Mobile game-based learning as a solution in COVID-19 era: Modeling the pedagogical affordance and student interactions

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Abstract

The closure of educational institutions due to the COVID-19 pandemic leads imperatively to the utilization of technological advances and the Internet for enabling the continuity of learning. To this direction, Mobile Game-based Learning (MGbL) can be beneficial to teaching and learning; since, from technological perspective, most students prefer to use their mobile devices, such as smartphones or tablets, and from pedagogical perspective, incorporating gaming in educational process can boost students' motivation for learning and improve their learning outcomes. Hence, this study investigates learners' intention to use MGbL as an alternative educational practice during the COVID-19 pandemic, by modeling the pedagogical affordance of this technology and student interactions with it. As a testbed for this research, a MGbL application was used for the instruction of the programming language C# in higher education, during the lockdown period of 2020. The findings reveal that the MGbL technology has a significant and positive impact on student engagement and academic performance.

Keywords Collaborative learning · COVID-19 · Educational use · Mobile game-based learning · Personalized learning · Structural equation modeling

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1 Introduction

The COVID-19 pandemic has disrupted human's normal life, leading to numerous limitations in all fields, such as market, employment, education etc. Regarding the educational field, the spread of COVID-19 has as effect the closure of educational institutions worldwide. Thus, it is imperative to use technological means in order to provide better access to the learning process (Almaiah et al., 2020). Such technological means include the development of educational software, either web-based environments or mobile applications, which through personal computers, smartphones or tablets, can be used as learning tools, without the barriers of time, place and space (Troussas et al., 2020a). Nowadays, mobile devices have surpassed the use of personal computers,¹ since they are more accessible providing similar capabilities.

The proliferation of mobile technologies offers possibilities to revolutionize education, combining mobile learning and game-based learning approaches (Chang & Hwang, 2019). This is known as Mobile Game-based Learning (MGbL). MGbL provides an environment where students can learn and/or test their knowledge using gaming through mobile devices. As such, they are engaged in it, not only for leisure pursuits but also for educational purposes (Huizenga et al., 2019). The related literature suggests that the use of MGbL improves the learning outcomes and students' motivation for learning (Mivehchi & Rajabion, 2020). However, the relationship between the interaction design requirements for the system acceptance by the users, the educational technologies incorporated into a MGbL environment for enhancing learning, and the pedagogical benefits for learners has not been investigated adequately as in the way this paper approaches it.

Indeed, it needs to be emphasized that MGbL approaches could serve as an effective alternative for education in the COVID-19 period, since the majority of learners had a smartphone, while a few had a personal computer. Furthermore, if a family had more members, the procession of more than one personal computer should be helpful but rather impossible. As such, smartphones were the tools that supported users to cope with the imposed online education.

Analyzing the related literature, there have been several studies (Agarwal et al., 2021; Muthuprasad et al., 2021; Tawafak et al., 2021; Vargo et al., 2021; Amir et al., 2020; Xie et al., 2020; Ionescu et al., 2020) that explore the impact and effect of COVID-19 pandemic in online education. However, the aforementioned studies examine learning management systems, web conferencing tools, social media websites or massive open online courses as the main learning tools used during the COVID-19 lockdown. On the contrary, this research investigates the pedagogical affordance of MGbL as a means of online instruction amidst COVID-19 pandemic.

On top of that, it needs to be emphasized that in the era of the imposed fully online education as a consequence of COVID-19 pandemic, a lack of learners' motivation has been reported (Panisoara et al., 2020; Iglesias-Pradas et al., 2021; Tawafak et al., 2021). Therefore, this study seeks to explore the effectiveness of

¹ <https://gs.statcounter.com/platform-market-share/desktop-mobile-tablet> -<https://www.broadbandsearch.net/blog/mobile-desktop-internet-usage-statistics>

the utilization of MGbL in tertiary education, as an alternative solution to motivate learners, strengthen knowledge acquisition and prevent them from dropping out.

In view of the above, this paper explores the acceptance of the MGbL technology in teaching and learning during COVID-19 lockdown, modeling its pedagogical affordance and student interactions. Therefore, a Structural Equation Model (SEM) was constructed, examining the relationships between the factors that affects students' intention to use this technology. In particular, the research model analyzes the effect of both interaction design requirements, namely ease of use and enjoyment, and educational technologies, namely personalized, collaborative and mobile game-based learning, on students' engagement in learning process and on their academic performance. As a testbed for this research, we used Quiz Time!, which is an intelligent mobile game-based learning application for assessing and advancing learners' knowledge in the programming language C# (Troussas et al., 2020a). This system was used by undergraduate students during the COVID-19 lockdown of 2020, and the evaluation results show a positive effect of the aforementioned factors on student performance, rendering the MGbL technology a key alternative learning approach.

2 Research model and hypotheses

The model, constructed to analyze the potential of the MGbL technology as a pedagogical tool, consists of 7 latent variables, which are the following:

- **Perceived Ease of Use (PEoU).** Perceived ease of use concerns the ease of information technology as perceived by users. As suggested by the Technology Acceptance Model (TAM), this factor highly affects the acceptance of the new system considering the users' intention to use it and their attitude towards its utilization (Davis, 1989). Regarding mobile applications, it is imperative to design easy-to-use interfaces in order to overcome the limitations on user interactions due to the small screen of mobile devices. Therefore, the following hypothesis is composed:

H1. Perceived ease of use has a significant influence on MGbL (PEoU → MGbL).

- **Perceived Enjoyment (PE).** Perceived enjoyment refers to the level of enjoyment the users experience while using the new system (Davis et al., 1992). In MGbL environments, this factor can motivate students and make learning more pleasant. Quiz Time! provides such an environment through an adaptive and collaborative quiz game. Therefore, the following hypothesis is composed:

H2. Perceived enjoyment has a significant influence on MGbL (PE → MGbL).

- **Personalized Learning (PL).** Personalized learning provides tailored learning to each student's needs and preferences, promoting a student-centered instruction (Troussas et al., 2020b). Incorporating personalization into educational software helps learners to achieve their learning goals and offers a more effective learning experience (Xie et al., 2019). Personalization in educational systems has been shown to be an effective approach for improved knowledge acquisition, as reported in the related literature (Krouska et al., 2020a; Lin et al., 2020). Quiz Time! provides adaptive advice to learners who answer incorrectly in quiz game, according to their characteristics, for helping them find the correct answer. Therefore, the following hypotheses are composed:

H3. Personalized learning has a significant influence on MGbL (PL → MGbL).

H4. Personalized learning has a significant influence on student performance (PL → SP).

- **Mobile Game-based Learning (MGbL).** This educational technology combines learning with playing, making the learning process more interesting (Zakaria et al., 2018). MGbL promotes the active participation of students in learning and their collaboration through peer gaming. MGbL can improve teamwork, students' learning motivation and their performance as well (Chang & Hwang, 2019). Also, MGbL has been reported as an efficient environment for students to advance their knowledge through an entertaining way according to the related literature (Krouska et al., 2020b). Quiz Time! is a MGbL application for assessing the learners' knowledge in the programming language C#, combining personalized and collaborative learning strategies with a gaming approach. Moreover, it incorporates motivational strategies through an integrated badge system. Therefore, the following hypotheses are composed:

H5. Mobile game-based learning has a significant influence on collaborative learning (MGbL → CL).

H6. Mobile game-based learning has a significant influence on student engagement (MGbL → SE).

H7. Mobile game-based learning has a significant influence on student performance (MGbL → SP).

- **Collaborative Learning (CL).** Collaborative learning enhances learning through working in groups (Zakaria et al., 2018). The formation of optimal groups is crucial for increasing learning outcomes through effective interactions (Krouska & Virvou, 2020). Collaborative learning can have strong pedagogical potential and support students through interaction, as stated in the related literature (Krouska et al., 2020c; Mahawan & Langprayoon, 2020). Quiz Time! provides personal-

Fig. 1 Research model

ized recommendations for co-players, aiming to better knowledge acquisition through a beneficial collaboration. Therefore, the following hypothesis is composed:

H8. Collaborative learning has a significant influence on student performance (CL $\rightarrow$ SP).

- **Student Engagement (SE).** Student engagement refers to the degree of attention, interest and passion that students show during the learning process (Heflin et al., 2017). It also includes the strategies that are adopted by the educator or incorporated into a system in order to motivate students towards active participation in their education, with the intention to improve their learning outcomes (Moubayed et al., 2018). Therefore, the following hypothesis is composed:

H9. Student engagement has a significant influence on student performance (SE $\rightarrow$ SP).

- **Student Performance (SP).** The success of an educational system is considered by the degree that the learning goals are accomplished (Krouska et al., 2019). Hence, the acceptance of the MGbL technology can be evaluated regarding its influence on student performance.

Based on the aforementioned hypotheses, Fig. 1 summarizes the research model used in this study.

Table 1 Demographic information of participants

Characteristics		Number/Level
Age	Female	19.2 years in average
	Male	19.5 years in average
Gender	Female	46
	Male	54
Area of origin	Urban origins	64
	Non-urban origins	36
Year of study	2nd year of studies	100
Computer skills		Advanced
Grade in studies (Average of first-year courses)	8.5 – 10	16
	6.5 – 8.4	59
	5 – 6.4	25

3 Research methodology and data collection

This paper investigates the pedagogical affordance of the MGbL technology and the intention of students towards this technology through Quiz Time!, a MGbL application presented by (Troussas et al., 2020a). In order to export valid conclusions from the evaluation results, a representative group of students was chosen using the probability sampling method. As such, the study took place in a public university in the capital city of the country with the participation of 100 students taking the mandatory course of the Programming Language C# at the Department of Informatics and Computer Engineering of the aforementioned University. Students used the Quiz Time! during the semester where the University was closed due to the spread of COVID-19. The demographic information of the participants is shown in Table 1. All of them are in the second year of their studies having passed successfully the first-year courses, and consequently, they have approximately the same age and educational level, as well as they have advanced computer skills due to their studies in computer science. Moreover, 54% of them were male, and 46% were female. Therefore, it can be considered that the population was balanced in terms of gender, age and academic level.

Data was collected using an online survey, developed by the authors. The survey consisted of 21 questions, one for each of the 3 indicators that had been defined for each latent variable (7 in total). A 5-point Likert scale was used in order the respondents to rate their experience of the utilization of the MGbL technology. The survey was distributed to students at the end of the academic semester, having a return rate of 100%.

Data analysis was conducted using the SmartPLS² software, applying partial least squares structural equation modeling (PLS-SEM). Regarding the PLS-SEM settings, the path weighting scheme was used, while the values of maximum iterations and stop criterion were set to 300 and 10^7 , respectively. Firstly, the measurement model was tested to confirm the reliability and validity of the model based on the

² <https://www.smartpls.com/>

composite reliability (CR) and Cronbach Alpha values, as well as the outer loading and AVE values. Moreover, in this stage, Fornell-Larcker Discriminant Validity Criterion was employed. Afterwards, the structural model was evaluated to determine the support of the model hypotheses. As such, we ran a bootstrapping with 1000 subsamples on Smart PLS for calculating the path coefficients, *t* values and significance of the paths.

4 Data analysis and results

4.1 Testing measurement model

In the measurement model, the internal consistency reliability, indicator reliability, convergent and discriminant validity were tested. The internal consistency reliability was defined using the composite reliability (CR) and Cronbach Alpha value, while indicator reliability was assessed with the factor loadings of the items. The results show that all indicators' loadings are significant since their values are above .700 and for each construct, the AVE values are greater than .500, while the CR and Cronbach's Alpha exceed .700 (Table 2). Therefore, the convergent validity is confirmed.

The discriminant validity of the model was examined using the procedure of Fornell and Larcker (1981). The results show that the square root of the AVE values for the constructs are greater than the variance of any of the inter-construct correlations (Table 3), suggesting an adequate discriminant validity of the measurement.

To sum up, the model's validity and reliability is satisfied without violence in data. As such, the structural model can be employed.

4.2 Results of hypothesis testing

The structural model is essential to test the bivariate relationships between the constructs included in the model. The results show that all the 9 hypotheses, proposed in this study, are accepted, since their *p* value is above .050 (Table 4). In particular, the highest impact on student performance is by the MGbL technology (H7, $\beta = .606$, $p = .000$), followed by personalized learning (H4, $\beta = .425$, $p = .020$); while student engagement (H9, $\beta = .136$, $p = .046$) and collaborative learning (H8, $\beta = .106$, $p = .042$) are of minor significance compared to the aforementioned variables. The MGbL technology has also a high positive influence on student engagement, confirming H6 with the result of $\beta = .564$ and $p = .003$. Regarding the relation between MGbL and collaborative learning, H5 is accepted showing that their relation is significant and positive ($\beta = .195$, $p = .028$). H3 that suggests a positive relation between personalized learning and MGbL is supported, since $\beta = .223$ and $p = .026$. Finally,

Table 2 Results of measurement model

Variable	Indicator	Outer Loading	AVE	CR	Cronbach's Alpha
PEoU	PEoU1	.909	.748	.898	.841
	PEoU2	.927			
	PEoU3	.748			
PE	PE1	.940	.595	.810	.821
	PE2	.758			
	PE3	.793			
PL	PL1	.927	.739	.894	.839
	PL2	.765			
	PL3	.879			
MGbL	MGbL1	.962	.691	.857	.780
	MGbL2	.916			
	MGbL3	.970			
CL	CL1	.838	.654	.845	.740
	CL2	.759			
	CL3	.812			
SE	SE1	.701	.642	.842	.750
	SE2	.788			
	SE3	.903			
SP	SP1	.859	.638	.840	.722
	SP2	.722			
	SP3	.808			

Table 3 Fornell-Larcker discriminant validity criterion

	PEoU	PE	PL	MGbL	CL	SE	SP
PEoU	.865						
PE	.541	.772					
PL	.327	.194	.859				
MGbL	.406	.612	.268	.831			
CL	.365	.398	.239	.325	.803		
SE	.193	.378	.541	.456	.157	.801	
SP	.160	.232	.496	.756	.192	.449	.798

The values on the diagonal (square root of AVE) are greater than their own row and column values (inter-construct correlations)

the results prove that perceived ease of use and perceived enjoyment have a significant influence on MGbL ($H1, \beta = .287, p = .032$ / $H2, \beta = .325, p = .038$).

Fig. 2 illustrates the structural model of this research.

Table 4 Results of hypothesis testing

Hypothesis	Path	β	Std. Dev.	t-stat.	p value	Supported
H1	PEoU $\rightarrow$ MGbL	.287	.155	2.563	.032	Yes
H2	PE $\rightarrow$ MGbL	.325	.156	2.485	.038	Yes
H3	PL $\rightarrow$ MGbL	.223	.166	2.884	.026	Yes
H4	PL $\rightarrow$ SP	.425	.152	3.005	.020	Yes
H5	MGbL $\rightarrow$ CL	.195	.164	2.691	.028	Yes
H6	MGbL $\rightarrow$ SE	.564	.132	3.604	.003	Yes
H7	MGbL $\rightarrow$ SP	.606	.112	6.467	.000	Yes
H8	CL $\rightarrow$ SP	.106	.162	2.328	.042	Yes
H9	SE $\rightarrow$ SP	.136	.165	2.089	.046	Yes

Fig. 2 Structural Model

5 Discussion

This research explores the pedagogical affordance of the MGbL technology and student interactions in such environments during COVID-19 pandemic, using a specific application, namely Quiz Time! (Troussas et al., 2020a). The nine hypotheses, stated in this study, were all confirmed, illustrating the positive impact of MGbL on student performance and its acceptance by the learners, as well as its capability to be used as a key alternative learning tool during COVID-19.

The findings reveal that Quiz Time! has a significant positive relationship with students’ learning outcomes and their engagement in the learning process. Quiz Time! is a mobile application for assessing students’ knowledge through gaming. It provides a pleasant and user-friendly interface, as well as an integrated badge

system. The incorporation of gaming in education makes learning enjoyable, easy to understand and accessible to students. Moreover, gaming activities are a great source of motivation, since they bring fun into learning, by motivating students to reach higher stages in the gameplay. These features are very beneficial at the COVID-19 era, where synchronous distance learning (replacing the traditional one) lasts for hours. As such, MGbL improves student engagement (MGbL → SE), and consequently, both of them help to achieve better academic performance (MGbL → SP, SE → SP).

Another interesting result, emerged from Quiz Time! evaluation, is that there is a positive correlation with collaborative learning. Quiz Time! provides social interaction capability, through which students collaborate as co-players towards the effective completion of a quiz. Gaming activities provide a fertile ground for collaboration between peers. Through them, students can interact effectively with others, share knowledge and develop problem-solving skills. Moreover, their satisfaction and self-esteem are increased. Due to COVID-19 lockdown, the interaction with others is crucial for dealing with loneliness and isolation. Hence, MGbL promotes collaborative learning (MGbL → CL), which also has a positive impact on student performance (CL → SP).

Personalized learning is another important factor that affects both Quiz Time! and students' achievements. This educational practice allows learning and teaching to be tailored to students' needs and preferences. Thus, a learner-centric environment is developed, helping students to accomplish effectively their learning goals. In our case, Quiz Time! incorporates a personalized recommender module for co-players with the aim of effective collaboration. Moreover, it provides tailored advice to learners for ameliorating their knowledge level. This approach is very beneficial for learning during COVID-19 lockdown, since the instructor can be absent. The evaluation results support that the incorporation of personalization into MGbL has a positive impact on the acceptance of this technology by students (PL → MGbL) and that adaptive learning environments affects positively student performance (PL → SP).

Finally, other influential factors are the perceived ease of use and perceived enjoyment. Both factors are crucial for affecting positively students' intention to use a system. Especially, for MGbL applications, there are technical challenges due to the small size of the devices they correspond to, and educational challenges regarding student motivation for learning. Quiz Time! has a user-friendly interface, enabling students to use it without effort. Moreover, it provides multimedia content and a gaming environment, attracting students to learn in an enjoyable way. Hence, students do not feel bored, even though the tutoring session lasts for hours. The findings of this study show that perceived ease of use and perceived enjoyment have a positive impact on student intention to use the MGbL technology (PEoU → MGbL, PE → MGbL).

6 Conclusions

In the light of the COVID-19 pandemic, the field of education had to be transformed and enriched with online technologies for the continuity of learning, due to the closure of educational institutions. In fact, there was a transition from face-to-face to

fully online synchronous instruction. In this new situation, from technological perspective, it is necessary that students have either a smart mobile device or a personal computer. From pedagogical perspective, it is essential to keep a high quality of education and provide environments that engage students in the learning process. To satisfy these requirements, the MGbL technology seems to be the ideal solution, since it requires a smart handheld device that most students have and motivates learners through gaming.

To this direction, this study emphasizes the MGbL technology and explores its utilization in higher education during COVID-19 lockdown. The findings reveal that MGbL is an ideal educational practice toward COVID-19 outbreak, increasing student engagement in learning process and improving academic outcomes. Moreover, personalized and collaborative learning further support the effectiveness of the MGbL technology. The results also show that perceive ease of use and perceive enjoyment affect positively the intention to use MGbL, since students can use it without effort and be motivated by the gameplay.

Limitations of this work include that it focuses on tertiary education students as well as it assessed the utilization of MGbL but not compared to other approaches, such as Learning Management Systems (LMSs), educational social networks etc. This research serves for recommending instructors to enrich the tutoring process by using alternative innovative approaches with strong pedagogical potential as well as learners to be acquainted with novel technological tools and achieve their learning objectives.

As future work, we intend to analyze new data of continuous flow due to the ongoing lockdown and how student attitude toward MGbL technology is affected. Also, we seek to analyze and interpret the individual survey questions. Our future plans also include the utilization of MGbL in other domains during the pandemic. Another interesting area for future investigation is the comparison of MGbL with other online educational practices, such as LMSs, using the newly acquired data.

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