JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

THE EFFECT OF USERS' BEHAVIORAL INTENTION ON GAMIFICATION AUGMENTED REALITY IN STEM (GAR-STEM) EDUCATION

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Abstract. *As people attach increasing importance to the learning environment and design of teaching materials in STEM, how to design teaching materials that enable students to seamlessly integrate the learning of scientific investigation, engineering design, mathematical reasoning, and technical skills has become increasingly important. The purpose of this research was to explore the behavioral intention of GAR-STEM teaching application users. The results showed that the best predictor of practicability, entertainment, and media interactivity for intention towards GAR-STEM app design was usage attitude (R^2= 0.547), followed by intent to use (R^2 = 0.528), practicability (R^2 = 0.408), and entertainment (R^2 = 0.186). The proposed model explained 52.8 % of the variance in behavioral intention. The overall findings suggested that usage attitude and intent to use may augment its function as a key factor for the procedural intention toward GAR-STEM app design.*
Keywords: *augmented reality, gamification apps, importance-performance matrix analysis, STEM education.*

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Introduction

With the rapid development of digital media in recent years, many textbooks have been equipped with the features of entertainment-oriented media. The gamification design idea has been integrated with new scientific technologies to facilitate teaching. In this way, the application of games in digital learning has been increased and the creative application of learning materials has been restarted. In particular, the application of augmented reality gamification in STEM education has been reinforced with each passing day. As a combination of science (S), technology (T), engineering (E), and mathematics (M), STEM covers the experiences in daily life and applications in the workplace. All these subjects (STEM) are interlinked and connected with the complicated problems facing individuals every day (Talley, 2016). The integrated knowledge education of STEM offers better solutions to tackle the challenges in daily life and in the workplace (Webb, 2013). Therefore, it is necessary for students in grades K-12 and college students to understand the concepts of STEM and develop the ability to integrate and apply these subjects so that they will have more chances to put STEM knowledge into practice (Bybee, 2013; English, 2017). Science, technology, engineering, and mathematics are mutually independent, and the core concepts of each subject provide a solid foundation for further studies. As people pay increasing attention to the application of STEM in K-12 and college education, interdisciplinary integration can help students gain a better understanding of subject concepts and transfer knowledge from one subject to another (Bell, 2016). According to the results of relevant studies, the combination of creative and advanced technologies and teaching can enhance the STEM learning participation of learners and improve their learning attitude towards STEM. Moreover, a simulated learning environment can strengthen the cognition and motivation of learning and make learning more effective (Kim et al., 2015; Stull, Fiorella, Gainer, & Mayer, 2018). The integration of simulated STEM learning environments is very important. Therefore, how to help students understand scientific concepts and solve interdisciplinary problems through creatively-simulated and seamless experience-based learning environments is an essential topic and one of the challenges facing education researchers (Katehi, Pearson, & Feder, 2009).

https://doi.org/10.33225/jbse/19.18.450

Augmented reality (AR) is an information and communication technology with scientific applications and has become a hot issue in scientific and education studies (Akçayır & Akçayır, 2017). With the help of scientific technologies, AR incorporates virtual 2D or 3D computer simulations into a real environment (Lee, 2012). Since its introduction, the technology has been widely applied in education. For instance, it has been used in the teaching of the tissues and organs inside the human body and that of earth science. The knowledge of different subjects has been incorporated into AR recognition labels on textbooks. The scanning of these labels leads to the display of 3D objects. Moreover, AR has been utilized to explore the models and performance of learning behavior, and it has been shown that AR has the potential of being applied to teaching (Azuma et al., 2001; Lee, 2012). AR-supported teaching features sensory organ immersion, simple operation, and a low cost, which together contribute to a greater learning effect (Cheng & Tsai, 2013). Relevant researches showed that the application of AR to science, technology, engineering, and mathematics (STEM) has potential educational value, including spatial understanding, technology application, problem-solving ability, concept understanding, and scientific exploration and learning (Cheng & Tsai, 2013; Wu, Lee, Chang, & Liang, 2013). Especially, AR is most welcomed when it is applied to such fields as the humanities, art, and science (Liu & Tsai, 2013; Martín-Gutiérrez et al., 2010; Squire & Jan, 2007). A previous research found that when AR-supporting teaching was applied in a physics lab for college students, it enhanced the learning efficacy of the students and equipped them with a positive attitude towards their work (Akçayır, Pektas, & Ocak, 2016). Some studies have revealed that AR has many advantages in an educational setting (Cheng & Tsai, 2013). For example, AR helps students with the exploration of the real world (Dede, 2009). By combining virtual elements with real objects, AR enables individuals to observe items that cannot be observed with the naked eye (Wu, Lee, Chang, & Liang, 2013). Hence, it can strengthen students' learning motivation and help them develop a stronger ability to explore things (Sotiriou & Bogner, 2008).

Gamification is defined as the usage of game mechanisms in daily activities. In 2010, there was a new trend of gamification, in which game-based projects and game features were used in ways unrelated to a game (Radoff, 2012; Smith, 2012; Wu, 2012). Gamification refers to game elements being applied to a non-game environment (Deterding, Dixon, Khaled, & Nacke, 2011). Aside from enriching the joyous experience in services and increasing the intention to use, it can create interaction among groups (Hamari & Koivisto, 2015; Huotari & Hamari, 2017; Liu, Santhanam, & Webster, 2017) and promote usability, productivity, and satisfaction (Saha, Manna, & Geetha, 2012; Rajanen & Rajanen, 2017), thus pushing forward publicity and generating a positive effect on performance (Rodrigues, Costa, & Oliveira, 2014). In recent years, gamification has been increasingly applied to various subjects, including education (Simões, Redondo, & Vilas, 2013; Kim, Song, Lockee, & Burton, 2018), environmental and ecological behavior (Prestopnik & Tang, 2015), health and medicine (Fleming et al., 2017), creative business and marketing (Roth, Schneckenberg, & Tsai, 2015), software development and machine learning (Chow & Huang, 2017), politics (Santos et al., 2015), tourism (Saoud & Jung, 2018), and energy popularization and application (Nicholson, 2012). Gamification is designed to adapt enjoyable and interesting game elements to the activities being publicized. Applying these elements to teaching strengthens learning motivation (Su & Cheng, 2015; Su, 2017; Su, 2018). The application of gamification to social activities is a highly pronounced category, especially in social network websites where people share their daily lives. Social games and gamification are also common in other fields, such as measurements of user loyalty, achievement (such as scores, virtual currencies, and levels) and employment (Zichermann, 2011). Therefore, the gamification of education refers to game elements being applied to learning environments, and it is often supported by ICT (information and communication technology).

Relation between Media Interactivity, Entertainment, and Practicability

The Media Richness Theory (Daft & Lengel, 1986) refers to the capability to carry information in media. Since different types of media load various information capabilities, it causes differences in how users select media. Daft, Lengel and Trevino (1987) divided media richness into the concepts of: (1) instant feedback; (2) multiple cues; (3) personal focus; and (4) language variety. Rice (1993) indicated that different types of media present distinct characteristics and result in various communication effects because of different objectives. Dennis and Kinney (1998) mentioned that using computers as the communication media could provide instantaneous feedback, deliver multiple cues, communicate with diverse languages, and focalize individuals. Wang, Hsieh, and Song (2012) pointed out the positive effect of users' perceived media richness on the perceived entertainment. Sullivan (1999) explained that interactivity is the dialogue between information systems and users; in addition to the interaction, information system users can respond to the information and content offered by the information systems in the process.

https://doi.org/10.33225/jbse/19.18.450

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Previous literature (Coyle & Thorson, 2001; Lan & Sie, 2010; Lu et al., 2014; Peltokorpi, 2015; Zhao, Hen, & Wang, 2016) regarded the positive effect of interactivity on the practicability of information systems and the assistance in better consistency between attitude towards use and use behavior. Thus, the following hypotheses were proposed:

H1: Media interactivity presents a positive effect on entertainment.

H2: Media interactivity shows a positive effect on attitude towards use.

H3: Media interactivity reveals a positive effect on practicability.

Relation between Entertainment Attitude and Behavioral Intention

The Theory of Planned Behavior states that behavior is controlled by behavioral intention and that other possible factors might indirectly influence behavior through behavioral intention, which refers to an individual's intention to engage in certain behavior. Behavioral attitude, referring to the perceived positive or negative evaluations of an individual executing certain behavior, is evaluated by behavior belief and results. An individual with a more positive attitude towards a behavior will present higher behavioral intention, and vice versa. Subjective norms refer to an influential or important person's opinions about specific behavior, which are determined by the beliefs and motivation of norms. Ajzen and Fishbein (1977) argued that attitudes and subjective norms are the major factors in behavioral intention. From past research, The Theory of Planned Behavior can be applied to explain different types of behavior. In the process of enjoyment, elements related to imagination, feelings, fun, and symbol meanings often appear in entertainment (Hirschman & Holbrook, 1982), which could be festive or ludic perceptions (Sherry, 1990). The characteristics of entertainment have been applied to research on behavior (Lee, 2009; Maes et al., 2014; Scarpi, 2005; Sherry, 1990; Wu & Chen, 2005) and present subjective and individual contents (Babin, Darden, & Griffin, 1994). From the aspect of using a system, users perceiving the higher "entertainment" of a decision system will show a higher intention of use (Gopal, Bostrom, & Chin, 1992). Accordingly, the following hypotheses were proposed in this research:

H4: Entertainment reveals a positive effect on attitude.

H5: Entertainment presents a positive effect on behavioral intention.

Relation between Practicability, Attitude, and Behavioral Intention

The Technology Acceptance Model proposed by Davis (1989) is an extension of the Theory of Reasoned Action, which aims to predict and understand human behavior. It is considered that individual behavior is determined by behavioral intention, while behavioral intention is possibly affected by personal attitudes and subjective norms. According to Davis' (1989) Technology Acceptance Model, user attitudes towards a system are influenced by perceived ease of use and perceived usefulness, users' behavioral intention is affected by attitude and perceived usefulness, and perceived usefulness affects the perceived ease of use. This model has been broadly applied to various studies on technology acceptance behavior, and the hypotheses in the model have been verified numerous times (Ahn, Ryu, & Han, 2007; Al-Gahtani, 2016; Mohammadi, 2015; Moon & Kim, 2001; Sánchez & Hueros, 2010; Venkatesh & Bala, 2008). The following hypotheses in the Technology Acceptance Model were therefore included in this research:

H6: Practicability presents a positive effect on attitude.

H7: Practicability shows a positive effect on behavioral intention.

H8: Attitude towards use reveals a positive effect on behavioral intention.

Therefore, to fill the gap left by the literature, this research adopted gamification augmented reality (GAR-STEM) and the Media Richness Theory to explore usage behavior. In addition, IPMA was utilized to analyze the features of GAR-STEM design, so as to find out its advantages and limitations. Matters worthy of attention and advice improving the intention to use GAR-STEM in the future were also included. This research proposed the following three research goals:

1) To integrate the explanation power of the GAR-STEM app user intention model;
2) To understand GAR-STEM app user intention;
3) To integrate the analysis strategies of Importance-Performance Map Analysis (IPMA) for the matrix analysis of the importance and performance of GAR-STEM app user intention in order to offer GAR-STEM apps designers with better strategic design thinking.

https://doi.org/10.33225/jbse/19.18.450

Research Methodology

Partial Least Squares (PLS) is a form of component-based Structural Equation Modeling (SEM) that can deal with smaller samples (30-100) and predict non-normal data with more variables, as well as deal with reflective indicators and formative indicators, thus making it suitable for developing theories (Chin & Newsted, 1999; Gefen, Straub, & Boudreau, 2000). Furthermore, PLS can overcome multicollinearity problems, effectively deal with moderating data and missing values, and present favorable prediction and explanation capabilities. PLS was adopted in this research because the retrieved data did not completely conform to a normal distribution and because only 177 samples were retrieved. In addition, the research issue was about theoretical exploration and discovery. As the number of research samples was small, analysis with PLS presented favorable prediction and explanation capabilities. Such a small sample would also not be affected by the number of samples and the distribution of variables. For the stable estimation of variables, 500 iterations of bootstrap resampling has been suggested for testing (Chin, 1998).

Research Structure

The integration of practicability, entertainment, and media interactivity was proposed to construct the measurement model for the intention of using GAR-STEM apps. After establishing the hypotheses, the positive, direct, and significant effect of media interactivity on entertainment, attitude towards usage, and behavioral intention was as shown in Figure 1.

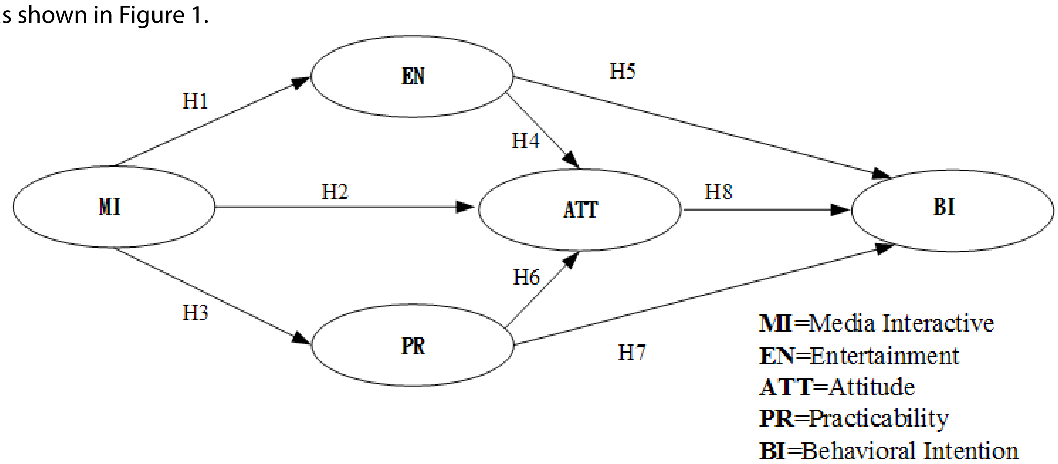

Figure 1. Model of behavioral intention to use GAR-STEM apps.

Operational Definition of Constructs

In order to test the above research hypotheses, a conceptual model was utilized, and the corresponding questions were constructed in this research. According to the conceptual model, the research variables in this research included media interactivity, entertainment, attitude towards use, practicability, and behavioral intention. A structured questionnaire was presented to the participants and was scored using a Likert 7-point scale (with answers ranging from extremely disagree to extremely agree) to collect relevant data. The results were processed and analyzed using SPSS, and PLS was utilized to analyze the research model. The five latent variables in this research were reflective indicators used for analyzing the relevance between variables and indicators. The definitions and measurement of the variables, including the five dimensions of media interactivity, entertainment, practicability, attitude towards use, and behavioral intention, as well as 16 questions, are listed in Table 1.

https://doi.org/10.33225/jbse/19.18.450

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 1. Operational definitions of constructs.

Variable	Operational definition	Questionnaire item	Reference
Media interactivity	Interactivity between app users and the app in the usage process (MI)	The visual design of the app is attractive. Overall speaking, the design of the app's user interface is favorable. Good interactivity with other users on the app. Being able to establish friendships with other users through the app.	(Coyle & Thorson, 2001)
Entertainment	Perceived entertainment of app users about the functions offered by the app (EN)	The app offers several funny and interesting functions. I am pleased at using the app's functions. I perceive fun in using the app.	(Csikszentmihalyi, 1975; Moon & Kim, 2001)
Practicability	App users' perception of the information or services offered by the app (PR)	The app offers the contents I desire. Overall speaking, the app is useful. The operation of the app is simple. The operation of the app is clear and understandable.	(Chen, Clifford, & Wells, 2002; Chen & Wells, 1999; Ducoffe, 1996)
Attitude towards use	App users' perceived preference for the app (ATT)	Overall speaking, I like to use the app. I have a positive evaluation about the app.	(Davis, 1989)
Behavioral intention	App users' evaluation of the intention and possibility to continuously use the app (BI)	I will continuously use the app. I will still choose to use the app even though there are other similar ones. I will recommend the app to others.	(Davis, 1989)

Sample and Scale Analysis

(1) Formal questionnaire respondents

In the formal test, in consideration of the impact of regional disparities, a two-step sampling method was applied in this research, namely, the stratified cluster sampling method and quota sampling. In step 1, the stratified cluster sampling method was applied based on school size in consideration of regional disparities, and four schools were selected as samples. In step 2, quota sampling was applied, and 186 samples were selected from the sample schools by considering different sampling percentages for different grades and dispatch questionnaires were dispatched. A total of 177 valid questionnaires were recovered, resulting in an availability of 95.1%. As the late responses could be similar to those who did not respond, the early response (n = 106) and late response (n = 71) samples were tested for nonresponse bias (Armstrong & Overton, 1977). All measured variables and control variables of the two groups of samples were compared with a t-test to judge the possible bias of the late responses. The result showed no significant difference in the responses between the first and the second stage, revealing insignificant nonresponse bias in this research.

(2) Test of Common Method Variance

Common Method Variance (CMV) refers to the man-made covariant relevance between independent variables and dependent variables resulted from using the same data sources, participants, measuring environments, scale semantics, and scale characteristics. CMV can be used to test if a single factor is able to explain more than 50% of the variance of all variables in the initial solution during factor analysis (Podsakoff, 2003). For this reason, Harman's One-Factor Test was applied to test for CMV among the research variables in this research and factor analysis was used to analyze the factors extracted from the initial solution in order to test for Common Method Variance. A total of nine factors with eigenvalues larger than 1 were extracted using confirmatory factor analysis. The explained variance of the first factor was 24.25% (maximum), which was less than 50%, and the accumulated explained variance of the nine factors was 83.22%. Accordingly, there was no obvious common source bias in this research (Saraf, Langdon, & Gosain, 2007).

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Research Results

In this section, the research results are presented in three stages. The reliability and validity of the measurement model were analyzed during the first stage, the path coefficient test of the structural model and the estimation of the model prediction indicator were analyzed during the second stage, and the Importance-Performance Matrix Analysis (IPMA) of the structural model was performed during the third stage. The detailed steps and explanations are described in the following sections.

Reliability and Validity Analysis of the Measurement Model

According to Fornell and Larcker's (1981) principles of convergent validity, the test of convergent validity of the designed questions needed to satisfy the following conditions. First, the factor loading (λ) should be significant and higher than 0.5 (Chin, 1998). Second, the composite reliability (CR) should be larger than 0.6 (Chin, 1998). Third, the discriminant validity-average variance extracted (AVE) should be larger than 0.5 (Chin, 1998) and the cross-loading matrix (Chin, 1998). The reliability analysis of the dimensions in this research was organized as shown in Table 2. The factor loadings showed a significance of p=.001 and all questions were higher than 0.5, the composite reliability was 0.80-0.96 and larger than 0.8, and the average variance extracted was between 0.67 and 0.85 and above 0.5, thus satisfying the above conditions. The measurement model showed that the factor loadings of all questions were 0.75-0.96 and the p value reached the significance level of 0.05, thus indicating convergent validity (Chin, 1998). The estimation of discriminant validity was tested from two directions (Henseler, Ringle, & Sinkovics, 2009). One was the cross-loading matrix, which indicated that the individual question loadings of the variables in this research were higher than the loadings of other variables (Fornell & Larcker, 1981). The other was the Fornell–Larcker criterion; that is, the AVE of each variable needed to be larger than the square of the correlation coefficient between paired variables to show the discriminant validity of the research variables (Fornell & Larcker, 1981; Segars & Grover, 1998). Table 2 presents the average variance extracted square roots of all variables, which were larger than the correlation value between variables. Table 3 shows that the individual question loadings of the variables were higher than those of other variables. Accordingly, the variables in this research had acceptable reliability and validity.

Table 2. Reliability and validity analysis.

	Mean	SD	Factor loading	CR	Cronbach's α	AVE	BI	EN	ATT	PR	MI
BI	5.21	1.1	0.92	0.96	0.94	0.85	0.92				
EN	4.83	1.3	0.87	0.94	0.92	0.75	0.61	0.87			
ATT	4.61	1.2	0.73	0.80	0.79	0.69	0.63	0.54	0.83		
PR	4.93	1.1	0.75	0.81	0.70	0.73	0.54	0.36	0.65	0.85	
MI	4.74	1.4	0.87	0.86	0.77	0.67	0.48	0.43	0.64	0.64	0.82

Note: SD= Standard deviation; CR= Composite reliability

Table 3. Factor loading analysis of the variables.

	BI	EN	ATT	PR	MI
BI 1	0.95	0.56	0.56	0.50	0.43
BI 2	0.95	0.60	0.60	0.51	0.43
BI 3	0.91	0.59	0.57	0.53	0.46
ATT1	0.45	0.51	0.76	0.43	0.43
ATT2	0.50	0.49	0.80	0.37	0.38
EN2	0.50	0.92	0.50	0.24	0.41

https://doi.org/10.33225/jbse/19.18.450

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

	BI	EN	ATT	PR	MI
EN3	0.44	0.89	0.42	0.30	0.32
EN4	0.68	0.87	0.51	0.44	0.45
PR1	0.23	-0.01	0.38	0.69	0.22
PR2	0.23	0.09	0.26	0.70	0.14
PR3	0.44	0.32	0.45	0.76	0.62
PR4	0.43	0.37	0.53	0.71	0.49
MI1	0.26	0.14	0.35	0.37	0.75
MI2	0.53	0.53	0.63	0.70	0.86
MI3	0.30	0.27	0.51	0.39	0.84
MI4	0.33	0.29	0.58	0.51	0.86

Path Coefficient Test of the Structural Model and Prediction Indicator Estimation Model

PLS was used in this research to analyze the structural model for the correlation strength and direction between research variables. If significance appeared after the test, the hypotheses would be supported as expected. PLS can be used to analyze and explain the percentage of the variance of exogenous variables to endogenous variables and to test the prediction capability of a research model. The structural model was evaluated based on six steps proposed by researchers, including: Step 1 - evaluating the multicollinearity of the structural model (VIF); Step 2 - setting the significance of the path coefficient as the standard; Step 3 - the test of R^2 and the path coefficient; Step 4 - evaluation of the f^2 effect size; Step 5 - evaluation of the predictive relevance (Q^2); and Step 6 - the goodness-of-fit index (Hair, Ringle, & Sarstedt, 2011; Reinartz, Haenlein, & Henseler, 2009; Rigdon, 2012; Tenenhaus, Amato, & Esposito Vinzi, 2004). First, the variance inflation factor (VIF) was utilized to evaluate the multicollinearity. The result showed the maximal VIF of 1.32 for all variables, which conformed to a VIF between 0.2 and 5 as suggested by Neter and Wasserman (Hair et al., 2011) and indicated there was no multicollinearity problem.

The structural model was further analyzed using PLS to list the variance explained (R^2), standardized path coefficient (β), and t value. R^2 and the path coefficient are the major indicators used to judge a model (Chin, 1998). The analysis of the structural model is shown in Figure 2. A complete analysis of the model was performed in this research. The path coefficient between media interactivity and entertainment was 0.432 (*t*=4.164) and had high significance, thus H_1 was supported. That is, the higher media interactivity with GAR-STEM apps showed the higher entertainment of the apps. The path coefficient between app media interactivity and attitude towards use was 0.284 (*t*=2.961) and had high significance, thus H_2 was partially supported. The stronger media interactivity with GAR-STEM apps showed a higher usage attitude towards using the apps. The path coefficient between app media interactivity and practicability was 0.638 (*t*=9.045) and had high significance, thus H_3 was supported, revealing stronger app media interactivity and higher practicability. The path coefficient between entertainment and attitude towards use was 0.293 (*t*=2.024) and had high significance, thus H_4 was supported, indicating that the higher the entertainment of GAR-STEM apps, the better the attitude towards use. The path coefficient between practicability and usage attitude was 0.360 (*t*=3.374) and had high significance, thus indicating that H_5 was supported. The result also showed a higher practicability of the app and better usage attitude. The path coefficient between entertainment and players' behavioral intention was 0.379 (*t*=2.949) and had high significance, thus H6 was supported. That is, higher entertainment will enhance players' behavioral intention to use GAR-STEM apps. The path coefficient between players' attitude towards use and behavioral intention was 0.275 (*t*=2.459) and had high significance, thus H_7 was supported. In other words, players with a better attitude towards using an app will present higher behavioral intention to use the app. Finally, the path coefficient between the practicability of an app and players' behavioral intention was 0.228 (*t*=1.692) and had high significance, thus H_8 was supported, indicating the higher the practicability of an app, the higher the behavioral intention of the players.

https://doi.org/10.33225/jbse/19.18.450

Generally speaking, the R^2 of the endogenous construct in a model can be evaluated as the overall goodness-of-fit in PLS (Hulland & Business, 1999). As shown in Figure 2, the R^2 of the four endogenous constructs were 0.186 for entertainment, 0.574 for attitude toward use, 0.408 for practicability, and 0.528 for behavioral intention. Attitude toward use and behavioral intention showed a high R^2, representing a favorable explanation among behavioral intention, the four antecedents, and a small unexplained residual. The result indicated a favorable goodness-of-fit between behavioral intention and the antecedents. The R^2 of entertainment was slightly lower, possibly because the practicability and usefulness of an app are emphasized in GAR-STEM apps. Entertainment, therefore, is not a major component of GAR-STEM apps. In sum, the four endogenous constructs showed a favorable explanation, revealing a good explanation of the research model and conformity to the principles suggested by Cohen (1988).

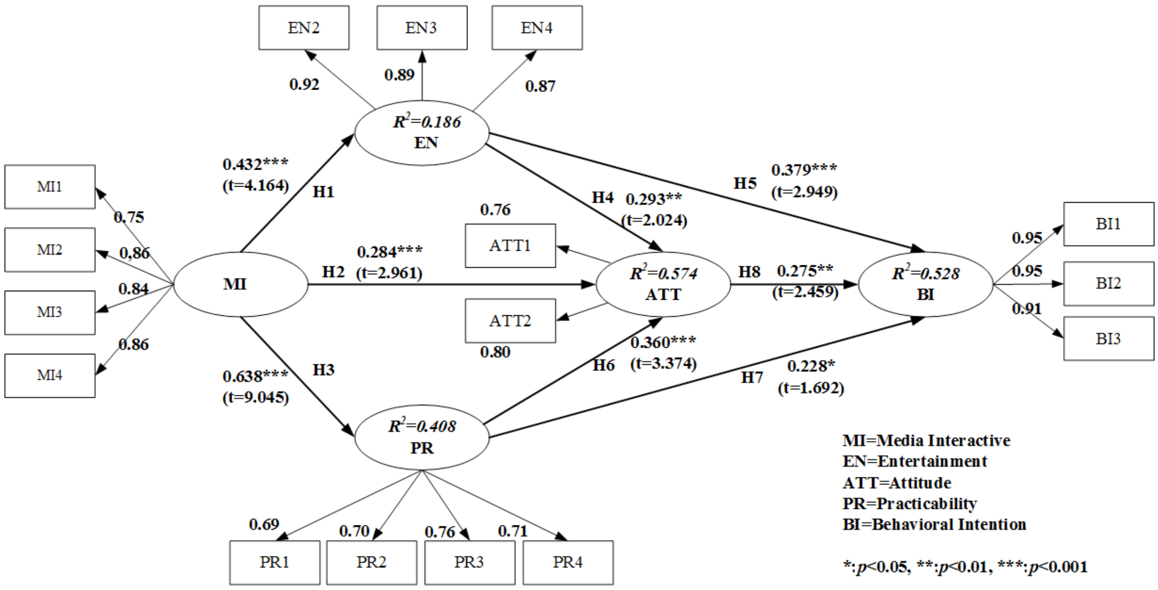

Figure 2. Path coefficient of intention to use GAR-STEM apps.

In addition to evaluating the predictive power of the model, the f^2 effect size of the structural model was another important evaluation indicator. In addition to evaluating the R^2 of all endogenous constructs by deleting the R^2 change caused by specific exogenous variables in the model, the f^2 effect size can be used to evaluate the effects of the deleted variables on the endogenous variables. Such a measurement is called the f^2 effect size. The equation is:

$$f^2 = \frac{R^2_{\text{included}} - R^2_{\text{excluded}}}{1 - R^2_{\text{included}}} \quad (1)$$

f^2 is generally evaluated by having the values of 0.02, 0.15, and 0.35 represent the small, medium, and large effect of the exogenous latent variables (Cohen, 1988). Table 4 shows the average of the f^2 effect size larger than 0.15 (the medium effect). In addition to R^2, researchers should test Stone-Geisser's Q^2 value, which is an indicator of a model's predictive relevance, to evaluate the prediction accuracy of the correlation Q^2 (Geisser, 1974; Stone, 1974). In regard to Q^2 in the structural model shown in Table 4, the Q^2 value of the endogenous latent constructs larger than 0 revealed the predictive relevance between the path model and constructs. Tenenhaus et al. (2004) and Tenenhaus et al. (2005) proposed the overall goodness-of-fit index (GoF) for PLS as "the possible program to verify the overall model of PLS" (Tenenhaus et al., 2004). Wetzels et al. (2009) suggested using the communality value of 0.50 (Fornell & Larcker, 1981) and the R^2 value (Cohen, 1988) to evaluate the goodness-of-fit of the PLS structural model as GoF_{small} (0.10), GoF_{medium} (0.25), and GoF_{large} (0.36). Table 4 shows that the GoF of 0.56 in this research was larger than 0.36, thus presenting an excellent goodness-of-fit of the structural model. The model predictive

https://doi.org/10.33225/jbse/19.18.450

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

indicators proposed by relative researchers and the goodness-of-fit organized in this research could be used as a reference (Table 5) for successive researchers, including the model predictive indicators and the goodness-of-fit checklist (Yang & Su, 2017).

Table 4. Analysis of Model criterion and IPMA.

	EN			PR			ATT			BI		IPMA		Model fit indicator			
	(D)	(I)	(T)	(D)	(I)	(T)	(D)	(I)	(T)	(D)	(I)	(T)	Performance	R^2	f^2	Q^2	*GoF*
MI	0.43		0.43	0.64	-	0.64	0.28	0.35	0.63	-	0.65	0.65	56.12	-	-	-	
EN	-	-	-	-	-	-	0.29	-	-	0.38	0.08	0.46	61.86	0.186	-	0.13	
PR	-	-	-	-	-	-	0.36	-	-	0.23	0.1	0.33	57.09	0.408	-	0.18	0.56
ATT	-	-	-	-	-	-	-	-	-	-	-	0.28	60.55	0.574	0.19	0.26	
BI	-	-	-	-	-	-	-	-	-	-	-	-	-	0.528	0.21	0.43	

Note: MI=Media interactive; EN=entertainment; ATT=Attitude; PR=Practicability; BI=Behavioral Intention

Table 5. Model predictive indicators and goodness-of-fit checklist.

Model evaluation	Criterion	Suggestion value	Model value	Result
Reliability and Validity & Measurement Model	Cronbach's alpha (CA)	Values must not be lower than 0.600	CA >0.80	Good
	Composite reliability (CR)	Values must not be lower than 0.600.	CR >0.80	Good
	Indicator loadings	Values should be significant at the .050 level and higher than 0.70	>0.70	Good
	Internal consistency reliability	Values must higher than 0.70 Composite Reliability (CR)>=0.70	CR >0.80	Good
	Convergent validity	Values must higher than 0.50 Average Variance Extracted (AVE) >= 0.500	>0.5	Good
	Cross-loadings	Factor Loading should higher than Cross Loading	Higher	Good
	Fornell-Larcker criterion	the square root of the AVE of each construct should be higher than the construct's highest correlation	Higher	Good
	Multicollinearity	0.2<VIF< 5	1.32	Good
Path Coefficient & Estimation Model	R^2	0.670 (High), 0.333(medium), 0.190(weak).	0.528	Good
	Path coefficients	p value <0.05	<0.05	Good
Model fit indicator & Prediction Indicator	Effect size f^2	0.02~0.15 (weak), 0.15~0.35 (medium), Value higher than 0.35(strong)	0.19 0.21	Medium
	Predictive relevance Q^2	Use blindfolding, Q2 >0 indicate a predictive relevance.	0.13	Relevance
	Goodness-of-Fit Index (GoF)	0.1(small), 0.25(medium), 0.36(large)	0.56	Good

https://doi.org/10.33225/jbse/19.18.450

Result of Importance-Performance Matrix Analysis (IPMA)

Importance-performance matrix analysis (IPMA) helps to gain additional insights by utilizing the extension of the PLS-SEM results and provides additional dimensions (Hock et al., 2010; Kristensen et al., 2000; Slack, 1994; Völckner et al., 2010, Su & Cheng, 2019). The analysis is established based on the estimation of the PLS-SEM path relevance and by adding the dimension of the latent variable mean value. For the endogenous variables of the specific target, IPMA compares the total effect (importance) of the structural model with the mean value of the latent variable fraction (performance) to decide the priority of management (or the specific focus in the model). More specifically, the result could point out the factors of ***high importance*** and relatively ***worse performance*** in the model for the improvement of successive key design elements and management (Hock et al., 2010; Rigdon, Ringle, & Sarstedt, 2010).

The calculation of importance in IPMA in this research required the total effect of all other constructs (i.e. media interactivity, entertainment, attitude towards use, and practicability) on the intention of using the target construct (in Figure 2) for judging the importance. The total effect between two constructs was the sum of all direct and indirect effects in the structural model and could be represented as total effect=direct effect + indirect effect.

The construct performance was calculated with:

$$Y_{ij} = \frac{(E[x_{ji}] - \min\ [x_j])}{(\max\ [x_j] - \min\ [x_j])} \cdot 100 \qquad (2)$$

where Y_{ij} stands for the i-th number (e.g. i=5 represents the latent variable fraction of the fifth observed value in the database) of the j-th latent variable (e.g. j=2 represents the second latent variable in the structural model) (Anderson & Fornell, 2000; Hock et al., 2010). The IPMA in Table 4 was plotted to show the correlation between the importance and performance distribution of the intention to use GAR-STEM apps shown in Figure 3. Furthermore, the management meaning could be explained with the acquired regional quadrant.

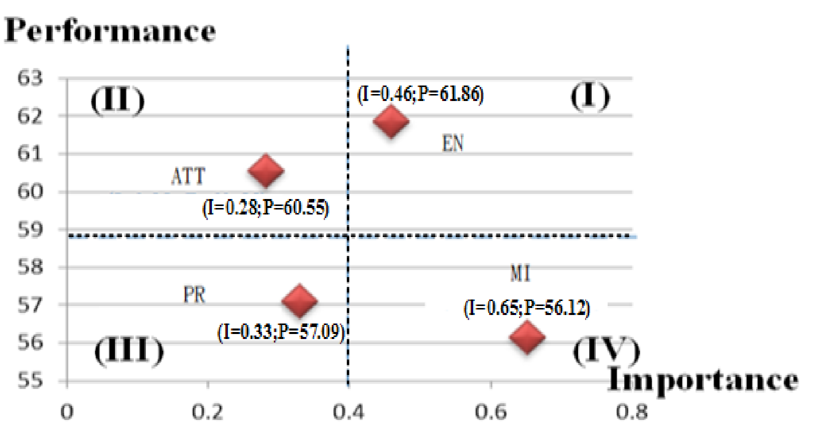

Figure 3. Importance and performance distribution of the intention to use GAR-STEM apps.

Quadrant I showed high importance and high performance and represented the "keep up the good work" zone, revealing that players place more stress on entertainment with high satisfaction. In this case, designers must maintain the original advantage and enhance the entertainment of digital cultural and creative games. This zone therefore was the core competitiveness in the design. Quadrant II showed low importance but high performance and represented the possible overkill zone, showing that players do not focus much on attitude towards use but present high satisfaction. Design resources could be adjusted and transferred to other variables with higher importance to reduce the cost. Quadrant III showed low importance and low performance and represented the low priority zone, revealing that app users do not place high emphasis or satisfaction on practicability. Designers therefore do not need to spend too much time on such items. Quadrant IV showed high importance but low performance and represented the "concentrate here" zone, presenting the high emphasis but low satisfaction of GAR-STEM app users

https://doi.org/10.33225/jbse/19.18.450

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

on media interactivity. In this case, designers should consider improvements and adopt relative design strategies and thinking to promote design standards for app media interactivity. Figure 3 reveals that media interactivity was located in Quadrant IV (the "concentrate here" zone), with high importance but low performance. In other words, the interface and user experience design need to be processed and improved, and further design strategies need to be adopted to enhance players' satisfaction with the media interactivity and encourage players to use the app through a favorable interactive interface design.

The research results revealed that the eight hypotheses were supported and that the path coefficient of each hypothesis had high significance (Table 6). After verifying the hypotheses with relevant research, the conclusion and suggestions were proposed as follows.

Table 6. Hypothesis test result.

H	Path	Description	Path Coefficient	*t*-Value	Results
H_1	MI->EN	Media interactivity presents a positive effect on entertainment.	0.43	4.164***	Supported
H_2	MI-> ATT	Media interactivity shows a positive effect on attitude towards use.	0.28	2.961***	Supported
H_3	MI-> PR	Media interactivity reveals a positive effect on practicability.	0.64	9.045***	Supported
H_4	EN-> ATT	Entertainment reveals a positive effect on attitude.	0.29	2.024**	Supported
H_5	EN-> BI	Entertainment presents a positive effect on behavioral intention.	0.38	2.949***	Supported
H_6	PR-> ATT	Practicability presents a positive effect on attitude.	0.36	3.374***	Supported
H_7	PR-> BI	Practicability shows a positive effect on behavioral intention.	0.28	2.459**	Supported
H_8	ATT-> BI	Attitude towards use reveals a positive effect on behavioral intention.	0.23	1.692*	Supported

Discussion

Higher Media Interactivity, Expectation of Entertainment, Attitude towards Use, and Practicability

The results of this research reflected the research viewpoint of Wang, Hsieh, and Song (2012), who indicated that users' perceived media richness of information systems will positively affect the perceived entertainment. Sullivan (1999) pointed out interactivity as the dialogue between information systems and users. In addition to the interaction, information system users can respond to the information and content offered by information systems in the process. Coyle & Thorson (2001) regarded the positive effect of interactivity on the practicability of information systems and the assistance in forming consistency between better attitudes towards information systems and use behavior. This result was also consistent with the studies of Wang, Hsieh, and Song (2012), Sullivan (1999), and Coyle and Thorson (2001).

Higher Entertainment, Expectation of Attitude towards Use, and Behavioral Intention

The results reflected the research viewpoint of Hirschman & Holbrook (1982), who pointed out high values for entertainment, expectation of attitude towards use, and behavioral intention. Ajzen & Fishbein (1975) claimed that attitude and subjective norms are the primary factors in behavioral intention. Elements related to imagination, feeling, fun, and symbolic meanings (Hirschman & Holbrook, 1982) or festive and ludic perception (Sherry, 1990) often appear with hedonic sensations in the pleasure process. The characteristics of entertainment have often been applied in research on behavior (Scarpi, 2005; Sherry, 1990) and used to present subjective and personal contents ((Babin, Darden, & Griffin, 1994). From the aspect of system use, users perceiving the higher hedonic sensation of information systems will reveal higher intention of adoption (Gopal, Bostrom, & Chin, 1992). Such a result was also consistent with the research of Scarpi (2005), Sherry (1990), and Gopal, Bostrom, and Chin (1992).

https://doi.org/10.33225/jbse/19.18.450

Higher Practicability, Expectation of Attitude towards Use, and Behavioral Intention

Davis (1989) indicated that better system practicability will enhance the expectation of attitude towards use and behavioral intention. Meanwhile, Davis (1989) proposed that individual behavioral performance in the Technology Acceptance Model is determined by behavioral intention, which can be affected by personal attitudes and subjective norms. According to Davis' Technology Acceptance Model, user attitude towards systems is influenced by perceived ease of use and that perceived usefulness and users' behavioral intention is affected by attitude and perceived usefulness, which also affects perceived ease of use (Davis, 1989). Such a model has been broadly applied to various studies on technology acceptance behavior, and the hypotheses in the model have been verified several times (Ahn et al., 2007; Moon & Kim, 2001; Venkatesh & Bala, 2008). As a result, the research result was consistent with Davis (1989), who indicated that system use is decided by behavioral intention, that behavioral intention is determined by attitude toward use and perceived usefulness, and that attitude toward use is decided by perceived usefulness and perceived ease of use.

Higher Attitude towards Use results in Higher Expectation of Behavioral Intention

The research result was consistent with the findings of Davis (1989), who mentioned that good attitude towards use will result in high behavioral intention. The Technology Acceptance Model was extended from Theory of Reasoned Action, which aims to predict and understand human behavior. It is considered that an individual's behavior is determined by behavioral intention, while behavioral intention might be influenced by personal attitudes and subjective norms. According to Davis' (1989) Technology Acceptance Model, user attitudes towards systems will be affected by perceived ease of use and perceived usefulness, users' behavioral intention will be influenced by attitude and perceived usefulness, and perceived usefulness will affect perceived ease of use. Such a model has been broadly applied to research on technology acceptance behavior and the hypotheses in the model have been verified numerous times (Ahn et al., 2007; Moon & Kim, 2001; Venkatesh & Bala, 2008). The results were consistent with the research of Davis (1989), Venkatesh & Bala (2008), and Moon & Kim (2001).

Importance-Performance Analysis (IPMA)

With IPMA, designers can realize the situations of players in the improvement of dimensions and coping strategies. Improvement would be required when a factor of the intention to use GAR-STEM apps was emphasized but presented low performance. On the contrary, when the importance of a dimension was low but showed high performance, it might be overemphasized, and the invested resources could be reduced. Nonetheless, it would be meaningless to focus on intention of use with low importance and consider the total effect of the path coefficient of the structural model, as some the high-importance intention of use items presented good performance. Through IPMA, it was found that players highly stress the media interactivity of GAR-STEM apps but do not show high satisfaction. The analysis value of media interactivity appeared in Quadrant IV, revealing high importance but low performance (the "concentrate here" zone), indicating that players highly emphasize the media interactivity interface and user experience design of GAR-STEM apps but are not highly satisfied. In this case, designers should take improvement into account and adopt relative design strategies and thinking to promote design standards for app media interactivity, such as the experience design of the user interface and players' experience design, to allow players to invest in the situation through favorable interface design.

Conclusions

The model proposed in this research could predict the behavioral intention in the application of GAR-STEM. In addition, the overall model evaluation scale had good research adaptability. The design of useful STEM teaching materials could be used to present and explain concepts in an effective manner and design appropriate teaching activities so as to enable all students to understand the contents they have learned. Good STEM teaching material design should cover different teaching objectives for different grades, and furthermore should note the understanding level of students on the subject and various teaching strategies and presentation methods in teaching. Therefore, this research put forth the following academic and practical implications:

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Academic and Practical Meaning

(1) Academic implications: Research on cultural and creative issues is increasing. The prediction model for the behavioral intention of GAR-STEM apps proposed in this research presents innovation and offers a reference for successful app design. From the viewpoint of the behavioral intention to use GAR-STEM apps, app designs with media interactivity, entertainment, and practicability are the key factors in players' attitude and intention of use. The research results therefore could be referenced in regard to GAR-STEM app design and behavioral intention theory.
(2) Practical implications: In respect of the teaching knowledge in STEM, teachers should be able to organize and understand learning contents and present them to students by effective interaction means. Techniques in presentation include the application of the most persuasive statements, examples, simulations, explanations, and demonstrations using teaching aids to present teaching materials in a way that is acceptable to students. In addition, teaching material design through multimedia scenarios could contribute to understanding difficult subjects, particularly science, technology, engineering and mathematics. However, teachers should also understand which subjects students are interested in, their difficulties in learning, and how to further transfer the contents in teaching materials into effective teaching, and they should be able to adjust teaching methods for students with different abilities and backgrounds (for example, how to design the experience design and user experience design in relation to the media interactive user interface of GAR-STEM). It is important to take the entertainment aspect into account. From the perspective of system application, the higher the "entertainment" of an information system a user experiences, the stronger the adoption intention will be.

Research Restrictions and Suggestions for Successive Research

This research merely utilized scales from the literature for the measurement to understand the inadequacy of the theoretical dimensions, and qualitative research based on expert interviews was not taken into consideration. Meanwhile, the representativeness of the samples was a major restriction in the quantitative research. The factors of the behavioral intention of GAR-STEM apps therefore were major concerns. Possible research directions are listed below.

(1) Practical research

In addition to referring to the literatures, qualitative expert interviews can be included to discuss the key factors in the behavioral intention to use GAR-STEM apps so as to reinforce the model prediction.

(2) Extension of the research model

Theoretical points of view were adopted in this research; however, only subjective behavioral intention and inferences were discussed. Regarding the factors of the behavioral intention to use GAR-STEM apps, it is suggested to include expert interviews to make up for the inadequacy of the quantitative research. It is also suggested to extend the research model by adding learning style and involvement as moderators in order to observe the moderation effect of involvement on intention of use. In this case, limited resources could be invested in moderators to achieve maximal efficiency.

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Received: *February 28, 2019*   Accepted: *May 26, 2019*

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https://doi.org/10.33225/jbse/19.18.450