Motivationally Appealing Computer Science e-Learning Games: An Inclusive Design Approach

Joseph Osunde[1], Liz Bacon[2] and Lachlan Mackinnon[3]
[1]University of Greenwich, London, UK
[2]Abertay University, Scotland, UK
[3]University of South-Eastern Norway, Norway

j.o.osunde@greenwich.ac.uk
l.bacon@abertay.ac.uk
lachlan.mackinnon@usn.no

Abstract: Research has shown that e-learning games do not have the same level of appeal to girls, as they do to boys; particularly in the crucial 11-14 age group. In the United Kingdom, this is typically when they start to make subject choices that impact their future studies and careers. Given the shortage of females who choose computer science as a career, this study explores how e-learning games can be designed to be motivationally appealing to young learners. It further explores the role of game representations and its appeal to this age group. This empirical study addresses the research question: "Can we develop e-learning games which appeal and motivate girls of age 11-14 to study computer science concepts?" Two e-learning games were developed: one included game representations such as game colour, graphics, character, age appropriateness, storyline, number of players, violence, identified as appealing to young females and the other game included antithetical or neutral representations. The two developed prototypes were used to explore key e-learning game representations as used to teach computer science concepts. A total of 304 participants, comprising of 152 girls and 152 boys from a combination of same sex and mixed secondary schools in Southeast England, engaged with both experimental games. The experiment also elicited information on how learners interact with these games and the resulting game appeal, motivation and learning. The insight gained from the analysis of data captured during the experiments, provide the evidence to demonstrate that inclusive e-learning games which motivate and appeal to girls of age 11-14 can be developed. This can have a positive influence on their willingness to use such games to learn computer science concepts. This implies that the study found positive outcomes related to e-learning game appeal, motivation and the learning of girls of this age group. A follow-up longitudinal study could investigate the impact of significant e-learning game representations that appeal to the target group. This could provide additional evidence on the changes in the appeal of the investigated significant game representations over time, due to the influence of other factors such as socio-economic and socio-cultural differences. This understanding can further enhance inclusive e-learning strategies to improve diversity in computer science education and consequently the career pipeline.

Keywords: Motivationally appealing, e-Learning games, Digital entertainment games, Educational game framework, Gender and games

1. Background

The underrepresentation of females in computer science education and careers is prevalent in almost every western country irrespective of intervention strategies over the years (Osunde, Windall, Bacon and Mackinnon, 2015; Hancock et al., 2021). Based on related work, the major factor responsible for the low representation of females in computer science education and careers has been the progressive lack of interest in the subject. This is due to a poor perception of the subject and its professional image (Charlesworth and Banaji, 2019, Vrieler, Nylén and Cajander, 2021). This poor perception has been shown to be mainly influenced by negative gender-linked beliefs in the home, educational institutions, workplace and society (Hancock et al., 2021). These perceptions, even if they are not accurate, shape the academic choices that girls make (Charlesworth and Banaji, 2019; Vrieler, Nylén and Cajander, 2021).

As part of measures to improve representation, e-learning games have also been designed and used to improve engagement with technology, computer science and learning content (Duggal, Singh and Gupta, 2021). However, there is evidence from related studies that negative gender-linked beliefs are embedded in e-learning games for young people, and as a result, such games appeal more to boys than girls (Yucel and Rizvanoglu, 2019, Malik et al., 2020).

In attempting to address this problem, both gender neutral and gender specific e-learning games have been designed and implemented. The outcomes from both approaches have resulted in further research into the design of effective e-learning games for young people. This leads to the research question explored in this

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study, which is: "*Can we develop e-learning games which appeal and motivate girls of age 11-14 to study computer science concepts?*"

The rest of this paper is structured as follows. First, a more in-depth discussion of the literature is provided, explaining what is currently known about this area and the gap in our knowledge. The design of the experiment is then explained in detail, which provided the evidence used in responding to the research question.

The main contribution to knowledge is the understanding that there are similarities and differences in game representations used in e-learning games for computer science education with this age group of learners. This understanding can be used to design e-learning games that appeal to girls of this age group. The findings from the study are relevant to e-learning game designers, domain researchers and policy makers in secondary education.

2. Overview of the Literature

E-learning games have been designed and implemented in recent years to engage more girls with technology and computer programming. Research work in this domain has suggested that the use of e-learning games involving both design and programming activities can support the learning of computer science concepts by girls of middle school age (Yucel and Rizvanoglu, 2019, Denner et al. 2019). Several studies conducted in this discipline show that this is a gender-neutral approach to teaching computer programming to girls because it supports higher-order thinking, abstraction skills, and activity enjoyment as summarised by Yucel and Rizvanoglu (2019).

Seminal studies have explored the use of games specifically designed to engage girls with programming concepts. Games such as *Talking Alice* for teaching basic programming concepts (Kelleher and Pausch, 2007; Denner, Werner and Ortiz, 2012), *Gram House* (Harteveld et al., 2014), *Gamher World* (Kamberi, 2015) and *CodeSpells* (Esper, Foster and Griswold, 2013) for teaching Java concepts to girls. Recent studies suggest that the use of such games can further improve the engagement of girls with computer programming and possibly support their interest in pursuing careers in computing (de Carvalho et al., 2020; Ottenbreit-Leftwich et al., 2021).

These games teach programming concepts using game representations that are motivationally appealing to girls. In the *Talking Alice*, appealing characters, pre-programmed behaviours such as dancing, talking etc. are used to engage the learners while learning key programming concepts (Zaidi, Freihofer and Townsend, 2017). The *Gram House* game is designed based on appealing game representations such as story and puzzle-based gameplay. In addition, other games such as *CodeSpells and Gamher World* implement the use of exploration in the multimedia environment to teach programming concepts.

Additionally, educational game frameworks have been designed and implemented to evaluate and provide guidelines for creating effective e-learning games for learning (Alsubhi, Sahari and Wook, 2020). Several educational game frameworks have been proposed and used to create e-learning games. Both seminal and recent work indicate that each design framework specifically focuses on the user experience by including appropriate game representations and embedding the learning outcomes in the game environment (Amory, 2007, Aleven et al., 2010, Nadolny et al., 2020). Significant to all e-learning game frameworks is the learning outcome, which fundamentally differentiates educational games from entertainment games. Common to both e-learning and entertainment games is the implementation of user-centric design frameworks.

Past studies have suggested that the changes in the design of e-learning games should result in the improvement of female perception and appeal of e-learning games (Boyle, Connolly and Hainey, 2012; Powell, Dainty and Bagilhole, 2012). The basis of this suggestion is the evidential improvement in the engagement demonstrated by girls when learning computer science concepts with games as *Talking Alice*, *Gram House*, *Gamher World, CodeSpells* etc. due to the appeal of these games.

There are no studies in the literature, or elsewhere, that focus on a holistic e-learning game design initiative to investigate the key game representations that could improve the appeal of learning games for computer science concepts with the 11-14 age group. Seminal and recent work have shown that this age group, in the UK and many other countries is where the pipeline leading to further study and careers in technology and computer science significantly starts to shrink, with the decline in the number of girls continuing to study these subjects particularly sever (Wang and Degol, 2013; Zaidi, Freihofer and Townsend, 2017, Charlesworth and

Banaji, 2019, Sun, Hu and Zhou, 2022). Furthermore, in the United Kingdom, the 11-14 year age group is also identified as a key age for educational choices (UK Royal Academy of Engineering, 2016, Cavaglia et al., 2020).

3. Methodology and the Design of the Study

To answer the research question, "*Can we develop e-learning games which appeal and motivate girls of age 11-14 to study computer science concepts?"* the methodology was broken down into two stages. The first stage was an exploratory study designed to identify the key game representation that improve the motivational appeal of e-learning games for girls and boys, aged 11-14. Details of the methodology and results of the qualitative exploratory study involving 24 girls and 8 boys engaging with e-learning games have been published in detail elsewhere (Osunde et al. 2015). The second stage, the main study, used these results to design two games, one with representations that appeal to girls, the second with neutral representations or the antithesis of what had been shown to appeal to girls.

With regards to the first stage, a combination of open and closed card sorting with 10 entertainment game videos from a range of game genres (Action, Maze, Adventure, Role Play, Simulation, Strategy, Arcade, Music, Puzzle and Casual) were used in this initial study. The open card sort was used to capture the possible constructs and the closed card sort was applied to aggregate the occurrence of the key constructs in the next phase of the experiment. The constructs that were common to participants by gender and the appeal were identified from the open card sort. The semantic clustering technique was used to analyse the constructs elicited from the participants of the study, identifying the constructs that had the highest commonality by gender.

The second stage explored the design of e-learning games, for learning basic computer science concepts, embedding the key game representations identified from the exploratory study. Seven significant game constructs as shown in table 1.0, with categories that appeal to girls, were selected based on the construct commonality frequency from the participating population, for further investigation in the main study. The seven characteristics were selected based on their importance in the overall set of characteristics identified, their discreteness, their higher relative importance to girls, and to reduce the complexity of the game design, which would have become unwieldy in trying to represent all the characteristics identified.

The design used the variations of the constructs, which are the different values within individual constructs e.g. the construct violence could have three variations - very violent, mild violence and no violence values, to identify antithetical values. The first prototype was developed based on the variations of the key representations that appealed to the girls. The second game was developed based on the antithetical representations to the first game. Both games were used in the main study experiment. The experiment was approved by the university ethics committee and parents / guardian consent was obtained in advance. The activities carried out in both stages are shown in figure 1.

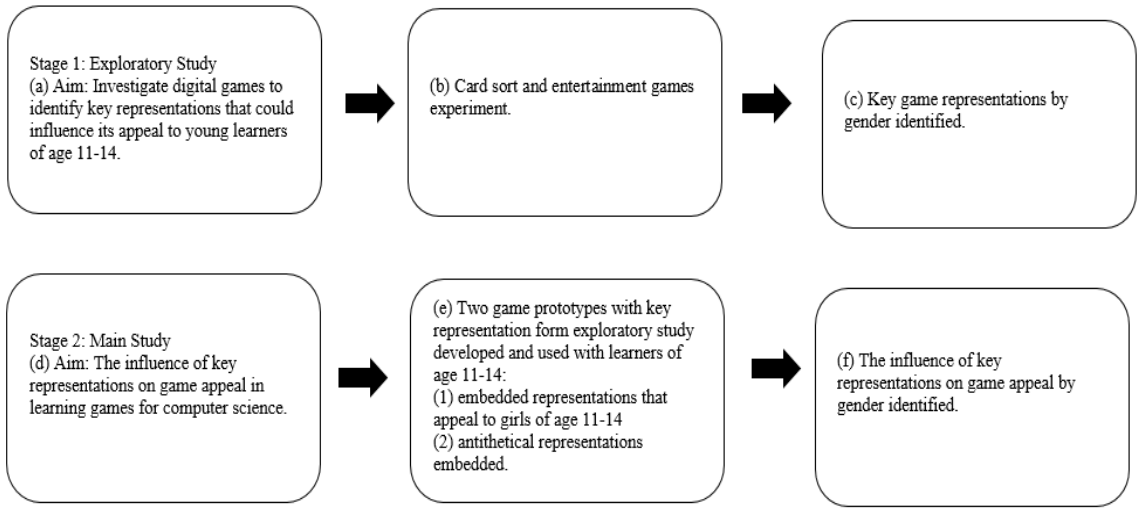

Figure 1: Diagrammatic representation of study methodology

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3.1 Main Study Investigation Technique

To investigate if these games constructs can be used to successfully create motivationally appealing e-learning games, for learning basic computer science concepts, with 11-14 year-old girls, a suitable methodology had to be identified. The methodology had to meet the following requirements:

- Identify an approach that could be used to investigate the game characteristics identified to appeal to the target group from the exploratory study. Two possible approaches were considered. The first was to design and create an e-learning game for learning basic computer science concepts, while the second was to adapt an existing game for the investigation. The second approach was considered and used because several e-learning games for the study of basic computer science concepts are readily available. Secondly, adapting an existing e-learning game provides the opportunity to evaluate existing games for their effectiveness as educational tools. Thirdly, existing games have been evaluated and designed based on established learning principles and methodologies.
- Evaluate the chosen game to confirm its educational effectiveness and how to alter the game to include the game characteristics identified from the exploratory study without compromising the educational effectiveness and value of the game. The process produced two experimental games i.e., one that should enhance the motivational appeal of girls age 11-14 and the other antithetical to the first.
- The data from the investigation needed to be captured using a suitable technique. Several techniques such as interviews, reports, and questionnaires were reviewed as possibilities for collecting participants' feedback during the investigation. The chosen method needed to capture an extensive range of information with accuracy (Garcia et al., 2012) and make effective use of time and available resources.

Based on the requirements for the main study, online (pre and post-study) questionnaires were chosen and used to capture participant perception, as this is a tried and trusted technique for collecting survey data. Questionnaires can also be used to measure preferences, opinions and intentions. The data captured can be analysed qualitatively and quantitatively, and most participants should be familiar with this information collection method.

Furthermore, questionnaires can be used to collect a range of information with accuracy and enable the study to be carried out in multiple locations without the researcher present, while still ensuring all participants are asked the same questions. The pre-study questionnaire captured participant perception and understanding of digital games before engaging with the games. The post-study questionnaire was used to collect participant feedback after engaging with the games.

The data collected using the pre and post-study questionnaires utilised a participant identification number provided by the instructors or teachers running the instance of the study, to ensure anonymity, and demographic information such as age and gender. The identification number was required to correlate the pre- and post-study data collected during the main study.

Other information captured using the pre-study questionnaire included information on entertainment gameplay habits (referred to as computer games in the questionnaire for simplification purposes for participants) and educational computer gameplay habits.

The data captured from participants using the pre-study questionnaire elicited existing knowledge of significant game characteristics, the perception and influence of computer games that appeal to the target audience. In addition, existing knowledge of the influence and perception of e-learning games (referred to as educational computer games in the questionnaire for simplification purposes) were captured using the pre-study questionnaire.

Three post-study questionnaires were created for the main study. One post-study questionnaire was created for each experimental game and was used to capture participant responses about each game after engaging with it, the participants were finally asked to answer an evaluative post-study questionnaire. The questionnaires also captured data on the appeal of specific game characteristics, the appeal of the game and the overall impact of the game. The evaluative post-study questionnaire captured comparative data on the impact of the games, and the more appealing of the two games to the target group.

This information showed the impact of the experimental games on the target audience by correlating the data with the pre-study data, exploratory study outcome, and related literature.

The questionnaires comprised open ended, Likert-scale (4, 5 and 7 points), and numeric scale (1-5) type questions. The Likert-scale point used for questions was determined by the level of granularity required from the responses. The scale values for the 4 point Likert –scale: *1= A lot, 2=Some, 3= Little, 4= Not A Lot;* 5 point Likert–scale value: *1= Strongly prefer, 2=Somewhat prefer,3= No preference, 4=Somewhat do not prefer, 5=Strongly do not prefer;* 7 point Likert-scale value: *1= Like very much, 2=Like moderately, 3=Like slightly,4= Neither like nor dislike, 5=Dislike slightly, 6=Dislike moderately, 7=Dislike very much.* The numeric 1-5 scale value was: *1=Very poor, 2=Poor, 3=Fair, 4=Good, 5=Excellent.*

3.1.1 Study sample size and materials

A total of 304 participants, comprising of 152 girls and 152 boys (the fact that the same number from both genders participated is purely coincidence), engaged with both experimental games for the main study and completed the study pre- and post-study questionnaires. The experiment with the participants, which lasted for about 60 minutes, involved the completion of the pre-study questionnaire, playing both games, completing the post-study questionnaire about each game and the comparative post-study questionnaire. The gameplay duration for each game was a maximum of 20 minutes. The participants could choose the order of gameplay hence randomised to reduce or eliminate the effect of order bias.

The rationale for this approach was to obtain two sets of data on the influence of both games on girls and boys involved in the study. The data collected from participants' engaging with each game included information on how much each game appealed to the participants, the appeal of the specific game characteristics used in the games and the influence of each game on participants' perception of e-learning games. It is important to note here that the study was carried out in five different schools, during computer Science lessons and each instance was run by the class teacher, thereby ensuring the participants were in a familiar and comfortable environment. There was no bias introduced by the presence of an unfamiliar researcher and learning environment. The class teachers were coached to run the instance of the study by the researcher.

The *Google Blockly maze game* was used for the design of both games as it met the study requirements (technical and educational) for customisation. Figure 2 illustrates the *Google Blockly maze game*, which was customised to create two experimental games for the investigation.

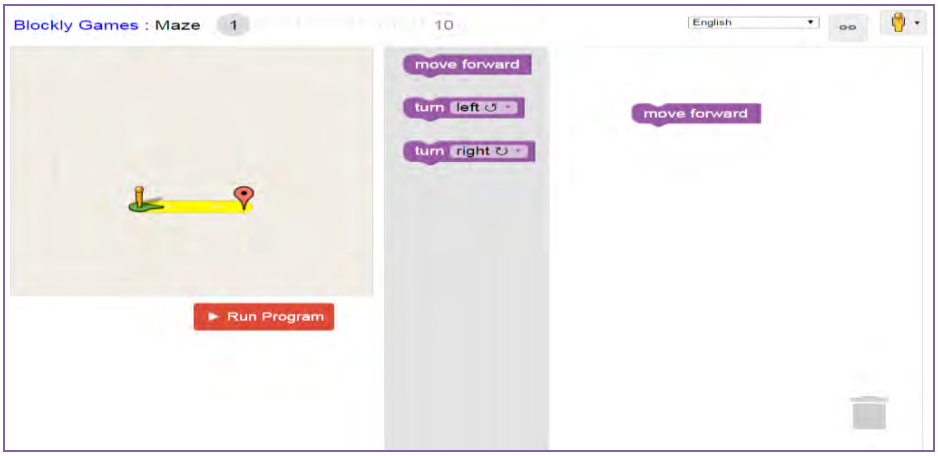

Figure 2: The Google Blockly maze game

There are 10 levels of play in the gaming environment, each focuses on the use of different programming constructs such as sequencing, decisions and repeat (loop) instructions. The less challenging levels of the game allow the player to use an unlimited number of instruction blocks. However, higher levels would limit the number of instructions blocks to successfully create a functional script making the game more challenging.

The first experimental game (*The Lost Astronaut*) included the variations of the significant game characteristics that positively appeal to the girls and the second *(The Lost Hippo),* the antithesis of the characteristics selected for the first game as shown in table 1.

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Table 1: Selected construct category pairings for further investigation in the main study

No	Female game constructs	Categories of appeal and game representations in *The Lost Astronaut*	Categories with antithesis appeal and game representations *in The Lost Hippo*
1.	Age-appropriateness	All ages/everybody (The use of the astronaut character, colour, narrative, cartoons instead of pictures and images that appeal to a wide age range)	Teenage games suited for the age group (The use of representations that appeal to a younger age group such as the use of the hippo as the main character in a fantasy scenario, dark colours, pictures instead of cartoons etc.)
2.	Game violence	No violence (No violent representations included)	Violent (Some violence such as explosions included in the gaming environment when the character navigates incorrectly)
3.	Game graphics	Cartoons (The use of cartoon graphics of the main game character and the background images)	Photographs (The use of real photos in the game background)
4.	Colour used	Bright colours (The use of bright colours for the main character and gameplay background)	Dark colours (The use of dark colours for the main character and gameplay background)
5.	Game character	Human with real scenarios (Human used as the main character in a realistic scenario of a lost astronaut in space)	Animal in fantasy scenarios (Animal used as the main character in a fantasy scenario of a lost hippo in space)
6.	Number of players	Player interaction (Multiple player social interaction using a chat room facility during gameplay)	Single player (No social interactive facility within the gaming environment)
7.	Storyline	Include a definite storyline (A pre-defined storyline or narrative of the lost astronaut in space included in the gaming facility)	No storyline (No storyline or narrative of the gameplay included in the gaming facility)

The framework proposed by Aleven et al. (2010) was used to confirm the educational effectiveness of the *Google Blockly maze game* which was customised to develop the two prototypes. This framework was chosen because it could be used to analyse the learning objectives of the games, the instructional principles and game mechanics, design and aesthetics (MDA). The MDA component, which is also a framework in its own right (Hunicke, LeBlanc and Zubek, 2004) provided the taxonomy for the game mechanics and aesthetics.

The selected key game representations i.e., the game materials as components of the mechanics were used to improve the aesthetics elements of the game e.g., fantasy, narrative, challenge, discovery, expression and submission. These in the player perspective is the "fun" associated with the games. Other game mechanics components such as game rules, play levels etc. did not change for either game as the focus was the game representations and their influence on player appeal.

Whilst in both games, the game aesthetics were near-enough identical, the game representations included variations of similar characteristics. For example, *The Lost Astronaut* included an age-appropriate main character of a human in a realistic scenario (space). In contrast, *The Lost Hippo* included an age-inappropriate main character *(The Hippo)* in an unrealistic scenario (space). Other variations between both games such as including a social interactive facility, a pre-defined storyline, violence etc. are further described in table 1.0.

Figure 3 illustrates the customised experimental games (a) *The Lost Astronaut* and (b) *The Lost Hippo.*

(a) *The Lost Astronaut* **(b)** *The Lost Hippo*

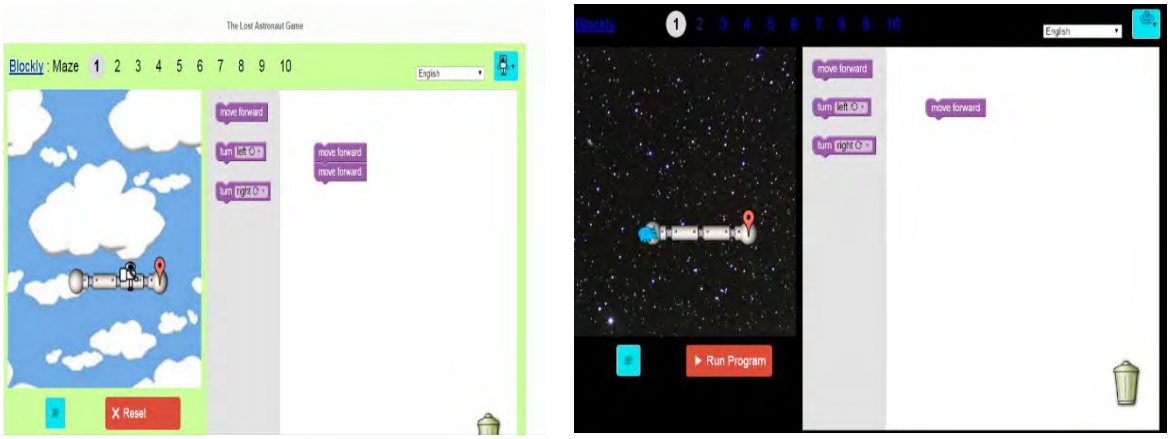

Figure 3: Example screenshots from the customised experimental games

To ensure that the findings from the experiment were valid, a threat analysis was conducted to establish the cause–effect relationships during the study, and actions were taken to minimise or eliminate the effect of confounding variables, which can bias the outcome of a study. Both internal and external threats were considered. Three internal validity threats including history, maturity and mortality had the potential to significantly impact the result of the study. The actions taken to eliminate or minimise the impact of these threats included conducting the experiment in a familiar environment to the participants (history), the session was a similar duration as lessons to ensure participants were not bored or tired (maturity). In addition, the comparative number of participating girls and boys at the start of the experiment were similar such that dropout of participants should not significantly threaten the validity of the experiment (mortality).

Irrespective of the internal validity threat elimination or minimisation, there are possibilities of the impact of confounding factors mistaken for the effect of experimental variables (selection interaction effects). An Example of this includes previous experiences of e-learning games for learning computer science concepts by participants. This can influence study outcomes favourably or otherwise. Providing measures to control internal threats such as history, maturity and mortality further minimises the impact of selection interaction effects.

The external validity threats of the study were minimised or eliminated during the study as the sample population of the study represented a real-world population. The ecological validity ensured the same study was conducted in five different locations with the same age groups and both genders.

The main study conducted across five different locations in Southeast England, United Kingdom comprised of three single sex schools (one girl only and two boys only) and two mixed gender schools. The data collected on the boys' interaction with the experimental games were used for comparative analysis with the results obtained from the girls.

3.2 Main Study - Data Analysis Technique

The analysis of the pre-study questionnaire data was designed to provide a better understanding of the perception of e-learning games by the target group before engaging with the experimental games designed for the study. The analysis of data collected using the pre-study questionnaire involved the use of qualitative analytical methods such as content analysis of participant responses by gender to establish a correlation with experimental games results.

Both qualitative and quantitative analyses were carried out on the data captured from the post-study questionnaires. The qualitative analysis also involved content analysis and the use of graphical representations to identify the trends in the data captured. The purpose of the qualitative analysis was to identify the game characteristics and the game that appealed more to the girls. It should also identify the reasons for the appeal of the game. The quantitative analysis involved the use of statistical tests to confirm the statistical significance of the qualitative findings and its generalisation to a wider context of the sample population. The results of these analyses are required to provide the empirical evidence of the impact on the girls.

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For the qualitative analysis of data captured using the pre and post-study questionnaires, the requirement for suitable application software involved the computation of data captured from participants and its visual representations. Microsoft Excel and the Statistical Package for Social Scientists (SPSS) were used for the analysis of data.

4. Results and Discussions

4.1 Comparative Analysis of *The Lost Astronaut* and *The Lost Hippo* games

Based on the responses of participants, the ranking of the game representations as used in table 1.0 in each of the experimental games were analysed using the *Friedman mean rank* to obtain a statistical ranking to enable us identify differences by gender, the motivation to play the game. The ranking of the representations by gender for both games are shown in tables 2 and 3 respectively.

Table 2: Statistical ranking of game representations investigated in the study as used in The Lost Astronaut by gender

No	Game representation	Friedman statistical ranking of *The Lost Astronaut* representations (Female)	Friedman mean rank of *The Lost Astronaut* representations (Male)
1.	Number of players	1	4
2.	Colour used	2	1
3.	Game graphics	3	3
4.	Game character	4	5
5.	Age-appropriateness	6	2
6.	Storyline	5	6
7.	Game violence	7	7

From the statistical ranking of the characteristics used in *The Lost Astronaut*, the interactive feature, colour used, and the game graphics were the top three in the rankings for the girls. For the boys, the colour used, age appropriateness of the game and game graphics were the top three representations ranked. The bottom ranks for both genders were game violence. Violence was absent in this experimental game and as a result, being the least rank was understandable for both genders as it was absent.

A similar analysis of the data captured for *The Lost Hippo* game is illustrated in table 3.

Table 3: Statistical ranking of game characteristics investigated in the study as used in The Lost Hippo by gender

No	Game representation	Friedman statistical ranking of *The Lost Hippo* representations (Female)	Friedman mean rank of *The Lost Hippo* representations (Male)
1.	Age appropriateness	1	4
2.	Colour used	2	1
3.	Game character	3	3
4.	Game graphics	4	2
5.	Number of players	5	5
6.	Game violence	6	6
7.	Storyline	7	7

The statistical ranking of *The Lost Hippo* indicated that the top three game characteristics for the girls were age appropriateness, colour used and game character. For the boys, it was the colour used, game graphics and character. Both genders had the number of players, game violence, and the storyline as the lowest ranked. There were no storylines and interactive facility (number of players) for this game; hence, the lowest ranking could be explained. However, for the game violence, it was either a case of the violence not appealing to the

girls because it was included and maybe too mild for the boys, hence it didn't appeal to either group. It is important to also note from the result of the analysis that whilst some of the game representations were equally or almost equally ranked, there were differences in the variations of the representations and how they may appeal to both genders. For example, colour used, appeared to be significant to both genders. However, bright colours appear to appeal to the girls, while dark colours to the boys.

4.1.1 The appeal of The Lost Astronaut and The Lost Hippo

The appeal of The Lost Astronaut game to the girls from all three locations (Locations 1 & 2 mixed gender; Location 3 single gender) is illustrated in figure 4. This data was extracted from the response to the 7-point likert-scale question – "How much do you like the game The Lost Astronaut?" in The Lost Astronaut post-study questionnaire. Cumulatively, across the three locations, an average of 28% of the girls liked the game very much as compared to 2% that disliked the game very much.

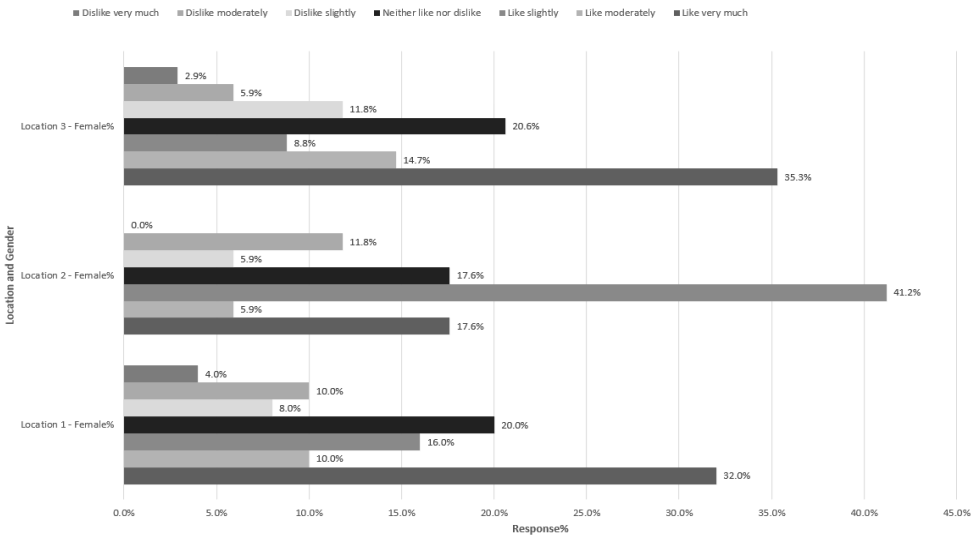

Figure 4: The appeal of The Lost Astronaut game to the girls by location

A comparative analysis of the boys' data indicated that most boys disliked this game *very much* or *moderately* (see figure 5.0). Cumulatively, across the four locations for the boys, an average of 9% of the boys indicated that they *liked* this game *very much*, compared to 45% that *disliked* this game *very much*. Generally, the boys from the mixed gender schools (Locations 1 & 2) appear to dislike the game more than the boys from the single gender schools (Locations 3 & 4). A possible reason for this trend could be the impact of *"gender role socialization"* in the mixed gender school. The analysis of data by gender suggested that *"The Lost Astronaut"* appealed more to the girls than the boys (average value of 28% girls as compared to 9% boys).

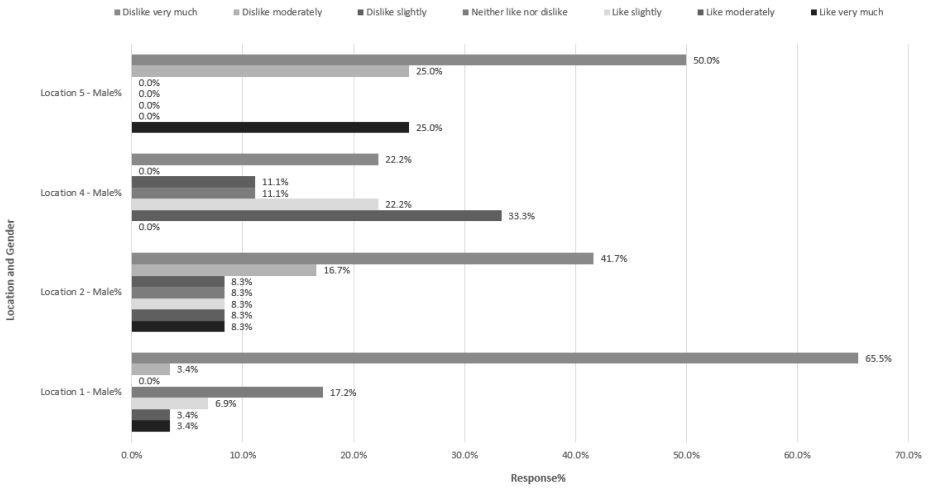

Figure 5: The appeal of The Lost Astronaut game to the boys by location

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A similar analysis for *"The Lost Hippo"* game was also carried out by gender for all locations of the study. Figure 6 illustrates the analysis by location for the girls. It indicated that this game was not as appealing as *"The Lost Astronaut"* game to the girls. This is evidenced by the fact that the average *dislike* for all three locations was 31% as compared to 5% *liking it very much*. The girls in the single gender school (Location 3) appeared to *dislike* (43.3%) this game *very much* more than the girls from the mixed gender schools-locations 1 and 2 (25.0% and 25.6% respectively).

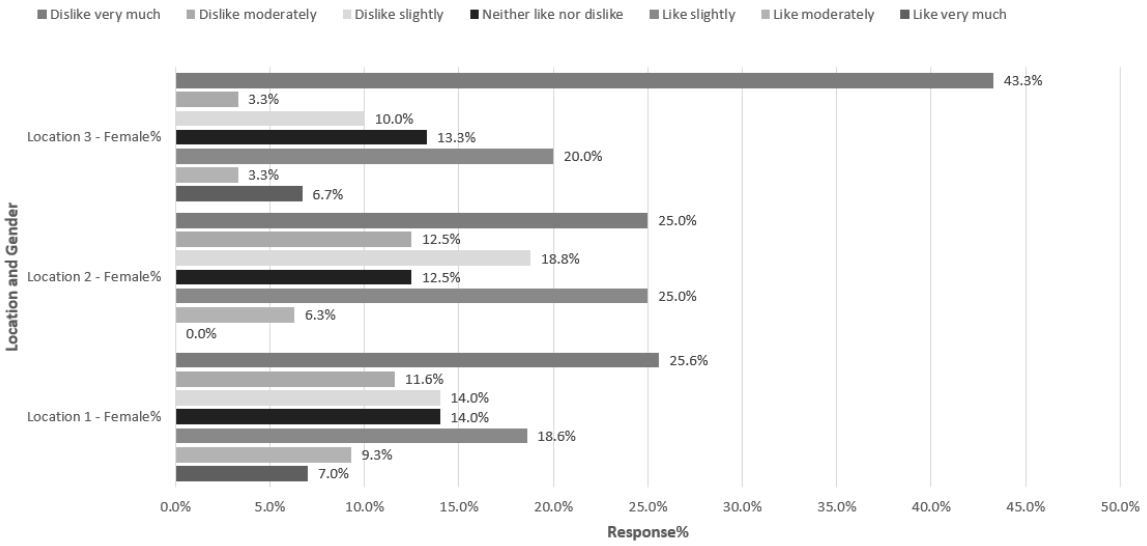

Figure 6: The appeal of The Lost Hippo game to the girls by location

A similar analysis by location for the boys as illustrated in figure 7 suggested that cumulative average for *like very much* was 32% for *"The Lost Hippo"* game as compared to 19% disliking *it very much*. The boys from the single gender school (66.7%) *liked* this game *very much* more than the boys from the mixed gender schools - locations 1 and 2 (45.8% and 10.0% respectively). The boys from the single gender school also appeared to be very clear on how they perceived this game. The analysis by gender for *"The Lost Hippo"* game suggested that it appealed more to the boys than the girls.

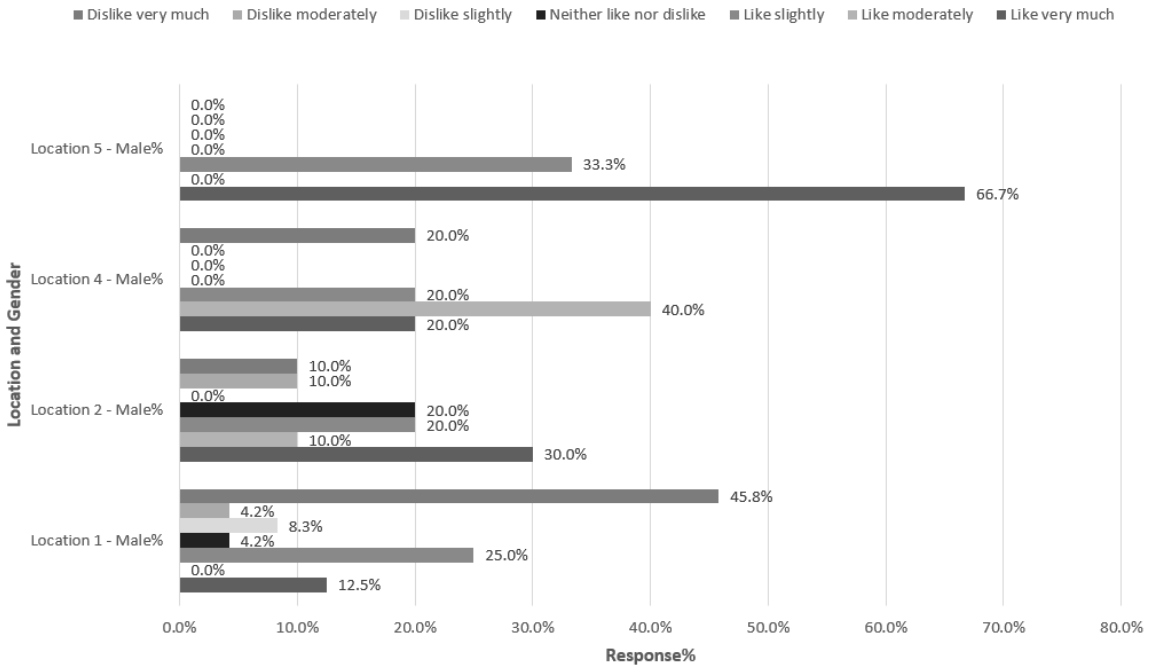

Figure 7: The appeal of The Lost Hippo game to the boys by location

An insight into the comparative appeal of both games to participating girls and boys was also gained from the analysis of data captured using the post-study evaluative questionnaire. The question used to capture the data was *"Which of the games (The Lost Astronaut or The Lost Hippo) do you like the most"?* This analysis investigated if there were any significant differences in the appeal of the games, considering that they included variants of the selected significant game representations obtained from the exploratory study. The result is illustrated in figure 8, which indicated that the girls found *The Lost Astronaut* (68%) more appealing in comparison to *The Lost Hippo* game (44%). In contrast, the boys found *The Lost Hippo* (56%) more appealing than *The Lost Astronaut* (32%).

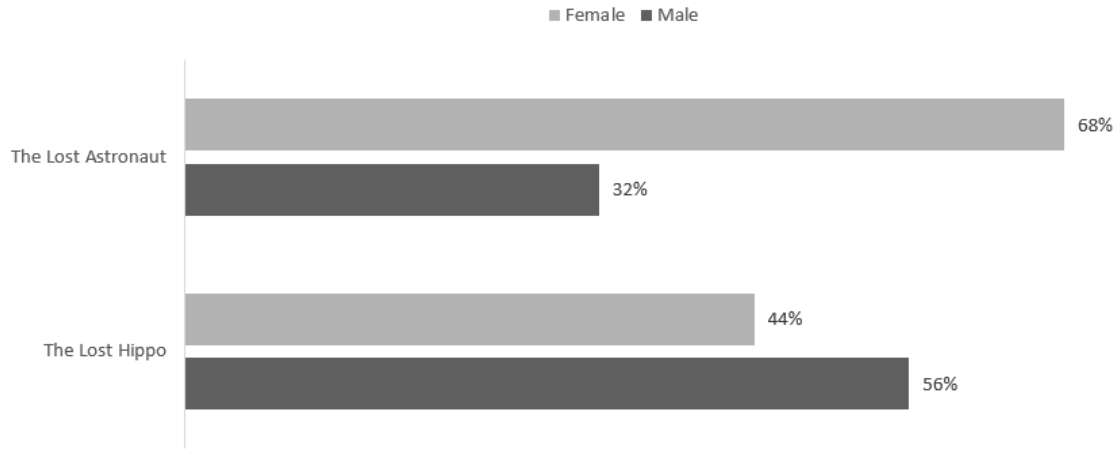

Figure 8: Comparative appeal of The Lost Astronaut and The Lost Hippo to participating girls and boys

To examine this result quantitatively in the context of the sampled population, a statistical analysis was carried out. A procedure to determine the normality of the distribution of the data was required to generalise the result. A normality test, described below, was completed to confirm the distribution of the data within the sampled population.

The test indicated that the data were not consistently normally distributed, by comparing the results provided from all three component outputs of -the *Kurtotic check* test (Doane and Seward, 2011), *Box plot* and the *Shapiro-Wilk test* (Razali and Wah, 2011).

The assumption that the data captured for analysis was not normally distributed was therefore made. Hence, parametric analytical tools were not used for the quantitative analysis, but rather non-parametric measures such as the *Mann-Whitney test*, which can measure the difference between two independent samples (*The Lost Astronaut* and *The Lost Hippo*) with ordinal data, was considered and used.

The *Mann-Whitney* test was used to test the significance of the difference in the appeal of the game that appealed more to the girls in comparison with the boys. On average, the appeal for *The Lost Astronaut* game for the girl participants (*Mean rank =64.10, n=80*) significantly exceeds those of the boy participants (*Mean Rank =76.95, n= 58), U=1888.000, z= -2.154, p=0.031 two tailed*. The null hypothesis for the test statistics is that there is no significant difference in the appeal as indicated by participating girls and boys for the game if *p>0.05*. The null hypothesis is rejected here as *p = 0.031*, hence there is a significant difference in the appeal of the games as indicated by participating girls and boys groups.

From this test, there is evidence that the difference in appeal is *statistically significant.* This has to be set against the fact that the differences between both games used in the study were only that the game representations were altered between both games - *The Lost Astronaut* and *The Lost Hippo.* This provides clear evidence that there are differences in the games that appeal to girls and boys.

It also confirms earlier findings from the exploratory study (Osunde et al., 2015) and related investigations (Poels et al., 2012; Melzer and Engelberg, 2016) that suggest that there are gendered characteristics in game representations. This study however extends the body of knowledge by providing empirical evidence that there are variants of game representations and different game representations that can improve the appeal of e-learning games. In the context of this study, educational games for learning computer science concepts for girls of age 11-14.

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4.1.2 *The influence of the preferred game on the perception of educational games for learning computer science*

The influence of the *preferred game* on the perception of the participants was also investigated in the analysis of data collected during the survey. The data was captured based on the 4-point Likert –question, *"How much has your preferred game influenced how you feel about educational computer games for learning computer science?"* The result is presented in figure 9 with, 48% of girls indicating that the *preferred game* influenced their perception of educational games for learning computer science *a lot*. Cumulatively, *The Lost Astronaut* game appeared to influence the perception of 75% of the girls as compared to 25% who indicated that the influence was *not a lot.*

Similarly, the *preferred game* for the boys – *The Lost Hippo* influenced their perception 30% (*A lot*), 30% (*Some*), 18% (*Little*). Cumulatively, 78% of the boys' perception appeared to be influenced compared to 21% who indicated that the influence was *not a lot*. Based on the qualitative analysis, conclusively the preferred game appeared to influence the perception of 75% of the girls and 78% of the boys.

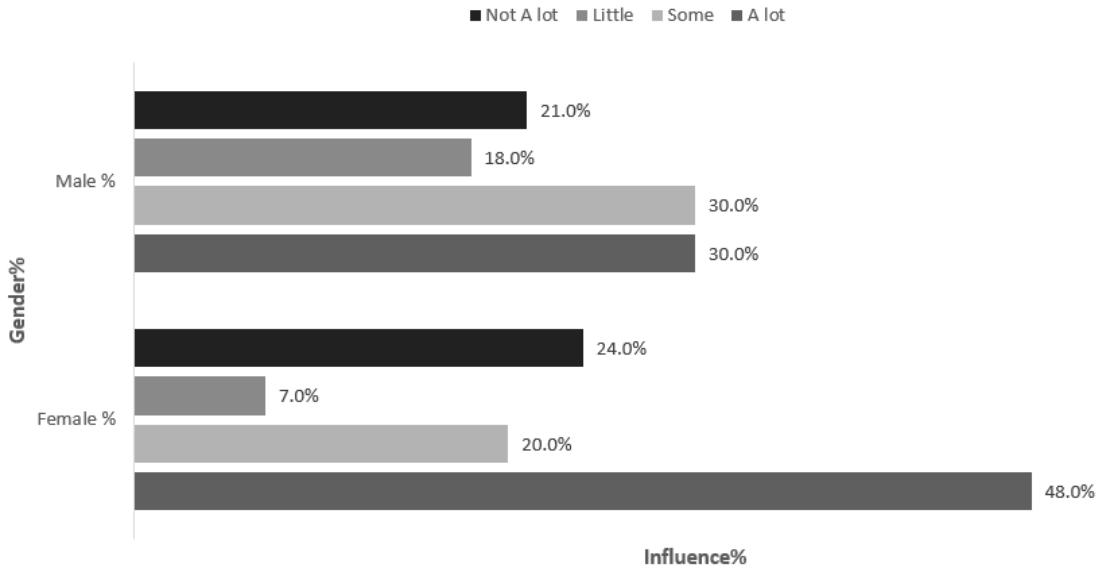

Figure 9: The influence of the preferred game on perception of educational games for learning computer science concepts

To confirm the statistical significance of the responses from the girls and boys, on the influence of the preferred game on their perception of educational games for learning, the *Mann-Whitney U test* was carried out on the analysed data from both games. On average, the influence of *The Lost Astronaut* with the girls, *(Mean rank =35.32, n=53)* significantly exceeds *The Lost Hippo (Mean rank =50.67, n=27), U=441.000, z= -2.897, p=0.*004 two tailed. The *Mann-Whitney U test* result conducted for the boys' population also indicated that on average, the influence of *The Lost Hippo* with the boys*, (Mean rank =23.91, n=34)* significantly exceeds *The Lost Astronaut (Mean rank =37.42, n=24), U=218.000, z= -3.164, p=0.002* two tailed.

For both genders, e-learning games that are preferred due to the inclusion of game representations that appeal to the target audience can significantly influence their perception of educational games for learning computer science programming concepts. Considering that the gameplay of both experimental games were identical with only the representations varied, it can be concluded from the analysis that the motivationally appealing game (preferred game) does support learning programming concepts and influences positively the perception of the subject to girls of age 11-14. This understanding, based on the study outcome, is that educational games which appeal to learners, supports learning and this is reinforced by Huang, Johnson and Han (2013) and Boyle et al. (2016).

This study has provided empirical evidence in support of the understanding that game representations that appeal to a specified group can be used to create learning games that appeal to that group. In the instance of this study, girls of age 11-14 in the context of learning computer science concepts. The study further provided evidence that e-learning games that appeal to a specified age group can also support their learning.

5. Conclusion

This research set out to answer the question – "Can we develop e-learning games which appeal and motivate girls of age 11-14 to study computer science concepts?"

An exploratory study was carried out to identify some key game representations that make some successful digital entertainment games appealing to this age group of girls. Based on the results of this exploratory study two experimental games (The Lost Astronaut and The Lost Hippo) were designed, one to be appealing to girls in the 11-14 age group and the other being an antithetical design. Both games were adapted from an existing e-learning game for learning basic computer science concepts – The Google Blockly maze game. Once these games had been developed, a main study was carried out comparing the reaction to both games and their impact on the perception of e-learning games for learning computer science concepts, with participants across five study locations.

The comparative analysis of the data captured from the interaction of participants with the games in the main study showed that, whilst the participating girls found The Lost Astronaut more appealing, the boys found the antithetical game The Lost Hippo more appealing.

Subjecting this insight to statistical analysis both validated the outputs of the exploratory study (Osunde et al., 2015) and confirms existing research (Poels et al., 2012; Melzer and Engelberg, 2016, Naranjo-Bock, 2023) that there are differences in the game representations that appeal to girls and boys in e-learning games. This study further provides the evidence to show that the motivational appeal is because of the variation of game representations, which could be similar or different between both genders. This motivational appeal was also shown to impact positively on the perception of the subject by both genders.

Whilst the study was predominantly concerned with the motivational influence on the perception of learning games for 11-14 year old girls, the evidence shows that the effect on the boys in the same age group was also significant, reflecting gendered variations of the game representations.

This study provides empirical evidence, until now missing from the literature, which shows that e-learning games which are motivationally appealing to girls in the age group 11-14 can be developed and can have a significant positive influence on their perception of computer science learning games, and hence their willingness to learn computer science concepts. The wider implication of this study is that the design and creation of e-learning games, which are inclusively motivationally appealing, could be used to effectively influence the perception of subjects that are identified as not motivationally appealing to a target group. Whilst previous studies (Esper et al., 2013; Zaidi et al., 2017) have suggested the use of e-learning games to encourage more girls into computer science, this study provides the empirical evidence on how this can be successfully implemented.

Future work will comprise of a longitudinal study to investigate the impact of significant e-learning game representations that appeal to girls of age 11-14. This study can provide empirical evidence of possible changes in appeal and motivation over time due to the influence of other factors such as socio-economic and social -cultural factors.

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