobile technology in higher education settings (Pimmer, Mateescu, & Gröhbiel, 2016). This topic has attracted increased attention in recent years, and is also the goal of educators, especially in the case of using technology in classrooms for enhanced collaborative learning (Dillenbourg, Nussbaum, Dimitriadis, & Roschelle, 2013).

In the past, some of the m-learning articles point out that this tech-inspired form of distance education could be recognized as a purpose that relies on the ubiquitous features of mobile technology to construct an environment with high learning efficiency. Many articles have explored m-learning from various perspectives, include but not limited to: concept of m-learning and the design (Chang, Sheu, & Chan, 2003; Chen, Kao, & Sheu, 2003; C. H. Lai, Yang, Chen, Ho, & Chan, 2007; Peng, Su, Chou, & Tsai, 2009); analysis of adoption factors (Hamidi & Chavoshi, 2018; Karimi, 2016; Kim, Lee, & Rha, 2017; Looi, Sun, Wu, et al., 2014; Martin & Ertzberger, 2013); the technology acceptance model (Al-Emran, Mezhuyev, & Kamaludin, 2018; Almaiah, Alamri, & Al-Rahmi, 2019; Almaiah, Alamri, & Al-Rahmi, 2019; Chavoshi & Hamidi, 2019; Hoi, 2020); and m-learning goals (Cheon, Lee, Crooks, & Song, 2012; Gikas & Grant, 2013; Hao, Dennen, & Mei, 2017; Schwabe & Göth, 2005; Sharples, Corlett, & Westmancott, 2002); consideration of educators goals (Cheon et al., 2012; Dennen & Hao, 2014; Gikas & Grant, 2013; Hao et al., 2017; Hwang & Chang, 2011; Kim et al., 2017) and learners goals (Karimi, 2016; Looi, Sun, Seow, & Chia, 2014; Looi, Sun, Wu, et al., 2014; Martin & Ertzberger, 2013; Shih, Chuang, & Hwang, 2010; Wu et al., 2012).

However, what is the crux of m-learning? We suggest shifting the focus to the essence of m-learning. Although some literature considers m-learning as a means, it has not been well-examined. We therefore hope to re-examine previous articles for an insight into the value of m-learning. Following this contextual path, we will proceed with a literature review, research methods, analysis, and conclusion for a comprehensive perspective of m-learning in higher education settings.

3. Literature review

3.1. Mobile Learning (M-Learning)

The early definition of m-learning is primarily based on the use of mobile technology, which can be learned through mobile computing devices (Quinn, 2000). Lehner and Nosekabel (2002) summarized this definition as providing digital content and teaching materials required by learners through services or devices that are not

limited by time and place, so as to assist learners to acquire knowledge. Hoppe, Joiner, Milrad, and Sharples (2003) emphasized that m-learning is a learning method using mobile vehicles and wireless transmission. Trifonova and Ronchetti (2003) mentioned that m-learning is the combination of action technology and digital learning, and m-learning devices have three capabilities: interaction, content access, and service access. Seppälä and Alamäki (2003) mentioned that m-learning is not just digital, it also holds the characteristics of mobile; m-learning is therefore superior to digital learning as it is not confined to geographic and time constraints. Chu, Hwang, Tsai, and Tseng (2010) mentioned that in addition to improving the learning efficiency of individual students, mobile devices and wireless communication also provide a practical way to carry out cooperative learning activities. However, inadequate instructional design may have a negative impact on learning achievements due to excessive cognitive load (Chu, 2014). Studies have shown that learners' attitudes and learning behaviors are significantly and positively correlated with the success of on-campus m-learning (Cheon et al., 2012). However, educationists should understand that nothing of the mentioned above could take place unless all learning activities are well designed and carefully implemented (Elfeky & Masadeh, 2016).

3.2. Actualizing mobile technologies affordance for learning

Actualizing is a goal-oriented and iterative process (Leonardi, 2011; Leonardi, 2013), which is defined as the action taken by actors as they take advantage of one or more perceived affordances through their use of technology to achieve outcomes in support of organizational goals (Strong et al., 2014). To actualize digital technologies within the organization, Leonardi (2013) introduces the concept of shared affordance, that is, an affordance shared by all members of a group in which all actors manifest similar use of technology features. This research suggests that only when actors agree on the usage of a similar sequence of technology features, that the affordance created by the interaction with specific technology can be actuated at an organizational level.

To achieve an organizational goal, Strong et al. (2014) identify three factors that both support and restrict an individual's affordance actualization: abilities and preferences of the individual, features of the system, and characteristics of the work environment. With the affordance perspective in place, the research proceeds to explore the IT elements, design, the learning dynamic between organizations and actors, and also the role of IT-associated organizational transformation. Furthermore, the digital education community also finds this theoretical insight helpful, specifically for educators who keep abreast of the latest digital technologies and the opportunities they offer (Haines, 2015). For example, an article points out the potential learning benefits of virtual learning environments by drawing on its affordance (Dalgarno & Lee, 2010). Jayarathna, Eden, Fielt, and Nili (2020) adopts this theory to introduce how higher education students can use digital technology for collaborative learning.

Despite the presence of literature on digital education to shed light on the importance of affordance (Bower & Sturman, 2015), few direct on how to "actualize" the digital technologies affordance for educational purposes. Moreover, mobile device owners in universities have inspired the increasing number of m-learning applications in higher education (Xiangming & Song, 2018), which lead to a growing number of m-learning studies. Hence, this study aims to systematically investigate the learning affordance of mobile technology in higher education, and to further the understanding of their potentials and affordance.

4. Research methodology

4.1. Main path analysis

Main path analysis (MPA) was first introduced by (Hummon & Doreian, 1990) who suggested that one can trace the major development trajectory of a scientific discipline through citation links. This method reduces massive amounts of information embedded in a citation network into a few crucial paths (Liu, Lu, & Ho, 2020). These crucial paths not only hint at the most significant articles but the main knowledge flow paths of a target field. In the beginning, this method was implemented in the social network analysis field (Batagelj & Mrvar, 1998), and now it has been widely adopted in a vase variety of disciplines (Park & Magee, 2017; Xiao, Lu, Liu, & Zhou, 2014).

Despite existing literature that has reviewed the high citation papers on the m-learning domain (Lai, 2020), the development trajectory of m-learning is still unclear. To trace the development trajectory of this domain, this study adopted a Key-route MPA to ensure that all the top significant links are included in the results (Huang, Chou, & Liu, 2021; Hung, Liu, Lu, & Tseng, 2014; Liu & Lu, 2012). MPA consists of two steps: The first step

calculates the traversal counts of each citation link in a citation network (Batagelj, 2003; Batagelj & Mrvar, 1998) and as a result, differentiates the significance of each citation link. Among the various traversal count algorithms, search path link count (SPLC) algorithm is utilized based on the suggestion from (Liu, Lu, & Ho, 2019). SPLC is the traversal count for a link on the premise that delivers knowledge through all possible paths from all the ancestors of the node to all the sinks (Hummon & Doreian, 1990). The second step is to search for the crucial paths according to traversal counts of the links.

These advantages allow one to examine multiple subfields while at the same time identify important contributors. With that in mind, this research applies key-route MPA to visualize the key knowledge development trajectory of m-learning. Key-route MPA is always associated with a key-route number, which indicates the number of top links to include in the resulting main paths.

Table 1. Search strategy and key words used

Database	Web of Science
Search strategy	TS = ("e-learn*" OR "mobile learn*" OR "m-learning" AND *("higher education") NOT ("e-learning"))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)*
Timespan	From January 1, 2003 to Aug 26, 2020

4.2. Literature search

To ensure the dataset is complete, this study follows the study by Ho, Liu, and Chang (2017), the steps are above: First, according to five recent review articles (e.g., Chee, Yahaya, Ibrahim, & Hasan, 2017; Chung, Hwang, & Lai, 2019; Crompton & Burke, 2018; Lai, 2020; Wu et al., 2012), we built several keyword sets to search publications. Second, the authors choose the keyword sets as our query strategy, as Table shown. This study references academic articles and associated citation information from the Social Sciences Citation Index (SSCI) and Science Citation Index Expanded (SCIE) databases of the Web of Science (WOS) service. It was curated between January 1, 2003 and Aug 26, 2020. 2003 was selected because it was the year that m-learning started to flourish. In order to ensure that the most relevant articles have been included, we have checked with five selected review articles, and manually added the missing papers into our dataset. Third, we checked whether the highly cited m-learning papers in WoS were also included in the dataset. Finally, we excluded irrelevant studies that have no citation relationship with the rest of studies. The final search results in a total of 935 papers. We then collect the citation content for each of these papers from the WOS database. The citation information is used to construct the citation network which becomes the base for MPA. Table 1 presents the search strategy.

5. Analysis

5.1. The Sub research themes

This study applies the global main path approach (Liu, Lu, Lu, & Lin, 2013) to examine the main paths in more detail, which traces the top most significant paths, thus uncovering the recent and earlier clusters of papers. By increasing the number of paths selected, the details of the citation network gradually surface. Our analysis, therefore, visualizes the four branches of literature in Figure 1. Each branch represents a sub research theme. Darker dots symbolize end nodes. Link weights are indicated with different line thickness. Thicker lines suggest heavier weights.

After examining the title, abstract, and keywords of these papers, we conducted a meta-analysis and extracted similar core concepts of the paper as research themes. The research themes are Mobile technology artifact, Educator motivation approach, Learner learning projection, and Contextual implementation. Table 2 presents the details of these papers.

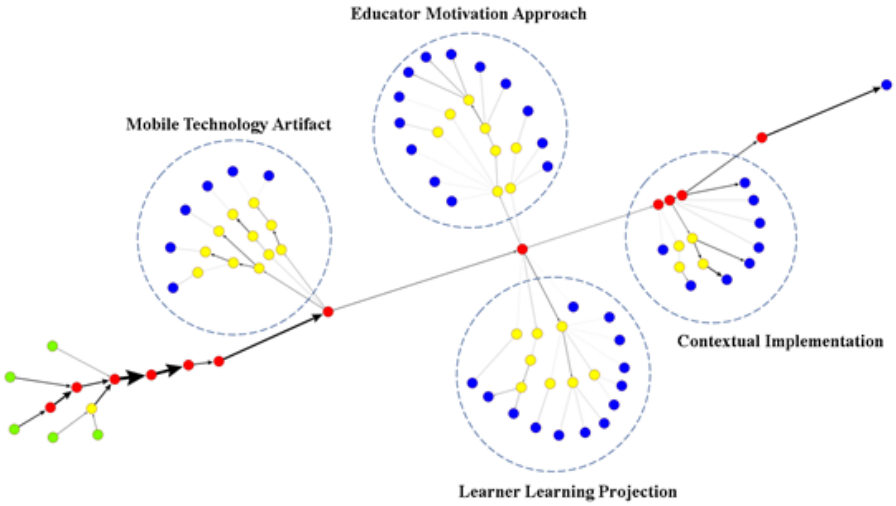

Figure 1. Multiple global main paths of mobile learning

5.1.1. Mobile technology artifact

Our analysis discovers that several literature writings make emphatic mentions on the IT feature of m-learning. To further our understanding of the design purpose of mobile technology, this study regards mobile technology as an IT artifact, and assigns these essays to mobile technology artifacts as their research theme. IT artifacts, by definition, are not "natural," "neutral," "universal," or given. As Grint and Woolgar (1995) note, objects are never merely and automatically just objects; they are always and already implicated in action and effect. Fundamentally, IT artifacts are designed, constructed, and used by people; they are also shaped by the interests, values, and assumptions of a wide variety of communities of developers, investors and users.

Mobile technology development and wireless internet service combined have given learners a better environment. Moreover, as users grew in their understanding and operational efficiency of mobile devices, the Internet, plus what they're able to achieve, mobile technology performance and service also progressed accordingly. In the past, the researchers were concerned mostly with information architecture of m-learning at the beginning of this phase. Several articles discussed the role of mobile devices in the teaching process (Seppälä & Alamäki, 2003), while other studies elaborated on the power of wireless service, particularly, Wi-Fi (Chen et al., 2003; Liu et al., 2003).

As IT architecture becomes more mature, scholars began to take notice of the interaction between mobile technology and the learning environment; The significance and responsibility of mobile technology raised during this particular era, its importance was elaborated by Peng et al. (2009), in which a genre of mobile education program was developed to facilitate an even more ubiquitous learner experience; this development rendered educational technology toward the status of ubiquitous knowledge. A study by Wu et al. (2012) discussed the application of clinical skills, comprehensive knowledge and other subjects, which traditionally were taught separately, to an in-class program via m-learning systems and transmission sensing devices, in order to develop ''Context-Aware Mobile Learning System'' that enhances the overall learning synergy. At this stage, the depiction of system features and the application of mobile technology artifacts, such as wireless networks and mobile devices, took the research spotlight.

5.1.2. Educator motivation approach

Our literature analysis identifies several writings that centered around the motivations from educator's perspective, usage methods and contexts for applying mobile technology. Bester and Brand (2013) concluded that ICT provides new possibilities to teaching as a career. Several previous research findings also show that ICT aids the learners with the development of cognitive skills, critical thinking skills and information accessing, evaluation and synthesising skills (Bester & Brand, 2013). Lau and Sim (2008) discovered that the use of ICTs in education could promote deep learning and allow schools to respond better to the needs of different learners. This could only be achieved if educators could truly integrate the ICTs into their teaching process.

As time and technology evolve with new discoveries, ways and the possibilities of incorporating ICT into educational programs have also organically expanded. That being said, researchers of this stage are concerned primarily with learner motivation and m-learning modes. For example, studies by Hwang and Chang (2011), Dennen and Hao (2014) focus on the mobile technology application framework.

Interestingly, some of the studies started to consider both the strengths, and the adverse effects of mobile devices on m-learners (Gikas & Grant, 2013). Conscious of these possible setbacks, scholars of this school would learn to anticipate the objectives achieved by m-learning from the get-go, and strive to promote the effectiveness of m-learning.

5.1.3. Learner learning projections

The importance of mobile technology in education multiplies more widely felt as time evolves. Several significant findings have revealed the benefits of mobile learning, namely that it can provide students with instant feedback (Hsu, 2015), improve learners' learning efficiency (Sung, Hwang, Liu, & Chiu, 2014) and bridges students' learning in class and in the field (Wang, 2016). A growing number of scholars, instead of focusing solely on the function and application, or the design and implementation of the m-learning system, begin to take other factors into consideration. As illustrated in Figure 1, the focus of research began to shift to educators and learners around 2013. In reviewing the essays produced around this time, we found that mobile technology has taken a more auxiliary role. The dynamic between learners and educators, rather, has moved to the center stage, which has a decisively positive impact on learning outcomes.

Martin and Ertzberger (2013) were among the first scholars to factor in the interactive elements between learners and educators, as they studied how mobile technology facilitated information reception from educators to learners, methods to apply mobile technology to inspire interests, and the influence of m-learning on grades and learner's experience.

Besides discussing the impact of m-learning on educators' teaching performance, Karimi (2016) attempted to identify elements that could encourage a more immersive m-learning experience for learners. Hamidi and Chavoshi (2018) further investigated factors that impacted the willingness of learners in higher education to use m-learning.

Fundamental differences between educators and learners in this stage pose a series of challenges for m-learning. In short, information systems efficacy, and the expectations of educators or learners are not the only considerations at play here for m-learning applications. Instead, comprehensive consideration, one that embraces environmental factors, is necessary so that a suitable contextual service could be incorporated to upgrade m-learning experiences. To that end, contextual implementation should be given priority scrutiny.

5.1.4. Contextual implementation

Contextual implementation, namely, is a problem-solving process under different circumstances for goal realization; the iterative process of realizing the goal is actualization indeed. (Leonardi, 2011; Leonardi, 2013; Strong et al., 2014). Research at this stage homes in on encouraging learners to accept a m-learning experience through mobile solutions. A study explores curricula and learning resources in the developing countries and discovers that social factors had greatly increased the acceptance of m-learning (Chavoshi & Hamidi, 2019). This essay also positions that support from the government and the approach to conducting mobile teaching will have an effect on social context.

In addition, Hamidi and Jahanshaheefard (2019) states that university institutions regard m-learning as a means to improving students' satisfaction with education programs on campus. Furthermore, different from previous literature that explored e-learning, summaries on m-learning put a heavier emphasis on the interactive relationship between teachers and students. A paper by Almaiah and Al-Khasawneh (2020) infers that mobile technology is now playing a more significant role in-class, as it provides necessary content in a more timely fashion to educators and learners. Whether it is to help students acquire a large amount of information, or to assist teachers with tracking students' learning, education delivery goals are met through m-learning.

Table 2. The label of m-learning literature

Sub themes	Content	Literature
Mobile Technology Artifact	*"The development of advanced wireless technologies for building an ad hoc classroom to create a modern and new learning environment."*	(Chang et al., 2003)
	"Mobile learning, conducted through the use of mobile devices such as PDAs, tablet PCs, and cell phones, is now widely considered an effective education solution due to its delivery of e-learning strengths; time and space that limit web-based learning systems are no longer a concern."	(Chen et al., 2008)
	"Learning systems that can track students' learning behaviors in the real world with the help of context-aware (sensor) technology."	(Hwang et al., 2010)
	"Teaching methods through the mobile device, the use of a short message service (SMS) and digital pictures as a part of the supervising process."	(Seppälä & Alamäki, 2003)
	"The aim is to construct an outdoor mobile-learning activity using up-to-date wireless technology."	(Chen et al., 2003)
	"An educational phenomenon enabled by mobile technology advancement, mobile learning, or m-learning, is beginning to offer 'stunning new technical capabilities' in education."	(Peng et al., 2009)
	"A decision-tree-oriented mechanism is developed for that purpose, enabling digital guidance for students to observe and classify real-world objects in learning activities during natural science courses."	(Chu et al., 2010)
	"Using mobile devices for learning activities in a real classroom context is found to spark student interest."	(Hwang et al., 2010)
Educator Motivation Approach	*"Even though this education solution seems to successfully heighten student interest, researchers have also advised for well-designed learning support to improve the students' learning efficiency."*	(Hwang & Chang, 2011)
	"A conceptual model that is based on the theory of planned behaviour (TPB), which explains how college students' beliefs influence their intention to adopt mobile devices in their coursework."	(Cheon et al., 2012)
	"Exploring teaching and learning processes when mobile computing devices, such as cell phones and smartphones, were implemented in higher education."	(Gikas & Grant, 2013)
	"This framework can be integrated with any instructional design process to engage instructors in the informed design of mobile learning activities."	(Dennen & Hao, 2014)
	"Pedagogical factors have the greatest effect on students' behavioral willingness to adopt mobile learning. Social influences, especially social image and subjective norm, also play a role."	(Hao et al., 2017)
	"Relative advantage, complexity, and inertia have significant effects on students' mobile learning resistance, with inertia being the most prominent."	(Kim et al., 2017)
Learner Learning Projection	*"To enhance the learning performance of the students, an inquiry-based mobile-assisted approach is employed to help students with constructing their own knowledge by taking cognitive load into consideration."*	(Shih et al., 2010)
	"As well as guiding individual students to perform physical assessment procedures on dummy patients, the learning system also provides instant feedback and supplementary materials in real-time if the operations or the operating sequence is incorrect."	(Wu et al., 2012)
	"Mobile technology opens the door for a new kind of learning, known as here-and-now learning, which occurs when learners have access to information anytime and anywhere to perform authentic activities in the context of their learning."	(Martin & Ertzberger, 2013)
	"As curriculum designs are not self-sufficient by themselves alone, the enactments of the teachers differ in how they leveraged on students' artifacts, and how they integrate the technology into the class."	(Looi et al., 2014)

	"Using qualitative data analysis methods, the study discusses the transformation of the classroom practices on teachers' pedagogical approaches, classroom culture, lesson plan design, linkages to informal learning, assessment methods, and parent involvement."	(Looi et al., 2014)
	"This study highlights the role of learners' character-traits in m-learning adoption, and highlights the importance of distinguishing between various types of m-learning projects."	(Karimi, 2016)
Contextual implementation	*"The factors related to adoption of mobile learning in higher education are categorized into seven main groups as: ease of use, trust, characters and personal qualities, context, perceived usefulness of using, behavioral intention, and culture of using a research model."*	(Hamidi & Chavoshi, 2018)
	"The goal of this research is to investigate the important factors affecting the acceptance of m-learning in Iran. These factors are divided into four macro groups: (1) Technological, (2) Pedagogical, (3) Social and (4) Individual issues."	(Chavoshi & Hamidi, 2019)
	"This study applies the Unified Theory of Acceptance and Use Technology (UTAUT) model to examine the effects of different factors that were identified from the literature on students' acceptance of mobile learning applications in higher education."	(Almaiah et al., 2019)
	"A new model is developed to study the effect of different factors on mobile learning applications development at the three main stages of usage (static stage, interaction stage and transaction stage)."	(Almaiah et al., 2019)

5.2. The transformation of research focus: From mobile technology affordance to mobile learning actualized

This section acknowledges the results of key-route MPA at 10 key-routes, consisting of 24 papers, which are shown in Figure 2. Arrows indicate knowledge flow direction, pointing from the cited papers to the citing papers. Each paper is assigned a label that begins with the last name of the first author, continues with the first initials of the co-authors (in capital letters), and ends with the publishing year.

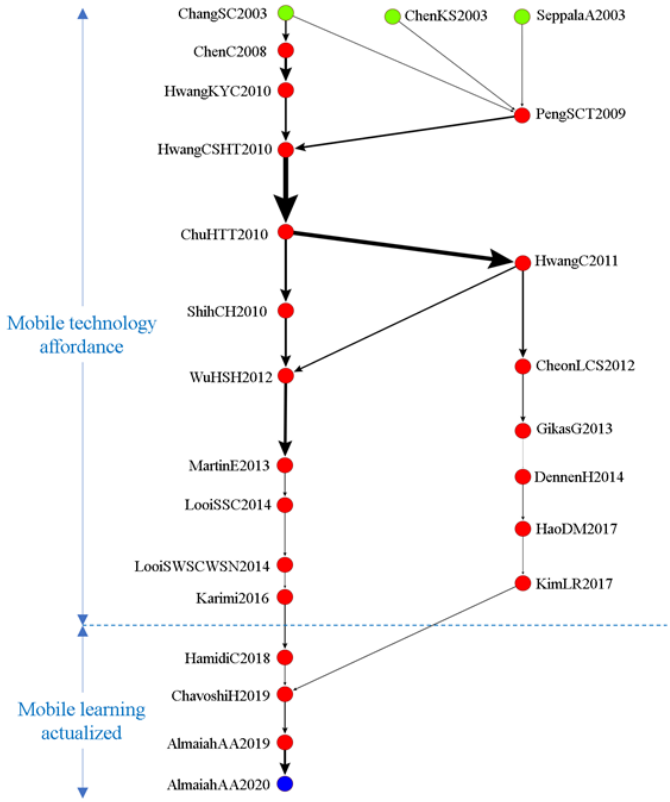

Figure 2. Key-route main paths and transformation of research focus

This study proposes the use of SPLC algorithm (Hummon & Dereian, 1989) to determine the significance of a citation link when applying MPA. The choice is based on the suggestion that SPLC fits the knowledge diffusion model better than the other traversal weights (Liu & Kuan, 2016). After the significance of each citation. The thickness of the links is proportional to their SPLC values.

In studying the research themes of MPA, we found that antecedent literature reviews put their focus first on the "Affordance" element, and later the attention is shifted to bringing "Affordance" of mobile technology into the learning environment. That being said, we suggest using "Affordance Actualization," proposed by Strong et al. (2014) to better integrate the essence of previous literature reviews.

5.2.1. Mobile technology affordance

Strong et al. (2014) suggests that "Affordance" can be divided into two central themes: "IT artifact" and "Actors and their goals." Having reviewed previous literature on main path analysis, we conclude that IT artifact is, in essence, mobile technology artifact, and characterized by a discourse on system features that encompass design models, specs, and adoption processes.

"Goal of learners and educators" in the following section is divided into two portions. One discusses the motivation of learning and teaching; the other, the projection outcome of m-learning projects. Goal fulfillment has consistently been the focus of m-learning researchers, with various essays and reports discussing ways to enhance learning effectiveness, or to improve the interaction during courses. Our analysis of this research topic identifies "the impact of mobile technologies on classroom education" as the core of m-learning. We agree with Stoffregen (2003) that positions affordance as an opportunity to help users of technology to realize their goals. To our knowledge, only by enhancing the understanding of mobile technology affordance be truly utilized. This concept has been applied to various fields in recent years, and it fills the bill for introducing this technology into educational programs.

5.2.2. Mobile learning actualizing

After analyzing previous writings that examine the clusters of actualizing m-learning, we are suggesting that this research theme is mostly concerned with the actualization of m-learning. As mentioned in the previous section, m-learning is conducive for helping students to acquire a significant amount of information, as well as to facilitate teachers' understanding of learner progress. Most importantly, m-learning also provides a way of creating more interaction between educators and learners.

The studies in this cluster considers mobile-assisted solutions for educators or learners to form a closer interactive relationship, even a more desirable study environment. By applying the theoretical framework of "Affordance Actualization," and examining previous literature on m-learning, we have proposed a learning affordance actualization model. A more in-depth discussion will follow in the next section.

6. Discussion and conclusion

To further our understanding of the development trajectory of m-learning, we adopt main path analysis in this study to examine previous literature on m-learning in higher education. Per the result of the main path analysis and theoretical foundation of affordance actualization, this paper develops a model of actualizing m-learning affordance (see Figure 3), and in turn identifies two m-learning research derivatives: Mobile-technology affordance and actualizing m-learning. In the initial stage of m-learning, the researcher focuses on mobile-technology affordance, and examines the intrinsic nature of mobile technologies. The research on this phase can be divided into three groups. The first is the Mobile technology artifact. Some studies highlight several technology features, such as Wi-Fi, mobile phone and tablet. The second is educator motivation approach, which emphasizes approaches educators take to inspire their learners. Finally, the research on learner learning projection, which examines the learner's perception of mobile devices, and how they can be smartly utilized to strengthen the learning experience. To that end, researchers are able to successfully dissect the intrinsic nature of mobile technology for higher education purposes, and address possible educational challenges accordingly.

Actualizing m-learning is the second phase of m-learning delivery. The research in this phase focuses on the contextual implementation of m-learning, and investigates the outcome of m-learning. When compared with the

previous phase, writings produced during this period have highlighted the importance of the context to consider the various factors that affect the deployment process of m-learning, and thus to dissolve the potential limitations of traditional learning.

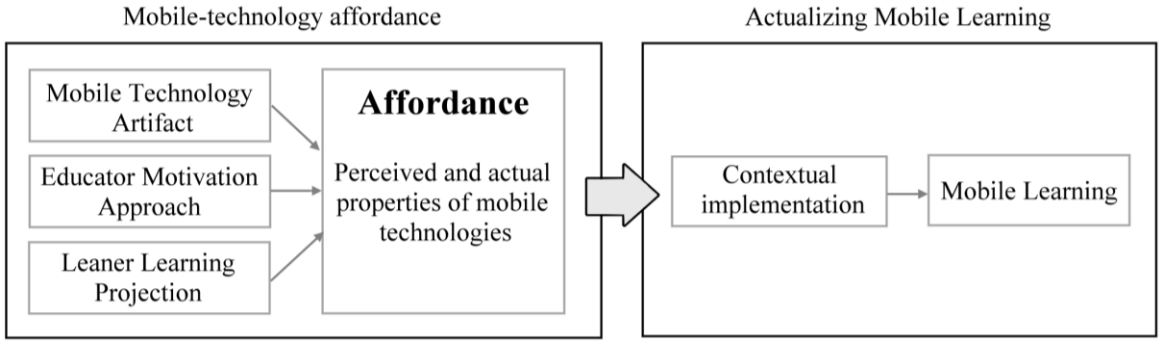

Figure 3. Model of mobile learning affordance actualization

Affordance actualization has been widely adopted in organizational research. This concept has inspired this essay to reference it into a digital education context, so as to explore the value of digital technology. By expanding the original model with more stakeholders, this version provides a comprehensive view of m-learning implementation. This is the greatest contribution made by this study to the academic circle.

6.1. Theoretical and practical implication

The key contribution of this study is through the process model of mobile learning affordance actualization to deliver the deployment approach of mobile education. In terms of theoretical contributions, it contributes to mobile learning in higher education, and affordance actualization literature.

First, this study contributes to digital education literature by introducing a theory from the IS domain, to deal with the increasing dynamic process of mobile learning adoption. Different from other education systems, mobile technologies play a more significant role than others. Because most people in higher education own a mobile device, which allows higher education to develop more mobile applications to interact with the learners who learn in universities. Moreover, to avoid taking mobile technology for granted, this study through affordance actualization analyzes each element in this, such as technology artifacts, educators (the people who teach in universities), and learners (the people who learn in universities). Moreover, the actualization perspective provides an approach to further discuss the practical issues of deploying mobile education in higher education.

Second, the affordance actualization has widely been used in organizational context, which mainly discusses how to adopt digital technologies in fulfilling a specific organizational need. However, the university is similar to the organization, yet lacks a similar structural approach about digital technology deployment. Therefore, this study suggests extending the scope of affordance actualization by appropriating this concept into the education domain. In analyzing the affordance actualization in educational context, we according to the factors in higher education to adjust the model in fulfilling the educational purposes.

Our study has important practical contributions as well. First, educators who are expected to implement digital technologies to enhance learning effectiveness within the classroom. Meanwhile, our model provides the higher educators to better actualize the potential power of digital technologies. For example, our model allows educators to enact related strategies to fit their specific education context by providing a more comprehensive view with the digital technology adoption. Second, this model is not only for mobile education, but also for other technologies. Because this is fit with the higher education environment, and helps educators to further understand the interaction between educators, learners, and technologies.

6.2. Research limitations

This section discusses the limitations of this research in two aspects: methodology and data collection. As regards methodology, we use the citation network constructed from the collected literature to find significant articles in the m-learning field. However, not all citations are equally meaningful. Sometimes an article is cited simply on account of its significance in the field, but it is not necessarily tightly associated in contents with the

article that cites it. This type of citation does not reflect actual knowledge diffusion and can weaken the results of MPA.

The other research limitation comes from data collection. Among the popular scholarly databases (Google Scholar, Scopus, and WOS), we adopt WOS for the understanding of its higher publication quality. However, WOS does not fully include conference papers published in the early years. For completeness, we exclude conference papers from our datasets.

Nevertheless, a certain proportion of the papers in the computer science field will only be published at top conferences and will not be published in journals afterward. We may have missed some important m-learning conference papers derived from the computer science field as a certain proportion of research is only published at top conferences and not in the journal afterward.

6.3. Future works

This study adopts MPA to present the m-learning research trend up to August 2020 and highlight the key articles from the period. It contributes to the m-learning field by providing the most up-to-date summary of research progress, which can be valuable information for both researchers and practitioners. In the future, researchers can further combine other analytical tools and methodologies to analyze the citation network, which is believed to be more meaningful to the research conclusions.

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