Avatar design types and user engagement in digital educational games during evaluation phase

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ABSTRACT

Avatar design types can range from human representations to abstract representations. In digital educational games (DEGs), avatars are frequently used to encourage users to play the game. However, the role of avatar design types and their engagement in digital games are still unclear and empirically under research. Therefore, a bespoke digital educational game in geography was developed and validated by six expert users. Then forty-five users participated in the evaluation phase to investigate engagement and avatar types on digital educational games using the user engagement scale (UES). The results reported aesthetics and satisfaction factors somehow influenced the avatar design types, but none of the UES subscales was influenced by preferred avatar design types. Moreover, the human-cartoon avatar, which was not entirely human and cartoonish, was the most popular avatar design type among young adults. Other issues discussed for future developers and research included incorporating more avatar design selections into the study, integrating social interaction features into the game, using the same drawing style for avatars and provide easy access to the bespoke game during data collection.

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1. INTRODUCTION

Digital educational games are often used as a tool to assist in teaching, learning and training. Although digital games motivate users to learn and encourage imagination, avatars in a game can assist players to engage more within the game atmosphere [1]. Furthermore, avatars' design types can range from human to abstract representations depending on one's preferences and age [2]. Nevertheless, the role of avatar design types and their engagement in digital games are still unclear and empirically under research. Therefore, this study aims to develop a bespoke digital educational game to investigate the relationship of avatars design type on user engagement. The contribution of this study is threefold; first, analyze the user engagement scale (UES) subscales on the bespoke digital educational game. Second, to identify the relationship of avatar design types and user engagement subscales on the bespoke digital educational game. Third, to investigate the most prominent avatar design types among this group of users.

An avatar is a humanoid character that acts as a virtual representation of a user [2], [3]. An avatar is designed with human characteristics such as verbal features, expressions, gestures, and postures. This user's representation could function in different ways depending on the design purpose of the avatar in the environment (game or virtual spaces) [4]. The different functions of avatar designs are to differentiate the roles of avatars and how they can have a motivating effect on players in game environments. Among the avatar design roles are as an identification of users-personal identification on profile and customizable, and as in-game character-representation of users or non-player characters [4]. For that, the avatar representation can take the form of a human representative, an icon, a cartoon character, an animal, or a combination of these forms in a digital game [5], [6] or augmented reality applications [7], [8]. Kao and Harrell [9] investigated three types of game avatars: scientist, athlete and geometric shapes and their role models using the game experience questionnaire (GEQ) and reported that the avatars significantly relate to players' game experience. At the same time, another study by Banks [10] investigated avatars by applying the player-avatar relationship (PAR) and categorized them into four: avatar-as-object, avatar-as-me, avatar-as-symbiote and avatar-as-social other. Tuah *et al.* [11] investigated avatars to foster a more meaningful relationship with individuals and categorized them into five categories: human-like, human-cartoon, mix human-animal like, hybrid and abstract. As a continuation study, this paper applies Tuah *et al.* [11] avatar design types as in-game character representation, to investigate the relationship between avatars and engagement using the UES discussed in later sections.

Digital educational games (DEGs) are now widely used in education [12] and healthcare [13]–[16]. DEGs have been reported to assist learning in many ways; this includes motivating [17], [18], engagement [19], enhancing learning [20], attention [21], [22] and assisting in problem-solving [23], [24]. A study by Opmeer [25] investigated negative emotional engagement in high school geography education and reported that games such as Minecraft sustain learning geography in a classroom environment. Moreover, Pokojski [26] reviewed a number of games in geography and reported that educational games promote fun learning and develop spatial imagination among students. Thus, a bespoke digital educational game in geography was created for the purpose of this study.

Depending on the field of study, there are many different definitions of engagement. According to Exeter [27], student engagement is defined as the amount of materials, energy and time spent on specific activities to improve learning. While Mango [28] defines engagement as the degree to which a student participates in a classroom with the effective instructional design exercise. In this current study which involves digital educational games, engagement refers to the sequence of temporal interactions that lead to completing the assigned tasks in a game [29]. The individual player and the environment are both factors that contribute to the engagement of gameplay.

Engagement is one of the main factors developers consider when developing digital games [30], [31]. Bigdeli and Kaufman [32] reviewed existing studies related to digital games in health for the benefits, flaws and engagement factors and reported that it is essential to focus on these three elements when developing a digital game in health. While a study by Hamari *et al.* [33] investigated the effect of flow and immersion on engagement in game-based learning and found that engagement has a significant positive effect on learning, and that engagement is closely related to game challenge and skilled player. Furthermore, engagement has a positive correlation to avatars or character creations and are known to build deeper connection [34]. These studies demonstrate the importance of engagement in digital games.

Measuring engagement can be implemented via many methods, which are not limited to behavioral metrics (e.g. session duration and mouse clicks), neurophysiological approaches (e.g., facial expression, eye-tracking, and electrocardiography) and self-reporting methods (e.g. questionnaires, observation, and interviews). The UES is a self-reporting approach to measure user engagement and used in many digital domains. O'Brien and Toms [35] introduced the UES, which includes factors related to engagement such as perceived usability, aesthetics, felt involvement, novelty, endurability, and focus attention. Subsequent research by O'Brien and colleagues generalized [36] and refined [37] the use of UES scale in other domains. In this study, the UES scale is applied in the evaluation phase; however, since this study is implemented in a digital education game environment, a revised UES by Wiebe *et al.* [29] was used, which only applied four factors related to engagement in video games environment. The four factors are focused attention, perceived value, aesthetics and satisfaction. Results and analysis of these factors are discussed in the results section.

Heuristics evaluations have been studied and discussed by many researchers in the field of human-computer interaction that involve different users on various platforms such as websites [38], mobile applications [39], [40] virtual reality [41], [42] augmented reality [43] and game development [44]–[46]. A study by Yeratziotis and Zaphiris [47] developed the heuristic evaluation for deaf web user experience (HE4DWUX) heuristics evaluation for deaf web users and reported that the heuristics could distinguish significant design elements for deaf users and provide a good web experience. While Othman and his colleagues [48], compared two sets of heuristics in identifying usability heuristics on a mobile learning application on museum users and reported that the SMART heuristics are more relevant and provide better user experiences. In this study, the heuristic evaluation that expert users applied during the design and development phase was based on Korhonen and Koivisto [49], and Barbosa *et al.* [50], which focused on usability and playability in digital games. Usability and playability components are the most prominent component when assessing heuristics for digital games [51].

2. RESEARCH METHOD

The entire study comprises four stages: the initial, design, development, and evaluation phase, as demonstrated in Figure 1. The initial phase includes activities such as literature review and identifying user requirements. A game flow diagram Figure 2 and low-fidelity (lo-fi) game design was drawn and assessed by six experts in the design phase. Two of the experts specialized in digital game developments, and four others were professionals in human-computer interaction. In the development phase, a high-fidelity (hi-fi) game was developed and assessed by the same experts using the heuristics evaluation (HE) from Barbosa *et al.* [50]. Feedback and comments are discussed in the results section and were taken into account to improve the game application used in the evaluation phase.

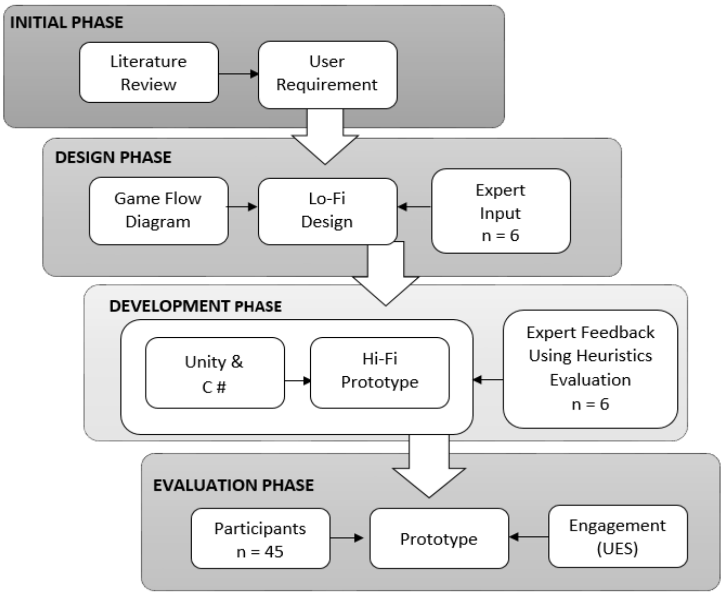

Figure 1. Conceptual design of entire study

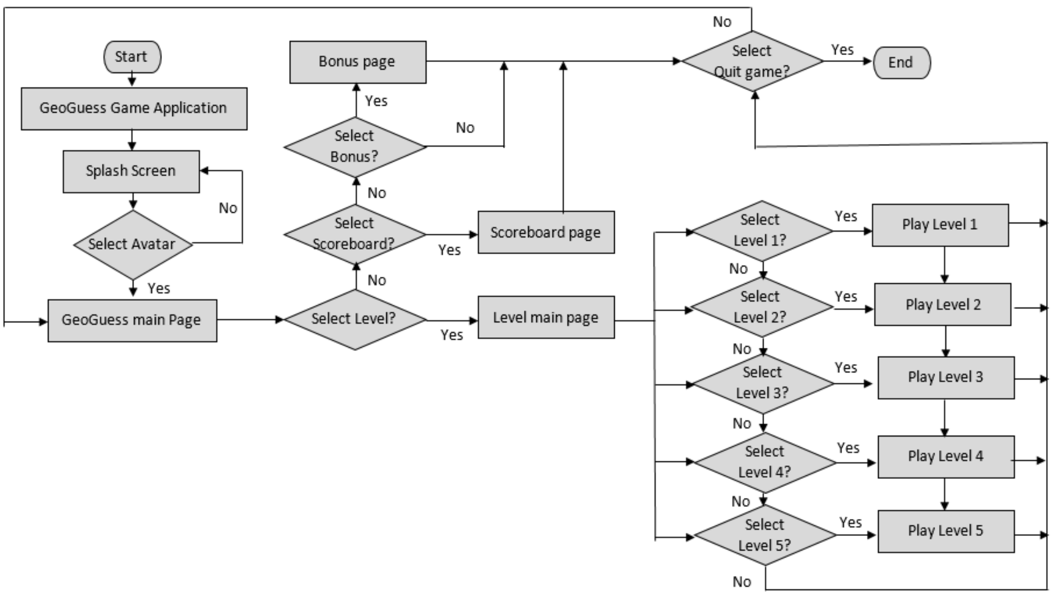

Figure 2. *GeoGuess* game flow diagram

In the evaluation phase, forty-five students aged between 18 to 26 years old participated in the experiment that applied the UES by Wiebe [29] in the questionnaire. The UES subscales were rated using the Likert scale 1 (strongly disagree) to 5 (strongly agree). Participants were asked to play the *GeoGuess* game by downloading the *.exe* file into their personal computers or workstation. After completing the game, participants were then required to answer the online questionnaire provided. Approvals and consent from participants were obtained before they answered the questions online. No pictures or videos of participants were taken for the use of this study, and all participants' identities were anonymous until the end. The outcomes from this evaluation are discussed in the results and analysis section.

For this study, the bespoke digital educational game named *GeoGuess*, was developed by using Unity, a game development platform software. The game design was built based on the Shi and Shih [52] game-based learning design model. Figure 2 illustrates the game flow diagram of the entire *GeoGuess* game. The game flow diagram allows the developer to understand how the game works. Basically, the *GeoGuess* is a game application that encourages users to learn about geography. Users are introduced to the basic information of a particular geographical area and are asked to answer simple questions in the game. Rewards are given for every level achieved. When starting the game, the user will be taken to the first splash screen to view all five avatars types on the same page Figure 3(a). Then proceed to the second splash screen that allows users to select their preferred avatar Figure 3(b) that was randomly arranged to reduce bias during selection. This step is necessary in order to conduct research on engagement and preferred avatar. The women in light blue are perceived as human-like avatars, the girl in maroon as human-cartoon avatars, the white-black cat as a mix-animal-and-human avatar, the apple as a hybrid-character avatar, and the red object as an abstract-character avatar Figure 4.

(a) (b)

Figure 3. Two splash-screen interfaces on the *GeoGuess* application: (a) viewing all five avatar types and (b) selecting preferred avatar

Figure 4. The five avatars design types used in this study

After users select their preferred avatar, they are brought to the *GeoGuess* "main page" of the game, as shown in Figure 5(a). A new user can click the orange button (in the center) to play the game directly, while returning users have other options such as straight to the level page, scoreboard page or bonus page. These options are to give more flexibility to the users. Figure 5(b) shows the "level page" that consists of five stages; level 1: Malaysia, level 2: Asia, level 3: America, level 4: Africa and level 5: World. An example of a "level main page" can be seen in Figure 5(c). Here users can decide to view and learn about the map first or directly play the level. Figure 5(d) shows an "info page" of level 1: Malaysia stage while, Figure 5(e) shows the “play page” of the current level. The user will need to click on the correct country name when the map highlights a particular country on the map. Players can use the hint icon on the top right of the screen for help. A feedback interaction will be given for any correct or incorrect answers. Figure 5(f) shows the “complete level page” after the player finishes all the questions in a level. Scores and earned trophies of the current level are displayed here. After playing all levels in the game, collected trophies and cumulative scores are presented on the “scoreboard page”, which can be accessed from the main page. Outlining the game flow of this game application allows developers to understand possible interaction and design flow before developing the game.

Figure 5. Few interfaces of the hi-fi *GeoGuess* prototype; (a) main page, (b) level page, (c) level main page, (d) info page, (e) play page, and (f) complete level page

3. RESULTS AND DISCUSSION

At the end of the development phase, six expert users assessed the hi-fi *GeoGuess* prototype using the heuristic evaluation from Barbosa *et al.* [50] that applied usability and playability components. The experts had to evaluate the game prototype based on a scale from 1 to 5. The lowest value indicated no design problems, while the highest values imply a design disaster. (i.e., no problem-1, cosmetic problem -2, minor problem-3, major problem-4, and disaster-5). The values of every heuristic in the component were summed up and reported.

Figure 6 illustrates the overall scores given by the experts for each game usability (GU) heuristic. The most violated GU heuristic was the GU2: Pleasantness of screen layout and visual. This issue was predicted since it was still in the first version state. One of the evaluators noted that "there was not enough contrast between the color of the text and the background". Three other heuristics that had issues were GU7: Feedback from players' action, GU8: Player cannot make irreversible errors and GU10: Game contains help. Only a few of the game pages had help buttons and feedback to players, which needed improvement.

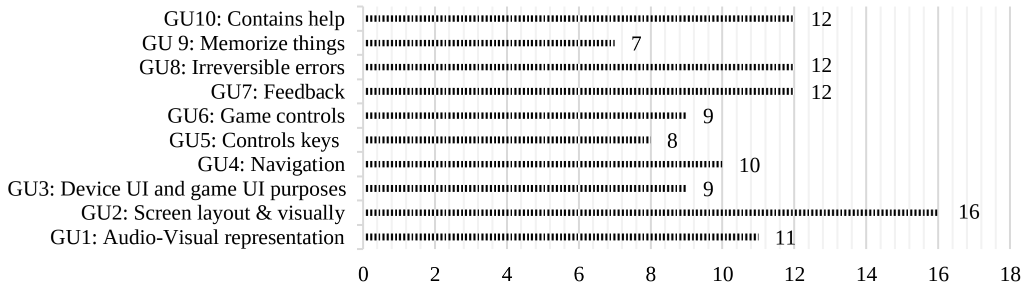

Figure 6. Game usability (GU) Heuristic scores by user experts

Figure 7 illustrates the overall scores given by the experts for each gameplay (GP) heuristic. The most violated heuristic in this category was GP6: first-time experience is encouraging. All user experts faced at least cosmetic problems on the game using this heuristic. One reported, "I cannot find the goal page and instructions to play the game?" again the help button was available but not on every page in the game design. Four other GP heuristics that had issues were GP3: rewarded and meaningful, GP7: game story supports gameplay and meaningful, GP8: no repetitive and boring tasks and GP 9: game does not stagnate. The game design was improved to have a better game story; however repetitive tasks could not be avoided since learning requires repetitive tasks. Figure 8 illustrates the overall scores given by the experts for each learning component (LC) heuristic. The most violated LC heuristic was LC3: learning objective achieved. All feedback on learning component heuristics were below average ($\bar{x}$ =15), indicating minimal issues.

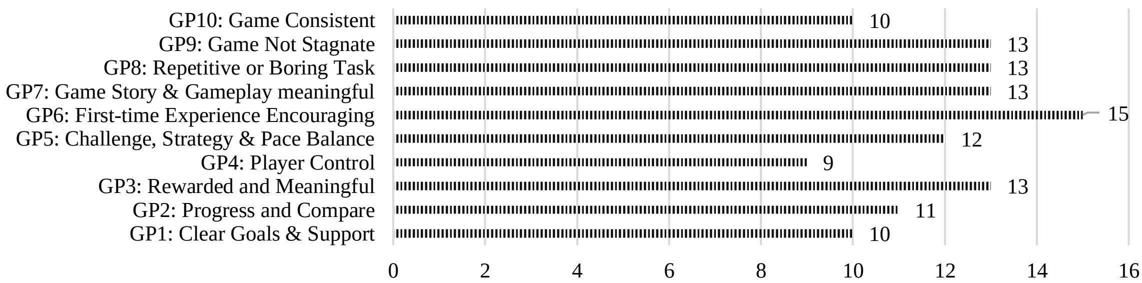

Figure 7. Game play (GP) heuristic score by user experts

Figure 8. Learning content (LC) heuristic scores by user experts

The comments from the six user experts on the *GeoGuess* game required additional improvement before being used in the evaluation phase. Changes to the color scheme, text type, icon, and button consistency were made to improve game usability. Some background images were removed, and responses to users were made consistent. For game play, the instructions were made clear to see and each page had access to the main page to ensure users had direct access to the score and bonus page. Interaction during crossover were also added to create interactive interactions. As to improve the learning content, although had minimal issues were enhanced and made easy to be understood. The language was simplified, and more information on the continents was included.

In the evaluation phase, a study was conducted to study the UES on the bespoke DEG and avatar design types. The UES scale comprises four subscales: focused attention, perceived usability, aesthetics and satisfactions, and is used to study game engagement [29]. Table 1 reports the mean and standard deviation of each subscale. It demonstrates that students are generally focused while playing the game (average answered between "Neither agree nor agree" and "Agree") and that the game provided pleasing aesthetics (average answered nearly to "Agree"). The game also gave them some satisfaction when playing (average answered "Agree") and that the game perceived good usability (average answered between "Disagree" and "Neither agree nor agree" to negative questions).

Table 1. The mean and standard deviation for each UES subscale

UES subscale	Min	Max	Mean	Standard deviation
Focused attention	1.75	5.00	3.53	0.73
Perceived usability	1.00	4.13	2.60	0.86
Aesthetics	2.80	5.00	3.91	0.46
Satisfaction	3.14	5.00	4.01	0.50

Table 2 shows the reliability analysis of each subscale in the UES, ensuring that each item in the questionnaire is consistent. There were eight items in both focused attention and perceived usability, with Cronbach's alpha values of =.87 and =.92, respectively. While aesthetics has five items with Cronbach's alpha values of =.88 and Satisfaction seven items with Cronbach's alpha values of =.94. All of the items in each subscale were consistent.

Table 2. Reliability analysis for each UES subscale

UES Subscale	Cronbach's alpha	No. Of Item
Focused attention	.87	8
Perceived usability	.92	8
Aesthetics	.88	5
Satisfaction	.94	7

Table 3 reports the correlation between each UES subscale applied on the bespoke DEG. Applying this scale on the DEG shows that there was a significant correlation between perceived usability on both aesthetics (N=45, r=0.40 p<.01) and satisfaction (N=45, r=0.36 p<.05). On top of that, there was a significant correlation between aesthetics and satisfaction (N=45, r=0.48 p<.01). This implies that aesthetics and satisfaction are both associated closely together and have a significant impact on perceived usability.

Table 3. Correlation between each UES subscale (*p<.05, ** p<.01)

UES Subscale	Factors			
	1	2	3	4
Focused attention	-			
Perceived usability	.159	-		
Aesthetics	.173	.403**	-	
Satisfaction	.190	.360*	.480**	-

Table 4 reports the median and ranges of avatar design types and the UES subscales in this study. The results show both focused attention (x^2 (16) =16.57; p>.05) and perceived value (x^2 (19) =7.88; p >.05) had no significant association with avatar design types. However, aesthetics (x^2 (10) =46.17; p <.01) and Satisfaction (x^2 (15) =73.40; p <.01) both had a significant association with the avatar types. This implies that aesthetics and satisfaction factors somehow influenced the avatar design types in the digital game.

Table 5 shows the median and ranges of preferred avatar design types among young adults in this study. The avatar design types in the questionnaire were define as; 1= human-like avatar, 2= human-cartoon avatar, 3= mix-animal-and-human avatar, 4= hybrid-character avatar and 5= abstract-character avatar. Based on the findings, participants preferred a human-cartoon avatar as their first choice (Mdn_{1st}=2.00, range=2.00-4.00), followed by a mix-animal-and-human avatar as their second choice (Mdn_{2nd}=3.00, range=2.00-3.00). The least preferred avatar was the hybrid-character avatar (Mdn_{least}=4.00, range=3.00-5.00). Among comments given when asked why that avatar was the least favorite, people said things like "character did not bring any meaning to me," "childlike," "not mature," and "the avatar does not represent me." The comments indicate that the hybrid-character avatar was not suitable for students in this age range.

Table 4. Median and range of avatar design types on the UES subscale

UES subscale	Focused attention	Perceived usability	Aesthetics	Satisfaction
Human-like	3.87 (3.18 to 4.28)	2.12 (1.63 to 3.09)	4.20 (4.00 to 4.55)	4.14 (4.00 to 4.50)
Human-cartoon	3.68 (3.06 to 3.87)	3.06 (2.37 to 3.50)	3.90 (3.60 to 4.00)	3.85 (3.60 to 4.00)
Mix-animal-and-human	3.81 (3.09 to 4.18)	2.25(1.62 to 3.15)	4.00 (3.65 to 4.00)	4.00 (3.78 to 4.53)
Hybrid	3.56 (2.78 to 4.06)	2.56 (1.56 to 3.37)	4.10 (3.55 to 4.70)	4.21 (3.78 to 4.46)
Abstract	3.00 (2.00 to 4.37)	2.12 (1.62 to 3.00)	3.80 (3.40 to 4.00)	4.00 (3.90 to 4.42)
Chi - Square	df = 16 x^2= 16.57, *p* = .41	df = 19 x^2= 7.88, *p* = .98	df = 10 x^2=46.17, *p* = .00	df = 15 x^2= 73.40, *p* = .00

Table 5. Median and range of preferred avatar design types

Preferred level	No of participants (N)	Median	Range
1st Prefer Avatar Type	45	2.00	2.00 to 4.00
2nd Prefer Avatar Type	45	3.00	2.00 to 3.00
Least Prefer Avatar Type	45	4.00	3.00 to 5.00

Table 6 reports the correlation of each UES subscale to the preferred avatar design type. A Spearman correlation test resulted no correlation for the first and second preferred avatar design type on any UES subscales. However, there was a statistically significant correlation on the least preferred avatar design type on two of the UES subscales, focused attention (N=45, r=0.37 p<.05) and satisfaction (N=45, r=0.44 p<.01).

Table 6. Correlation of UES subscale and preferred avatar (*p<.05, ** p<.01)

UES subscale	Preferred level		
	1st prefer avatar type	2nd prefer avatar type	Least prefer avatar type
Focused attention	.060	.069	.371*
Perceived usability	.231	.149	.170
Aesthetics	.101	.059	.263
Satisfaction	.127	.146	.443**

In summary, this evaluation results reported that even though the items of each subscale were consistent, only aesthetics and satisfaction factors somehow influenced the avatar design types. Meaning that avatar design plays a role in user satisfaction and aesthetics is important, supporting the statement from [34]. When studying the preferred avatar design types (1^{st} and 2^{nd} choice) on the UES factors, none were significant. However, there was a significant correlation between the least preferred avatar type and the Focused attention and satisfaction factor. These results on preferred and non-preferred avatar types, on the UES factors, were unexpected and unlikely. For example, there should be at least some engagement factors associated with preferred avatar types and otherwise. Nevertheless, there is more room for improvement in future studies. Following are issues from this preliminary study that can be improved for future research:

- Include more avatar designs per group type: samples used for the avatar design type in this study were limited to one design per group type. Multiple examples of the same group type should be given in the questionnaires and game application to understand the avatar type design fully. This could provide users with more options in one group type and prevent them from being persuaded by a single design of the group type.
- Using the same drawing style of avatar designs: avatar designs used in the study ranged from human-like avatars to abstract characters using different drawing styles. In future research, a standard drawing style on the avatar design per group type, such as a cartoon-ish design or a more life-like design, should be used. We discovered that joining cartoon-ish and life-like avatars could contribute to bias in the final result.

- Allow social interaction features: the *GeoGuess* game design could include social interaction, allowing users to interact with other players via leader boards, badges or levels and advocate the "focused attention" subscale. Allowing social interaction in a game can trigger players to become absorbed and connected in the game [53] and lose track of time. However, some form of control and limitation of social interaction should be considered in advance to avoid distraction and low learning efficiency [54].
- Easy access to the game application: during the evaluation phase of this study, the *GeoGuess* game file was distributed to participants via *.exe* files on a cloud storage. Participants had to download the .exe game file and install it in their workstations before answering the questionnaires online. This method was eventually used considering the Covid-19 Pandemic, where social distancing and frequent lockdowns are a norm. Nevertheless, this annoyed some of the participants, resulting in a small number of participants. Therefore, it is suggested that the game application be made available and accessed directly online for future studies rather than installing the game on participants' workstations.

4. CONCLUSION

Exploring and learning about other parts of the world using a digital education game could be fascinating and appealing for students in this age. However, developing such an application requires rigorous phases. Beginning from the requirement stage to the evaluation stage possess various challenges. In this study, expert users assisted in validating the game prototype and improvement of the game was discussed. In the evaluation phase forty-five potential users participated in investigating engagement and avatar types on digital educational games. The results reported that aesthetics and satisfaction factors somehow influenced the avatar design types, but none of the UES subscales were influenced by preferred avatar design types (1^{st} and 2^{nd} choice). Moreover, the human-cartoon avatar, which was not entirely human and not entirely cartoonish either, was the most popular avatar design type among young adults. Suggestion for future work such as including more avatar selection per group type, allowing social interaction features and using the same drawing style for avatars in the study was also discussed. The next stage of this research will focus on avatar design types using a neurophysiological approach such as electroencephalogram or eye-tracking data. These alternative methods may provide useful and valuable information to future game developers.

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