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Impact of Mobile Technology on Collaborative Learning in Engineering Studies

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Abstract: Collaborative learning has been identified as an essential aspect in the process of learning. As accelerated advancement continues to characterize the developments of technology, innovative mobile technology appears to be transforming the way collaborative learning is taking shape. This study focused on identifying whether mobile technology has a significant impact on collaborative learning in engineering studies in a private University in Malaysia. Using a quantitative approach, an online survey was administered for the data collection. Some 221 participants were selected randomly among undergraduate engineering students in the University. Data were analyzed using SmartPLS. The research findings revealed that mobile technology has a significant impact on collaborative learning. The findings also indicated that two of the mobile technology dimensions, namely mobility and immediacy have significant impact on collaborative learning. Consequently, this research suggests engineering educators can integrate mobile technology into their future instruction for more collaborative learning and create a smart workforce consisting of fast and adaptive engineers as well as other learners in Malaysia.

Keywords: *Collaborative learning, engineering study, Malaysia higher education, mobile technology, SmartPLS.*

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Introduction

Recent concerns of 21st-century skills have elevated collaboration to the status of a significant educational result in its own right, rather than just a means for students to acquire information via engagement and practice (Al-Rahmi et al., 2015). In Malaysian Initiatives & Research Findings, the Ministry of Higher Education Malaysia provided a variety of explanations supporting the position of collaboration as a crucial ability for every student living in the twenty-first century (Embi & Nordin, 2013).

Collaborative learning has been shown to improve learning outcomes, material content satisfaction, self-esteem, and diversity awareness (Ziden et al., 2017). Substantial and thorough research and investigations conducted over the last 10 years have shown that active and collaborative learning techniques have a positive effect on student learning. Consequently, it is commonly believed that practically any active collaborative strategy has the potential to enhance educational results in science, technology, engineering, and mathematics (STEM) courses compared to the lecture-dominated pedagogical approach (Aouine et al., 2019).

The practice of engineering is inextricably related to the notion of collaborative effort (Ivleva, 2016). The majority of engineers do not work in solitude. Engineers work with one other and with specialists in a number of areas. These engineers must have the capacity to interact with others, evaluate their own work, and accept criticism and other points of view (Uhomoibhi, 2013). It seems inconceivable that a huge engineering project of immense complexity, such as the rapid transit system or a satellite communication network, could be designed and constructed by a single engineer. Therefore, collaborative learning seems to be an effective method for preparing engineering students for future obstacles. In response, engineering education reformers have called for more student collaboration in order to better prepare students for professional life (Fotopoulou et al., 2019).

Indeed, advancements in educational technology have significantly altered higher education. The fast incorporation of contemporary technology into the education sector, is facilitating not only how students learn but also how they are instructed with profound impact (Frykedal & Chiriac, 2018). Additionally, the manner in which students cooperate with

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one another nowadays is not exceptional. Technology has the potential to better support and cultivate collaborative learning abilities. Learners of the Net Generation rely heavily on information and communication technology to engage in and participate in collaborative activities (Ahmed, 2015).

As technological progress continues to rise, innovative mobile technology has emerged and changed the practices of collaborative learning. Mobile technologies play a crucial role in bringing students together and enhancing their ability to connect with one another. Therefore, their collaboration is more effective and efficient. Even accessing course information seems to be more open and adaptable nowadays (Sung et al., 2017). The purpose of these technologies that promote collaboration and communication is to enhance learner engagement and communication quality by providing students with devices that enable them to communicate and collaborate more effectively, in their meaningful discussions with ease (Hollabaugh, 2016). To do this, mobile technology should facilitate the formation and management of workgroups and provide more flexibility, accessibility, and immediacy (Houston et al., 2016).

The purpose of this research is to examine the impact of mobile technologies on collaborative learning in engineering courses. This research is useful for engineering educators and curriculum designers in making informed judgments on the use of mobile technology in the planning, design, and implementation of successful instructional techniques for collaborative learning. In addition, this research may help with the integration of mobile technology into contemporary educational environments.

Literature Review

Collaborative learning involves learners participating in group activities to share their understanding, information, and expertise (Scager et al., 2016). There is such a wide variety of ways in which this term is used within various academic fields (Dillenbourg, 1999). Although several academics have given different definitions of collaborative learning, Dillenbourg's definition is perhaps the most frequently accepted: "collaborative learning is a situation in which two or more people learn or attempt to learn something together" (pp.14). According to Dillenbourg, collaborative learning is a strategy that entails the following: (1) a setting in which (2) at least two or more people (3) learn or attempt to learn something jointly, (4) depending on their interactions. A careful explanation is thus required, as these components can be described in a variety of ways, depending on the way different situations exhibit the phenomenon.

Collaborative learning allows students to share their own perspectives and experiences with their classmates. Undoubtedly, employing a collaborative learning paradigm in engineering courses has various benefits. Initially, participants learn more efficiently (Ahmed, 2015). They promote critical thinking skills, enhanced motivation, shared responsibility for learning, and engagement in learning by everyone, including the instructor, all of which lead to the growth of confidence and self-esteem (Sulaiman & Shahrill, 2015). By activating the cognitive process, collaborative learning enhances team members' grasp of a subject (Ivleva, 2016). The effect of shared accountability and responsibility for the group's outputs is to reduce task-related anxiety (Idris & Rajuddin, 2012).

Malaysia's Ministry of Higher Education has exerted substantial pressure on institutions to create engineers who are competitive in the marketplace, recognizing the need for training future generations of highly qualified engineers (Yusof et al., 2019). Students of engineering might form collaborative interdisciplinary groups to seek efficient solutions for such circumstances (Yusof et al., 2019). The desired attributes of future engineers, such as the ability to operate in a diverse team, a grasp of professional and ethical duties, and the capability to communicate effectively, may thus be achieved via collaborative learning (Slivar et al., 2018).

Hossain et al. (2012) affirmed that collaborative learning has been a fascinating and alluring area of research owing to its positive influence on STEM education in Malaysia. By cooperating in small groups, it was found that students might increase their academic achievement while boosting their interpersonal skills. Long-term collaborative learning activities aid engineering students by enhancing their performance, critical thinking, communication skills, and values in the context of Malaysian education.

Mobile Technology

In addition to the developments in information technology, wireless communication and mobile technology are utilized to supplement traditional learning (Osipova et al., 2016). These technical advancements, as well as the widespread availability and cheap cost of mobile technology, provide a tremendous opportunity to use the power and pervasiveness of mobile technologies to improve learning and increase educational possibilities (Viberg et al., 2018). As long as mobile terminals remain accessible, even students who are not in the classroom will be able to communicate visually with their instructors, allowing teachers to steer their learning.

The term "mobile technology" refers to portable electronic devices that use Wi-Fi or cellular networks to access apps, e-mail, messaging, and the Internet (Ismail et al., 2013). Tablets, e-readers, smartphones, PDAs, and smart-capable portable music players are all examples of mobile technology (Kim et al., 2013).

The most commonly cited advantage of mobile technology is mobility, which allows computing to occur anywhere and at any time (Jaldemark et al., 2018). Accessible from any place and at any time, mobile technology may reduce time and space restrictions in gaining access to vital information and improve communication, coordination, collaboration, and knowledge sharing (Yu et al., 2014). The use of mobile technology in education has the potential to alter the learning and teaching processes and the learning environment (Batista & Barcelos, 2014).

Mobile technology facilitates collaboration and engagement (Avci & Adiguzel, 2017). Students may communicate and connect with their peers, teachers, and subject matter experts while on the go (Hsu, 2015). Mobile technologies provide instantaneous communication between students and teachers, peers, and educational institutions (New South Wales Department of Education, 2018). The educational technology may be used widely in managerial and educational processes in a range of organizations. It also contributes considerably to the growth of interaction inside and outside of the classroom in educational institutions (Viberg et al., 2018). Despite the acknowledgement of significance of integrating mobile technology into education, there is limited study in this field. The study field of mobile technology is relatively fresh and developing. In addition, the use of mobile technology in education is at best in its infancy (Ismail et al., 2016). There is a need for study in this area to inform practice and guide future research endeavors. Innovative ways to collaborative learning must be the subject of more studies and practices (Avci & Adiguzel, 2017).

Methodology

Research Design

The purpose of this research is to obtain an insight into the impact of mobile technology on collaborative learning. This research was designed to be a quantitative survey-based study using inferential statistics with the aid of Smart PLS analysis on the relationship and predictive relevance. There are two research questions in this study.

1. Is there a significant impact of mobile technology on collaborative learning?
2. Among the three dimensions (mobility, accessibility and immediacy) of mobile technology which is/are the best predictor(s) of collaborative learning?

Sample and Data Collection

The target population for the current study is all undergraduate students attending engineering courses in a private University in Malaysia. The researcher pulled a random sample from the faculty of engineering to provide a representative sample. Considering factors like participant availability and respondents' rate of return of questionnaires, the researcher decided the sample size for this study to be 300 actively enrolled engineering students in the university.

Research Instrument

Collaborative learning questionnaire and mobile technology questionnaire were adapted by the researcher. The collaborative learning questionnaire combined three questionnaire sections: "Cooperative Learning Questionnaire (CAC) Section" (adapted from Fernandez-Rio et al., (2017)), "Knowledge Sharing Survey Section" (adapted from Chalak et al. (2014)), and "Guide to Rate Critical Thinking Section" (adapted from Kelly-Riley et al. (2001)). The collaborative learning questionnaire was adapted to include seven dimensions, namely interdependence, interaction, accountability and responsibility, social skills, group processing, knowledge sharing and critical thinking in order to obtain students' perception of collaborative learning in this study.

The mobile technology questionnaire combined three questionnaire sections: "Mobile Learning in Distance Education Questionnaire Section" (adapted from Yousuf (2007)) and "ICT Skills Questionnaire Section" (adapted from Pande (2018)). It should be acknowledged that the research instrument in this study used seven-point Likert scales to measure student's perception towards using mobile technology for collaborative leaning purposes.

Reliability

Drost (2011) stated that reliability is "the extent to which measurements are repeatable when different people perform the measurement on different occasions, under different conditions, supposedly with alternative instruments which measure the constructs or skills". In this study, reliability is measured by internal consistency reliability, composite reliability, and reliability coefficient rho A, which are summarized in Table 1 below. All three measures of reliability for the instrument registered high values, ranging between .878 and .957 indicating good measures of reliability for the instruments.

Table 1. Reliability of Research Instrument

Research Instrument	Cronbach's alpha	Rho A	Composite Reliability
Collaborative Learning	.948	.949	.957
Mobile Technology	.878	.882	.925

Validity

Validity refers to the extent to which a measure adequately represents the underlying construct that it is supposed to measure (Drost, 2011). Using both theoretical and empirical data, validity is assessed. In the present study, the self-administered questionnaire was forwarded to an expert for content validation to confirm that the research instruments sufficiently address the investigated construct. In empirical evaluation, validity is determined by quantitative analysis using statistical approaches. This study utilized Smart PLS to examine the validity parameters. The convergence validity and discriminant validity were evaluated separately. Using Average Variance Extracted (AVE), the convergent validity of the scale items was evaluated for collaborative learning as .761 while that of the mobile technology was found to be .803 as shown in Table 2 below. In exploratory research, values of AVE higher than .5 are considered acceptable. The discriminant validity was determined using the Heterotrait-Monotrait (HTMT) correlation ratio, which was found to be .874 in Table 3. As Henseler et al. (2015) suggested that HTMT ratio lower than .90 was considered valid. Based on the results, this study is considered as following good measurement practice by implementing the procedural remedies related to questionnaire and item design (Podsakoff et al., 2003).

Table 2. Average Variance Extracted (AVE) of Research Instrument

	Average Variance Extracted (AVE)
Collaborative Learning	.761
Mobile Technology	.803

Table 3. HTMT Ratio of Correlation

	Collaborative Learning	**Mobile Technology**
Collaborative Learning		
Mobile Technology	.874	

Pilot Study

A pilot study was conducted to identify potential problem areas and deficiencies in the research instruments prior to implementation during the full study. One hundred engineering students enrolling in the September 2020 semester at the university were randomly chosen and asked to participate in the pilot research. The percentage of response was 76%. Exploratory Factor Analysis (EFA) was performed to determine if the suggested factor structures correspond to the actual data. The EFA findings indicated the necessity to delete six items from the questionnaire on collaborative learning and two indicators from the questionnaire on mobile technologies. Following exploratory factor analysis, the research instruments for the complete study were adjusted.

Data Collection and Analysis

The institution's faculty of engineering approved the use of Wen Juan Xing, a cloud-based survey site that collects and saves survey data anonymously. In conjunction with the faculty, the researcher sent emails to eligible respondents encouraging them to participate in the present study. This research recruited three hundred (300) students to participate. However, a valid sample size of 221 respondents (n = 221) participated in this survey, reflecting a participation percentage of 74%.

Findings

Impact of Mobile Technology on Collaborative Learning

The path coefficient represents the impact of mobile technology on collaborative learning. The path coefficient between mobile technology and collaborative learning is .808, as shown in Figure 1. This figure implies, according to Guildford (1956), that mobile technology has a significant impact on collaborative learning. In addition, 65.3 percent of the variation in collaborative learning is shown to be explicable by mobile technology.

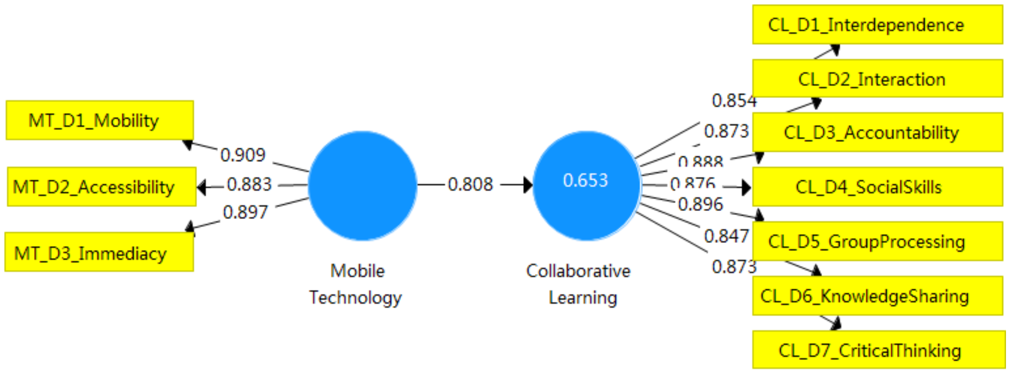

Figure 1. Illustration of Path Coefficient Between Mobile Technology and Collaborative Learning

To confirm that this highly correlated relationship is significant, bootstrapping technique was employed subsequently with a subsample size of 5,000. The t-statistics value of the "mobile technology - collaborative learning" linkage is 24,665 and the p value is .000, as shown in Table 4. Consequently, it can be concluded that mobile technology has a significant impact on collaborative learning.

Table 4. t-statistics Between Mobile Technology and Collaborative Learning

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	t-statistics (|O/STDEV|)	p values
Mobile Technology -> Collaborative Learning	.808	.811	.033	24.665	.000

Best Predictor(S) of Collaborative Learning Among the Three Dimensions of Mobile Technology (Mobility, Accessibility and Immediacy)

The strength of the path coefficients identifies the most accurate predictor of collaborative learning among the three components of mobile technology (mobility, accessibility, and immediacy). As seen in Figure 2 below, mobility has the greatest value for route coefficient at .406, followed by immediacy at .383. The path coefficient between accessibility and collaborative learning is determined to be .107, which is regarded to be quite low.

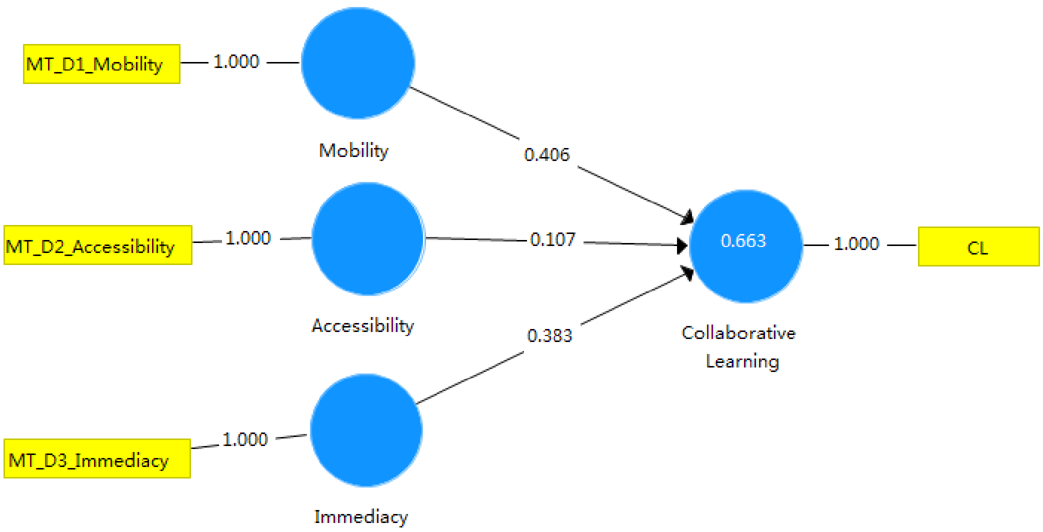

Figure 2. Illustration of Path Coefficients of Predictors for Collaborative Learning

The greatest predictor, mobility, is reflected by a t-statistics value of 4.517 in the "mobility - collaborative learning" linkage and a p value of .000, as seen in Table 5. The second predictor, immediacy, is indicated by a t-statistics value of 4.613 and a p value of .000 in the "immediacy - collaborative learning" linkage. On the basis of these findings, it is possible to infer that the links between mobility and collaborative learning and immediacy and collaborative learning are both important.

On the other hand, it is shown that the t-statistics value of 1.532 in the "accessibility - collaborative learning" linkage does not meet the condition of t-statistics value being more than 1.96 at a p value of .05. According to the findings, the association between accessibility and collaborative learning is not significant. Mobility is the strongest predictor of collaborative learning among the three features of mobile technology, followed by immediacy, whereas accessibility is not a predictor.

Table 5. t-statistics of Predictors for Collaborative Learning

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	t-statistics (|O/STDEV|)	p values
Accessibility -> Collaborative Learning	.107	.117	.070	1.532	.126
Immediacy -> Collaborative Learning	.383	.389	.083	4.613	.000
Mobility -> Collaborative Learning	.406	.392	.090	4.517	.000

As an exploration on how exactly the present data fits a model connecting mobile technology and collaborative learning, the Smart PLS was engaged. Subsequently, it was found that a new structural model emerged that could still explain the literature support for the relationship between mobile technology and collaborative learning both in direct and indirect manner. The illustration of the new structural model is presented in Figure 3.

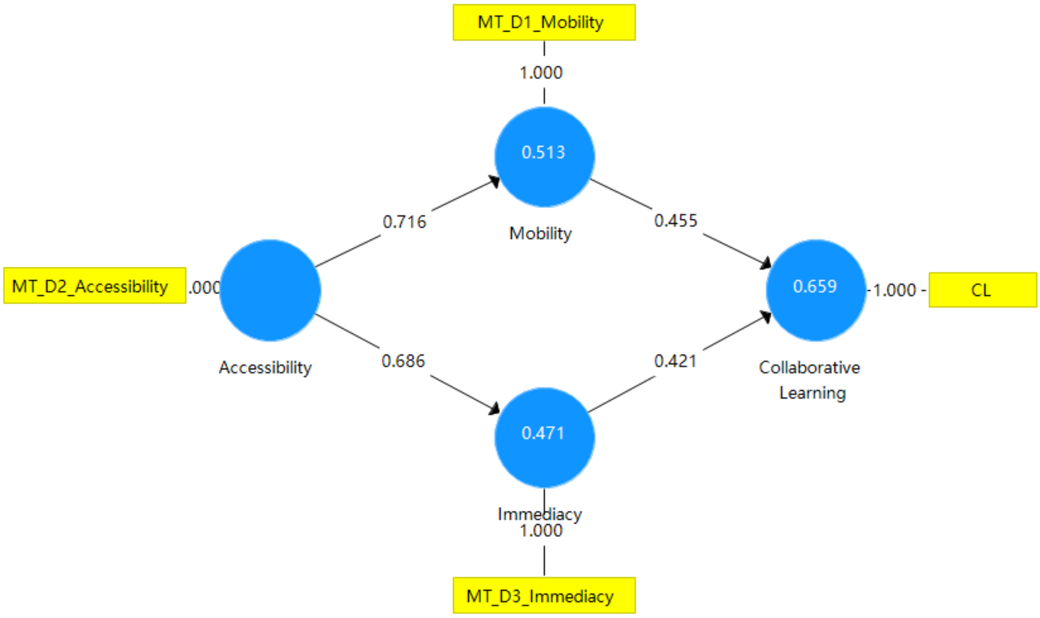

Figure 3. Illustration of New Structural Model

According to the data, the path coefficient between mobility and collaborative learning is .455, and the path coefficient between immediacy and collaborative learning is .421. In addition, the investigation revealed that, contrary to the earlier assumption of a direct relationship, there is an indirect relationship between accessibility and collaborative learning, where the path coefficient between accessibility and immediacy is .686 and that between accessibility and mobility is .716, both of which are regarded as high.

As shown in Table 6, the t-statistics value of 15.796 in the "accessibility - immediacy" linkage, along with a p value of.000, and the t-statistics value of 16.490 in the "accessibility - mobility" linkage, along with a p value of .000, suggest and lead to the conclusion that the relationship between accessibility and mobility and accessibility and immediacy is significant. In the meanwhile, the t-statistics values of 5.855 and 5.898 for the "immediacy - collaborative learning" and "mobility - collaborative learning" linkages, respectively, remain significant.

Table 6. t-statistics of New Structural Model

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	t-statistics (|O/STDEV|)	p values
Accessibility -> Immediacy	.686	.687	.043	15.796	.000
Accessibility -> Mobility	.716	.716	.043	16.490	.000
Immediacy -> Collaborative Learning	.421	.430	.072	5.855	.000
Mobility -> Collaborative Learning	.455	.446	.077	5.898	.000

Specific indirect effects were required to establish the significance of the indirect links between accessibility and collaborative learning through mobility and accessibility and collaborative learning via immediacy. According to Table 7, "accessibility – mobility – collaborative learning" linkage represented by a t-statistics value of 5.852 and a p value of

.000, and "accessibility – immediacy – collaborative learning" linkage represented by a t-statistics value of 5.792 and a p value of .000 lead to the conclusion that the indirect relationships between accessibility and collaborative learning via mobility and immediacy are both significant.

Table 7. Specific Indirect Effects of New Structural Model

	Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**t-statistics (|O/STDEV|)**	**p values**
Accessibility -> Mobility -> Collaborative Learning	.313	.307	.053	5.852	.000
Accessibility -> Immediacy -> Collaborative Learning	.288	.294	.050	5.792	.000

Discussion

This study found a strong impact of mobile technology on collaborative learning. Hence, it suggests mobile technology could present advances in conjunction with inherent collaborative learning (Troussas et al., 2014). Mobile technologies render educational system ubiquitous, pervasive with enhanced capabilities for rich and meaningful collaboration. In other words, collaborative learning can be improved by exploitation of crucial and immediate information provided by the mobile technology (Vassilakaki et al., 2016). Further, engineering studies can benefit from mobile technology, that provides opportunities for learners to personalize their collaborative educational process, to learn more autonomously and to collaborate with their peers at anytime and anywhere. Mobile devices seem to act as mediated tools for collaboration that support the learners' personal relationships and social interactions with classmates, friends, family, group peers, tutors, etc. (Koschmann, 1993).

Among the three dimensions of mobile technology (mobility, accessibility and immediacy), mobility was found to be the best predictor of collaborative learning, followed by immediacy. This indicated that using mobile technology gives learners an opportunity to access the information whenever and wherever they want (Hsu, 2015). In this way, mobile technology provides flexibility and ubiquity by accessing learning materials anytime, anywhere and adapt them to learners' personal features, preferences, and interests, as well as pervasiveness by means of the latest wearable devices for learning across contexts (Hull, 1993). In another note, immediacy of information access available in mobile technology as well as enhanced hands-on learning experiences engage students in their collaborative learning. (Cheng et al., 2016). According to Santi et al. (2010), studies of informal learning almost always suggest that most of adults' learning activities happens outside formal education. Mobile technologies, with their reduced size and ease of use, provide the potential to support such informal activities too.

Moreover, by realizing the potential of mobile technologies in collaborative learning, more and more institutions around the world are now adopting this new mode of learning, due to its significant benefits that include cost effectiveness, convenience, anytime and anywhere, flexibility, as well as immediacy of information and interaction (Ossiannilsson, 2018). Sung et al. (2017), in their meta-analysis, found that when integrating mobile devices on student learning the overall effect of using mobile devices appears to be better for learning than not using the devices at all.

On the other hand, accessibility was not found to be a predictor of collaborative learning. Some literature suggests that the use of accessibility features of mobile technology should be based on individual student needs and preferences to be most effective (Okai-Ugbaje et al., 2017). In this study, accessibility of mobile technology was not found to be having a direct relationship with collaborative learning. Although accessibility features are provided to students, there is evidence that they do not always lead to valid results. This conclusion was also confirmed by Perry (2019) and Yurdagül and Öz (2018). For example, students are sometimes over-accommodated or under-accommodated, which may lead to ineffective use of the accessibility features and have an impact on students' collaborative learning experiences.

Mobile devices provide a unique opportunity to have learners embedded in a realistic environment at the same time as having access to supporting tools. Each learner carries a networked device which allows them to become part of the dynamic system they are learning about. Therefore, learners are able to experiment and learn from the environment by themselves.

Conclusion

Mobile technology is advancing into today's institutions of higher education and is a major influence on student collaborative learning. This study had determined the strong and significant impact of mobile technology on collaborative learning. The analysis found that mobility and immediacy features of mobile technology can predict collaborative learning in higher education. Therefore, imbedding mobile technology into the pedagogy has great potential to help improve and enhance student collaboration and thereby elevating their social, and academic success.

Recommendations

Results from the current study could be utilized by institutional stakeholders in making informed decisions on new and updated mobile technology in ensuring the mobility and immediacy of such technology for everyone who is involved. Mobile technology, in its various forms, is used in and out of classroom. However, these forms need to be integrated purposefully in instructional and curricular designs. It is also essential to understand that mobile technology may have its limitations. This implies that considerable research is still needed if in case mobile technology is to be deployed as tools to support collaborative learning in Malaysia.

It is recommended that this study be replicated with investigations on identifying some best ways to use mobility to promote learning. Obviously, it is important to examine strategies of both mobile technology and collaborative learning, and the best ways to blend the two to create effective learning experiences for students. In this attempt, some of the best types of mobile technology applications for different types of collaborative learning activities may surface to assist students in collaborative learning.

Another recommendation may involve different groups of collaborative learning activities (ad hoc informal groups, formal collaborative learning group, and the most formally organized group) as suggested by Brame and Biel (2015). These groups may be investigated for the best ways to blend mobile learning and collaborative learning to create effective learning experiences for students.

Limitations

This research has two significant limitations. First, this research only covered engineering students from a single university. Therefore, the results cannot be generalized to other programs, universities, or institutions of higher education. Second, this research was intended to be purely quantitative. Qualitative approaches involving interviews with students may have produced additional and useful data that could have uncovered deeper meanings and explanations.

Authorship Contribution Statement

Gong: Conceptualization, design, data acquisition, data analysis and interpretation, statistical analysis, drafting manuscript. Sathiamoorthy: Editing/reviewing, supervision, critical revision of manuscript, final approval. Kamalanathan: Editing/reviewing, supervision, critical revision of manuscript.

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