A STUDY INTO THE CHARACTERISTICS OF GAME-BASED LEARNING SOFTWARE THAT APPEAL TO 11-14 YEAR OLD GIRLS

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A thesis submitted in partial fulfilment of the requirements of the University of Greenwich for the Degree of Doctor of Philosophy

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DECLARATION

"I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others".

X--

Joseph Osunde

X--

Professor Liz Bacon

(First supervisor)

X--

Professor Lachlan MacKinnon

(Second supervisor)

To my loving wife, children and mother – Moinca, Osamuyimen, Imade, Noruwa, Esosa and Esther.

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ABSTRACT

The motivation for this study is the under-representation of females in computer science education and careers, which can be seen as both a waste of talent and the loss of educational and career opportunities for girls and women. This problem, commonly referred to as the "*shrinking pipeline*", acknowledges the progressive reduction in the number of females in computer science education and careers over a period of years. Strategies and initiatives implemented over the years to solve this problem include attempts to dispel computing career myths, promote the use of mentors and provide accurate information about computing to key influencers of girls. Technological initiatives have also explored the use of digital educational games to engage more girls with computer science.

The limitation with these technological initiatives lie in their inability to engage as the many girls as boys, which is reflective of the situation that we see with digital entertainment games. Educational software designed for students and children has been described as exemplifying the same problems as experienced with games designed for boys, because the characteristics often promote negative gender stereotypic constructs about computer science. Considering the ubiquity of digital games, their impact is far reaching across all age groups, but it is particularly important for 11-14 year olds, as this is the age group where a gender divide over computer science appears in schools. To resolve this problem, gender neutral and gendered games were designed to make digital educational games more appealing to girls. The outcomes from these design techniques have resulted in suggestions to including game characteristics that appeal to girls in digital educational game design solutions. Consequently, the research questions addressed by this study are:

(1) *"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"*
(2) *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

The approach of the research was to conduct an exploratory study of digital entertainment games with a view to identifying the significant game characteristics that make them motivationally appealing to the 11-14 year old girls.

The findings of the exploratory study were used to create two digital experimental educational games, one designed around the characteristics with the most positive appeal, and the other designed around the antithetical values of those game characteristics.

The experimental games were designed using an adaptation of the Aleven et al. (2010) framework and based on the Google Blockly maze game which facilitated the combination of the learning objectives, game mechanics, dynamics & aesthetics (MDA) and instructional principles. The main study which followed thereafter involved 304 participants (girls=152 and boys=152), from five different locations in southeast England. The participants engaged with both games and online questionnaires were used to collect their views and opinion of the games. The boys of a similar age group were included in the study to provide comparative data for the study.

The evidence from the main study identified the significant game characteristics which can make digital educational games appealing to the target group, namely 11-14 year old girls. The evidence indicated that the significant game characteristics are a key criterion in making the experimental games appealing to girls. This knowledge can be used to inform the design of gender-specific digital educational games and gender inclusive games. This can be achieved through the application of design frameworks, and the customisation of the significant game characteristics that appeal to this target group.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This introductory chapter sets out the research investigating the motivational appeal of digital educational games for learning basic computer science concepts, and how it can be improved for 11-14 year old girls. The chapter begins with the motivation for the research and a background to the problem. The second section of the chapter is a statement of the research problem and question. The research aim and objectives are outlined in the third section. The scope of the investigation is reviewed in the fourth section. The list of papers published and conference presentations are presented in the fifth section. The sixth section concludes the chapter with an overview of the structure of the thesis.

1.1 Motivation and background of the research

The motivation for this research is the under-representation of females in computer science education and careers. A considerable amount of related literature currently exists on this subject and initiatives such as gender grouping, collaborative working, role models and mentoring, working parties and initiatives, changes to educational policies and use of digital educational games as motivating tools, have been implemented over the years to attempt to increase female representation in computer science. Irrespective of these interventions, the situation persists as shown by the UK Research Council Statistics (2010), Sax (2012), UK Higher Education Statistics Authority (2012), e-Skills UK (2013, 2014) and Zagami et al. (2015), hence predicating a further review of how to improve female representation in computer science education and careers.

This problem has been referred to as the *“shrinking pipeline”* by Camp (1997) due to the progressive reduction in the numbers of females engaging with computer science from early education stages through the tertiary stage and into the workplace. The problem has a history dating back to the early 1980s.

Female under-representation is also historically a problem with other Science Technology Engineering and Mathematics (STEM) disciplines and careers (Beede et al., 2011; Sax, 2012; Webster, 2014) but a greater problem with computer science. The United Kingdom STEM education qualifications statistics from WISE (2015) indicates that amongst STEM disciplines offered at General Certificate of Education (GCSE) and Advanced Level qualifications for 16-18 year olds computing has made the least progress in addressing female under-representation.

Available data from the United States of America, Australia, Western Europe, Southern Europe, Scandinavia and Africa also indicate that this problem is widespread (Dryburgh, 2000; Beyer et al., 2003; Sanders, 2005; Townsend, 2013). In a seminal paper, Galpin (2002) showed that the participation level of females in computer science education ranges between 10-40% in most countries. Galpin further argued that there are some countries where female participation is below 10%, some with participation above 40%, and a few where females are in the majority. Secondary data analysis from related studies have shown that this pipeline leaks at the educational and career stages are widespread in almost every western country (Vitores & Gil-Juárez, 2016). This problem continues in spite of a global trend of females achieving better results than males in public examinations at secondary educational level (Tam & Bassett Jr, 2006; Klawe, Whitney & Simard, 2009; JCQ, 2005, 2009, 2011 & 2015).

Many may ask the question why is it important to have a gender balance in computing given many other professions do not achieve this. Some of the reasons cited in the research literature are as follows:

a) It is a key area for global competition and it is beneficial for computer science to become more gender-inclusive as diversity can improve both the products of computer & software teams (Whitecraft & Williams, 2010) and company performance (McKinsey & Company, 2015);
b) The projected growth and demand for computing jobs is predicted to grow faster than jobs in all other professional sectors (Ashcraft & Blithe, 2009). If the trend of female under-representation continues, the industry can only fill half of the available jobs by 2016 (Bureau of Labor Statistics, 2014, 2015).

In other words, the industry will benefit from participation by all people of both genders that show promise and capability;

c) As the technology industry grows and becomes more diverse, to remain effective and competitive in the global markets, the labour market should also represent gender and racial diversity to remain relevant (Kochan, 2010). According to the article on *“Why diversity matters”* by McKinsey & Company (2015), there is the likelihood that companies in the top quartile for diversity (gender and ethnicity) financially outperform those in the bottom quartile.

1.2 Problem statement

A major factor in the low representation of females in computer science education and careers has been a progressive lack of interest due to poor perception of the subject and profession. The poor perception is mainly influenced by negative gender-linked beliefs in the home, workplace and society (Cheryan et al., 2012; Fox & Tang, 2014).

Over the years, due to the success of digital entertainment games with girls and boys, digital educational games have also been designed and used to improve engagement with technology, computer science and learning content (Davis, 1989; Papastergiou, 2009; Connolly et al., 2012; The Entertainment Software Association 2014; Ke, 2016). However, it is only very recently that the number of girls playing digital entertainment games has equalled the number of boys, as the digital entertainment game industry has recognised the need to engage more female players by authoring a wider range of digital games with less negative gender linked content.

There is evidence that negative gender-linked beliefs are equally embedded in digital educational games for young people, and as a result, such games do not appeal to girls (Hartmann & Klimmt, 2006; Ihamäki, 2011). In attempting to address this problem, both gender neutral and gender specific educational games have been designed and implemented.

However, the outcomes from both approaches have resulted in further research into the design of effective educational games for young people.

In addition, educational games frameworks have been designed and implemented to evaluate and provide guidelines for creating effective digital educational games (Wilson et al., 2009; Bedwell et al., 2012).

Recent literature indicates that the changes in the design of educational games should result in the improvement of their perception and appeal of digital educational games (Przybylski et al., 2011; Boyle et al., 2012; Powell, Dainty & Bagilhole, 2012). Current studies have also focused on a variety of age ranges of females with investigations into different elements of game appeal such as storytelling through game authoring and gameplay (Kelleher & Pausch, 2007; Hayes & Games, 2008; Kafai et al., 2008; Denner, Werner & Ortiz, 2012).

There is currently no literature that focuses on educational game design initiatives with the specific age group where the pipeline significantly starts to shrink, which is around the ages 11-14 (Dryburgh,2000; Wang & Degol, 2013). The 11-14 year olds are also identified as a key age for educational choices (UK Royal Academy of Engineering, 2016).

It has been suggested that the engagement with computing within this age group can have a significant impact on female representation in computer science education and careers due to the following:

a) This age group for girls and boys spend more time playing video games than any other age group (Rideout et al., 2010; Stewart et al., 2013). As a result, the impact of game representations that are based on gender stereotypes is significant to this age group;

b) Reduced enthusiasm for information communications & technology (ICT) teaching in schools often referred to as "*dull*" or *"boring"* due to a lack of creativity in the curriculum and the competence of teachers (Clayton et al., 2012; The Royal Society, 2012);

c) The significant impact of gender - linked roles and poor perception of the computing person and professional e.g. nerdy (Mercier et al., 2006; Cheryan et al., 2013). This has been shown to impact on the interest in the subject and the educational choices made by age 16.

It is important to note here that, in the majority of international educational systems, it is at this age that pupils will make subject choices that determine the rest of their academic careers, and potentially their working careers thereafter.

Based on the above introduction, the research questions addressed in this study are: (1)*"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"*

(2)"Can we use this knowledge to create computer science learning games that appeal to this audience?"

1.3 Research aim and objectives

The aim of this research is to investigate in digital educational games the impact of game characteristics that appeal to the target group of 11-14 year old girls.

To achieve this research aim, the following objectives were set:

1. Investigate some successful digital entertainment games with a view to identifying the key criteria for their success with the target group;
2. The outcome of this investigation would be used to create experimental digital educational games for learning basic computer science concepts with the target group;
3. The analysis of data collected from the investigation with the target group engaging with the experimental educational games should provide a response to the research question.

1.4 Definitions, key terms and scope of the study

The issue of terminology was identified during the review of literature in this area of study. It is, therefore, important that it is addressed early on in this thesis. The definitions as provided by The Royal Society UK (2012) are predominantly used in this thesis as they also acknowledged this issue as a global concern.

The Royal Society (2012) defines computer science as the scientific discipline covering principles such as algorithms, data structures, programming, systems architecture, design, problem-solving etc.

The discipline focus on how computer systems work and the development of new systems by writing software (Computing At Schools, 2012).

The Royal Society further commented, "*Computing is used with a very broad sense. Computing is concerned both with computers and computer systems – how they work and how they are designed, constructed and used with the underlying science of information and computation".* This broad subject area is roughly equivalent to what is called Information and Communication Technology (ICT) in schools, and Information Technology (IT) in the IT sector (The Royal Society, 2012).

ICT is the school subject defined in the National Curriculum as a response by the UK government to establish computing as a component of the National Curriculum. This term is currently no longer in use as directed by The Royal Society (2012) as it has attracted too many negative connotations.

IT has been shown to have different meanings in education and the industry. In schools, according to The Royal Society, "*IT is the application of computer systems and the use of pre-existing software to meet user needs. It is the assembly, deployment and configuration of digital systems to meet user needs for specific purposes."* The definition in universities is usually different from schools and often support the usage in the industry as represented in the literature based on higher education studies (Denning & McGettrick, 2005; Ahuja et al., 2006).

A definition based on industry usage is *"the interconnection of technical and organisational innovations in electronic computers, software engineering, control systems, integrated circuits and telecommunications which make it possible to collect, generate, analyse and diffuse large quantities of information at low cost"* (Rees, 1992). This definition implies that IT in the industry is not just about how computer systems are used, but also the development of applications. The Royal Society (2012) acknowledges this broad definition as it stated that the definition of IT in schools is narrower than as used in the industry, which generally includes computer science. A possibility for the broader definition of IT in the industry could be related to the fact that the industry employ individuals from multiple backgrounds and many never have studied either computer science or IT previously.

These overlapping meanings present some issues for the literature review because of the use of different definitions. The research and statistics are not always directly comparable as they use different datasets, despite using the same terminology. For the purpose of this study and to aid the analysis of the literature, a working definition of the terminology and scope has to be agreed upon. The term *“computer science”* in this study refers to computer science as a discipline as defined by The Royal Society (2012). The term “*computer science education”* as used in this thesis refers to the educational models, methods and levels of education associated with the discipline.

The term “*computer science careers”* refers to the associated careers in computer science such as artificial intelligence, computer engineering, human-computer interaction and robotics etc.

Furthermore, the term “*computer game”* is often used interchangeably with “*video game”* in related literature: the term “*computer game”* being used to refer to personal computer based games and “*video games*” for console-based games. In this thesis, the term *“digital game*” is used to represent both usages (computer game and video game). A digital game is defined as “*one that provides some visual digital information to one or more players; takes input from players; process input according to a set of programmed game rules and alters the digital information provided to players*” (Kirriemuir & McFarlane, 2004).

The scope of the study is confined to computer science as a discipline and associated careers where females are under-represented as they appear to be less ‘women-friendly’ (Ahuja et al., 2006). To establish the nature and severity of the problem of female under-representation in computer science education and careers, the evidence is reviewed in detail in section 2.1.

This study was conducted in the southeast of England, United Kingdom. The scope of the study is focused on girls of age 11-14 in this part of the country. Although the study also collected and analysed data from 11-14 year old boys, this information was used for a comparative analysis of results between both genders.

1.5 Papers published during the course of this research

The conferences and journal publications related to this thesis are as follows:

1. Osunde, J., Windall, G., Bacon, E.A. and Mackinnon, L. (2013). Female under-representation in Computer Science education and workplace- *A survey of issues and interventions, moving towards a game-based learning solution.* Association for Learning Technologies Conference.
2. Osunde, J., Windall, G., Bacon, L., & Mackinnon, L. (2014). Female Under-Representation in Computing Education and Industry-A Survey of Issues and Interventions. *International Journal of Advanced Computer Science & Applications*, *5*(10).
3. Osunde, J., Windall, G., Bacon, L., & Mackinnon, L. (2015). An investigation of digital games features that appeal to young females and males. The 9th European Conference on Games Based Learning.

1.6 Thesis overview

The overview of the thesis is as follows:

- Chapter 2 is a review of relevant literature. It initially presents the evidence of female under-representation in computer science education and careers. It then provides a review of female representation in computer science and other Science, Technology, Engineering and Mathematics (STEM) disciplines and careers. The suggested causes of the problem from the literature, the intervention strategies implemented and their achievements over the years are then reviewed. The chapter concludes with a review of educational game frameworks and game customisations. This chapter is the basis of the first and second publications.
- Chapter 3 describes the methodology used for the study and the rationale for carrying out the two studies: exploratory and main. This chapter further describes the methodology and the rationale for the analysis of data that was collected during both studies. The chapter concludes with a summary discussion. The third publication includes a review of the exploratory study methodology discussed in this chapter.

- Chapter 4 reports on the exploratory study data analysis and results. It initially presents the analysis of data collected by location, construct, gender and appeal of constructs. The chapter concludes with a summary of the findings of the exploratory study and directions of the main study. The third publication also includes the results of the exploratory study.
- Chapter 5 initially reviews the findings of the exploratory study and choice of a suitable digital educational game for customisation. This is followed by a discussion of the design framework applied to the creation of the experimental games. The chapter concludes with a description of how the games were created and a summary of the chapter.
- Chapter 6 reports on the design of the main study to include the outline of the investigation with rationales, experimental subjects, variables, threats to the validity of findings and ethical issues for consideration during the study. The chapter concludes with a summary of the design of the main study and how it contributes to obtaining a response to the research question.
- Chapter 7 presents the data analysis from the main study, results obtained and the validation of the results. The results of the qualitative and quantitative analysis of data conducted are presented in this chapter. The chapter concludes with a discussion of the conclusions drawn from the results and how they empirically address the research question.
- Chapter 8 outlines and reviews how the research aim and objectives were met. It also identifies the main contribution of the work to the body of knowledge and the limitations of the research. The discussion on the future work and final reflections concludes the chapter and this thesis.

CHAPTER 2

REVIEW OF LITERATURE

2.0 Introduction

This chapter presents a detailed review of the relevant research literature to this study. Section 2.1 discusses the evidence of the problem of female under-representation in computer science education and careers. The section also presents a comparative review of female representation in other Science, Technology, Engineering and Mathematics (STEM) disciplines and careers.

Section 2.2 critically reviews the suggested causes of female under-representation in computer science education and careers as reported in the literature. The various arguments as presented are discussed in this section. Section 2.3 reports on the various intervention strategies that have been implemented and their overall impact. Section 2.4 focuses on the use of digital entertainment games as a strategy to engage girls and boys with technology.

Section 2.5 discusses the use of digital educational games as a tool for engagement and motivation for girls and boys. This section also reviews the challenges associated with the use of digital educational games with young people and the solutions explored. Section 2.6 is a review of educational game frameworks used in the design of digital educational games. Section 2.7 discusses how digital game customisation is used to create motivationally appealing games for a specific audience. Finally, the chapter concludes with a discussion and summary of the literature in section 2.8.

2.1 Evidence of female under-representation in computer science education and careers

The evidence of the problem is reviewed based on the participation levels of females in both computer science education and careers. The review of evidence also includes the comparative representation of females in other STEM disciplines and careers.

2.1.1 Computer science education and careers

The review of related research on the participation rates of females in computer science education and careers indicates that the participation level is low in many parts of the world (Galpin, 2002; Varma, 2010; Abbate, 2012; Hansen, 2015). This trend has a history dating back to the early 1980s, although prior to this time there was a good level of female representation in computer science careers (Light, 1999; Gurer, 2002). As at 1960, 65% of computer programmers in the United States of America were women and historically women have been highly influential in the field of computing (Gurer & Camp, 2002; Misa, 2011).

Empirical studies show that the number of females in computer science education decreases progressively from the early stages of secondary education through tertiary education and into the workplace (Papastergiou, 2009; Whitney et al., 2013; Way et al., 2016). In the seminal papers on this issue, Camp (1997) and Gurer & Camp (2002) describe this effect as *"the pipeline shrinkage problem."* This pipeline effect has been identified as a widespread issue as data collected from many parts of the world presents a broadly similar picture. However, there are some exceptions in countries such as Malaysia, Singapore, India and Thailand, where the female representation in computer science education is 50% and above (Galpin, 2002; Misa, 2011; Abbate, 2012, Gupta, 2014).

According to Gupta (2014), an argument for the difference in the representation of women in developing countries can be attributed to the representation of computers as non-masculine and being perceived as *'women friendly'*. It is also important to note that the scope of the data on the female participation in computer science education and careers in these countries might be subject to issues associated with the use of terminology where IT includes computer science and associated careers.

A review of related literature on female representation from developing countries indicates that the non-technical segment of IT, which is the part of the industry that comprise of routine task that do not require specialised technological knowledge e.g. sales and human resources comprise predominantly of a female workforce (Gupta, 2014). This information is usually included in the analysis of female representation in developing countries (Hafkin & Taggart, 2001; Wong et al., 2003; 2007). Furthermore, Gupta (2014) suggested that the difference in role reporting in the IT industry may skew the figures on female representation.

The achievement data from the United Kingdom (UK) secondary education level examinations for 16-18 year olds suggests that those females that do engage with computer science, mathematics and computing related disciplines such as information communications technology (ICT), outperform the males. The achievement performance data from the UK Joint Council of Qualifications board between 2004 and 2011 indicates that females between the ages of 16 and 18 have consistently outperformed the males in ICT and computer science at both General Certificate of Secondary Education (GCSE) and Advanced Level qualification stages.

Between 2001 and 2008, females outperformed males in mathematics with the males outperforming the females between 2009 and 2011. For Advanced Level mathematics, females outperformed males between 2001 and 2011 and in additional mathematics between 2003 and 2011(JCQ, 2014). This trend of females outperforming the males in computing and ICT examinations at Advanced Level has continued to-date. Since the introduction of computing as a GCSE qualification in 2013, females have consistently outperformed the males (JCQ, 2012–2015). Irrespective of this academic capability and higher attainment levels, the percentage of females taking up computer science at Advanced Level is on a progressive decline from 12% in 2004 to 8% in 2014 (e-Skills UK, 2014, WISE, 2015) . A review of female representation in tertiary education in the UK also indicated that undergraduate computer science qualifications which includes computer science, information systems, software engineering, artificial intelligence, health informatics, games, computer generated visual & audio effects obtained by females dropped from 18% in 2010/2011 to 17% in 2013/2014 (WISE, 2015).

A similar picture is reported in the United States of America where the number of female tertiary education graduates increased generally except in computer science education. According to Computing Research Association (2008), there has been a consistent decrease in the awards of Bachelor’s degrees in computer science from 18% in 1993/1994 to 12% in 2006/2007. Although there was a slight increase in 2013 to 14.2%, this was relatively low compared to the males at 85.8% (CRA, 2014).

Unsurprisingly, the decline in the number of females studying computer science correlates with the female under-representation in the computer science careers despite generally improving employment opportunities in this field. Employment statistics indicate a progressive increase in employment rates due to skills shortages in the industry (Lazowska, 2002; BIS, 2011; Bureau of Labor Statistics, 2014; Koebele, 2015). Although the UK computer science graduates have excellent employment rates, computer science also has the highest rate of unemployed graduates due to a number of issues such as skills, agility and work-readiness (Shadbolt Review, 2016).

Considering that computer scientists are a source of talent for the technology sector and of immense economic value, the progressive drop-off in the uptake of computer science degrees, especially amongst females, has been identified as a great concern for education and industry (e-Skills UK, 2014; Tech Women UK, 2015).

2.1.2 Comparative trend with other STEM disciplines and jobs

As discussed in chapter 1, the acronym STEM stands for Science, Technology, Engineering and Mathematics. According to the UK department for Business Innovation and Skills, STEM is defined to include physical and biological sciences, engineering and technology, mathematics and computer science (BIS, 2011). However, the specific disciplines included in the definition of STEM across the industry in different countries can vary, making comparisons hard. A historical review of the trends in UK STEM education indicates that the uptake of STEM disciplines at GCSE for both females and males are broadly similar (WISE, 2012).

Hayden et al. (2011) indicated that the strategies implemented to improve female representation in STEM education include the use of role models, development of gender-specific content, improved teaching, use of real-world scenarios in exercises and addressing misconceptions about STEM careers.

According to Women in Science Technology and Engineering UK (WISE, 2015) there have been improvements in the numbers of females engaging with almost all STEM disciplines. It was indicated that almost equal percentages of girls and boys were entered for GCSE additional science, science, mathematics, biology, statistics, physics and chemistry in 2014.

Furthermore, female representation in Advanced Level chemistry and physics increased by 13% from 2009 to 2012. The number of females taking Advanced Level mathematics increased by 17% in 2012 in the same period. However, the number of entries for Advanced Level computing has fallen progressively for ten years with the subject accounting for just 0.4% of all Advanced Level subjects. Only 6.5% of entrants were females in 2013, which is 1.5% lower than 2012 (e-Skills UK, 2014). The number of female entries for Advanced Level computing decreased from 10% in 2009 to 7% in 2013. As at 2014, it increased to 8% (Tech Partnership, 2015).

According to WISE (2015), in the UK higher education, there was an increase of females obtaining undergraduate science qualification in all courses except computer science (17%) and engineering & technology (14%). The statistics further indicated that between 2003 and 2014 the proportion of female undergraduates studying computer science decreased from 22% to 17% (Trauth, 2006; WISE, 2015).

With regards to STEM careers, both the UK Business, Innovation & Skills (BIS) and the United States of America Economic and Statistics Administration (ESA) departments indicated that there is no standard definition of what constitutes a STEM career as there is less agreement about whether to include positions such as educators, managers, technicians, healthcare professionals and social scientists (ESA, 2011; BIS, 2011). The ESA (2011) define STEM jobs to include professional and technical support occupations in the fields of computer science and mathematics, engineering, life and physical sciences. Three management occupations – computer and information systems, engineering and natural sciences managers are also included because of their clear ties to STEM (ESA, 2011).

The BIS (2011) report provides a career classification into STEM-core (careers related to degree disciplines e.g. laboratory technicians), STEM-related (degree disciplines related to the career e.g. accountancy as a career is seen as strongly degree-related to mathematics) and unrelated to STEM (the careers do not apply the related disciplines e.g. a sports scientist working at a local fitness centre is a degree-related to STEM but neither the role nor the sector is regarded as within or related to STEM). In this thesis, the term *"STEM career"* is used to refer to professional and technical support professions associated with STEM disciplines.

However, wherever data or literature includes other careers that are not directly associated with STEM degree disciplines e.g. education jobs; this is indicated in the discussion.

Historically the representation of females in STEM careers and disciplines such as mathematics, physics, chemistry, computer science and technology has been poor. The Economic & Statistics Association (USA) indicated that 40% of men with STEM degrees work in STEM careers compared to 26% of women (ESA, 2014). In the UK, 13% of the STEM workforce between 2011 and 2012 were women but increased marginally to 14.4% in 2015 (WISE 2012, 2015). Although there was a slight increase, this is low compared to the representation of males in STEM careers.

Furthermore, the ESA (2014) reported that within the STEM careers, computing and mathematics jobs account for close to 47% of all STEM employment. Women's representation has varied over time across the STEM occupations, with the female share in computer science declining over the years as their share has risen in other STEM occupations such as physical life sciences and STEM management jobs (ESA, 2014; Beede et al., 2011; Riegle-Crumb et al., 2012; Baker, 2015).

In summary, the general representation of females in STEM disciplines and careers have increased in recent years with the exception of computer science as a discipline and career choice for females (Zagami et al., 2015).

2.2 Possible causes of female under-representation in computer science education and careers

Three factors have been reported to explain female under-representation in computer science education and careers. These factors can be classified into essentialist factors (Trauth, 2002; Wajcman, 1991), socio-cultural factors (Trauth, 2006; Ryder, Ulriksen & Bøe, 2015) and structural factors (Teague, 1997; Ahuja, 2002; Ferriman et al., 2009; Ceci et al., 2009; Ceci & Williams, 2009).

Arguments based on essentialist theory suggest that under-representation of females in fields such as computer science is caused by fixed inherent differences between females and males.

Alternative theories based on the socio-cultural viewpoint hold that the differences are caused by external factors (e.g. stereotyping) and internal factors (e.g. self-expectation) which influence the development of females and males (Epstein, 1998; Teague, 1997; Ceci & Williams, 2011). Both external and internal factors originate from societal and cultural perceptions. They translate into accepted *"norms"* and *"beliefs"* which influence how girls and boys develop their self-perception in relation to computing. According to Shashaani (1994 &1997) and Huffman et al. (2013) girls self-perception results in them feeling less confident with computers in comparison to the boys, and seeing computers as a boy's domain.

Closely linked to socio-cultural factors are structural factors, which arguably constrain the representation of females in computer science education and career. Structural constraints can be found in home and family life, the learning environment and the workplace. Wright (1997) suggested that this could result in many girls showing a lack of interest in computers and computer science careers.

Both socio-cultural and structural factors have been shown to affect career choice, career persistence and advancement (Ahuja, 2002; Wang, & Degol, 2013). The following sections review in detail the contributing factors from all three perspectives.

2.2.1 Inherent gender differences and engagement with technology

This theory assumes that fixed inherent gender differences such as the typical empathising (female) and systemising (male) brain wiring (Baron-Cohen,2009) can influence female and male decisions to engage with technology including computing (Wajcman, 2000; Thomson et al., 2015). In a study to obtain explanations for the under-representation of females in science by Cerci et al. (2009), it was concluded that the evidence for inherent biological differences is inconclusive. A similar conclusion maintained by Nash & Grossi (2007), Jordan-Young & Rumiati (2012) and Fine (2010; 2012). A critical conclusion proposed by Trauth (2002) and Wagner (2016) to this argument, in addressing female under-representation in computer science education and careers, is that females and males should be treated differently but equally.

A serious problem with the essentialist perspective is that it further isolates females as they emphasise gender stereotypes that can patronise women (Adam et al., 2001; Trauth, 2002). Furthermore, the essentialist perspective goes against all evidence of female achievements in computer science education (JCQ, 2005, 2009, 2011 & 2015) and in countries such as India, Singapore and Malaysia where females dominate the industry (Misa, 2011; Abbate, 2012; Gupta, 2014). While the essentialist arguments are made to explain the issue of under-representation, there is very limited and conflicting evidence to support those arguments.

2.2.2 Socio-cultural factors

The socio-cultural argument identifies gender as a cultural term used to refer to men and women in social groups with expectations for each sex to have characteristics that equip them for tasks their sex performs in their society (Wood & Eagly, 2002). Over time, these roles become engrained into the society and guide social behaviour (Eagly et al., 2000). According to Unger (1979), gender can be expanded to include assumptions made by others about a particular gender or self-imposed ideas about how a man or woman should function in a given society. Huffman et al. (2013) further commented that in the society, men are typically associated with being more skilled with technology.

Furthermore, gender bias against females by other people in the society with regards to their competence in comparison to the males in the computing learning environment, media, work and family has been noted in related literature as a factor that can discourage females from engaging with computer science education and careers (Garson 1995, Lovegrove & Segal, 2013). In some cases, gender bias in these environments (learning environment, media, work and family) could be unintentional i.e. unconscious gender bias (Wyer et al., 2013; Smyth & Nosek, 2015).

The socio-cultural argument further indicates that societal factors instead of inherent factors primarily shape the individual and their relationship with computing (Marini, 1990). The socio-cultural argument suggests that gender differences with computer science are as a result of societal norms and beliefs that it is a male domain (Huffman et al., 2013; Cheryan et al., 2015). This results in significant differences in confidence demonstrated by girls and boys towards computers (Busch,1995; Huffman et al., 2013).

Confidence is higher in the boys as they believe that mathematics and computing is a domain for males (Huguet & Regner, 2007; Master et al., 2014; Cheryan et al.,2015). Shashaani (1993) referred to this as the *"gender role socialization".* Wood & Eagly (2002) further reviewed the implication of gender roles in modern society as contributing to the sex-typed division of labour.

Wang & Degol (2013) also reported that differences in gender roles created by society and confidence contribute significantly towards career decisions. This is because our behavioural choices can be guided by our expectations, confidence in our abilities and personal efficacy (Eccles, 2009). In addition, unconscious bias towards females also hinders the access and progression within computer science careers (Whitney et al., 2013; Davis, 2015). A review of different aspects of socio-cultural factors is further explored in the next section.

2.2.2.1 Confidence and motivation

There are significant differences in self–confidence exhibited by females and males in the computer science environment.

This has been evidenced to be common with educational or career settings dominated by societal expectations for females and males (Sanchez & Crocker, 2005; Peterson, 2010). Consequently, females exhibit low self-confidence in the computer science environment as compared to the males who are very confident (Shashaani & Khalili 2001; Durndell & Haag, 2002; Huffman et al., 2013).

In an academic setting, females often become more motivated by striving for favourable judgements of their competence from colleagues as opposed to actually enhancing their competence. This could be because of the common understanding between the genders that mathematics and computer science are for boys (Temple & Lips, 1989; Dweck, 2008; Devine et al., 2012).

According to Fine (2011), the effect of socially constructed gender differences results in stereotypic educational and work environments. This consequently influences female confidence and motivation to study computer science as a discipline and access computer science careers.

Research has also established inter-relationships between motivation, confidence and efficacy (Phillips & Lindsay, 2006; Butler & Lumpe, 2008). To develop self-efficacy, there has to be confidence in the ability to accomplish the task, however, to improve one's ability takes time. The confidence to improve increases rapidly given a positive stimulus or experience leading to the motivation to complete the set task (Wu et al., 2011). This motivation can be intrinsic or extrinsic. Intrinsically motivated learners have been considered more successful because their learning goal is to achieve satisfaction and enjoyment. Extrinsically motivated learners tend to make the minimum effort required to avoid punishment or to gain rewards (Lepper, 1998).

Alternatively, the negative stimulus such as stereotypic beliefs diminishes all three variables: motivation, confidence and efficacy. Behm-Morawitz & Mastro (2009) and Cheryan et al. (2015) indicated that negative stereotypic beliefs such as the characterisation of the computer scientist tend to be also presented in popular media and other environments such as online educational materials. The influences from these sources subconsciously affect the social perception of gender differences leading to unconscious bias in computer science education and careers.

2.2.2.2 Perception of the Computer Scientist

Studies on societal perceptions of the computer scientist suggest that society has a profound influence on young girls' image of themselves in relation to computer science (Badagliacco, 1990; Ahuja, 2002).

Most of the images of the computer scientist are negative and imply that computing is for *"nerds"* or men who are socially awkward, isolated and do not engage in community activities such as helping or working with others (Mercier et al., 2006; Cheryan et al., 2013).

In a study involving eighth-grade pupils' (13-14-year-olds) expectations of what a knowledgeable computer user would look like by Mercier et al. (2006), it was shown that the majority expected a male user with glasses. However, the picture created by the sixth-grade pupils (11-12-years-olds) presented less stereotypic characteristics and a reasonable number of female representations. This perception of the computer scientists was also supported by Misa (2011) in a report on defining the problem of gender codes in computing and Wong (2017) in a study on how digitally skilled young people viewed the computer person. This gender-specific view of computer science begins to develop from the early stages of secondary education and becomes entrenched towards the end of secondary education (Dryburgh, 2000, Zaidi et al., 2017). This invariably influences the career choices of girls towards the end of secondary education (Wang & Degol, 2013).

2.2.3 Structural factors

Structural factors have been shown from empirical studies to also impact on education and career access, choice and advancement (Ahuja, 2002; Wang & Degol, 2013). The key structural factors include:

2.2.3.1 Home and family life

In academia and industry, men and women face challenges in pursuing demanding careers like computer science while meeting family responsibilities. However, research indicates that women and men are affected differently by the *"family penalty"* (Simard et al., 2008).

Women tend to forego marriage or children and may delay having children in order to pursue demanding careers such as computer science (Hill et al., 2010). Although marriage does not appear to impact on a career, having children in the home may affect work-related productivity because traditionally women are the primary caregivers in the home setting (Stack, 2004). In addition, women have also been identified as the predominant caregivers to elderly parents and grandchildren, which are likely to impact on labour force participation and progression (Hirschfeld & Wikler, 2003; Lee & Tang, 2013).

2.2.3.2 The learning environment

Both external and internal factors in the computer science learning environment have been identified as a contributory factor of the under-representation of females in computer science education (Miliszewska et al., 2006). External factors such as the perception by females that the computer science learning environment is *"male-dominated"* (Miliszewska et al., 2006), *"Hostile"* (Wilson, 2002) and *"Nerdy"* (Mercier et al., 2006), can result in females having low self-confidence in their computing skills (Lazowska, 2002).

In a study on the influence of the computer science learning environment on the level of attrition at the tertiary educational institution by Miliszewska et al. (2006), it was concluded that other factors excluding the computer science learning environment were responsible for the high attrition levels. The factors indicated were family concerns about the course, lack of interest in the course from the beginning and the overall difficulty of the course especially the programming elements (Miliszewska et al., 2006).

However, studies have indicated that gender stereotypic learning environments which promote the notion that females are not as good as males in computer science do influence the mindset of females negatively (Hill et al., 2010; Beede et al., 2011; Vekiri, 2013; Godsil, et al., 2016).

2.2.3.3 Attitudes towards computers

Chen (1986) and Durndell & Haag (2002) reported that young males held more positive attitudes towards computers and had lower computer anxiety than their female counterparts. This was supported by Simsek (2011) in a related study on the relationship between computer anxiety and computer self-efficacy.

There is also a significant gender difference concerning attitudes towards computers, with females having attitudes that are more negative i.e. a general perception that males are more competent with computers as reported by Levin & Gordon (1989), Shashaani & Khalili (2001) and Sáinz & Eccles (2012). Busch (1995) reported that socialisation provides an explanation for the gender differences in attitudes towards computers.

Busch (1995) argued that gender-role identity is formed initially within the family, where norms are internalised, attitudes learned and self-image acquired. These behaviours are later reinforced or shaped in school and work settings where society's basic culture is transmitted to its inhabitants. Busch further stated that gender differences in attitudes towards computers may be a reflection of social experiences. These experiences as discussed in section 2.2.2.1 could influence the motivation, confidence and personal efficacy to engage with computer science (Wu et al., 2011).

2.2.4 Summation of arguments

A review of the three arguments for the causes of female under-representation in computer science education and careers suggests that both socio-cultural and structural factors contribute significantly to this issue. Although there have been discussions on the third argument (inherent gender differences), it is very controversial with limited evidence in its support. Consequently, in this thesis, this argument is not pursued further.

Studies have also shown that there is a considerable difference in gender confidence with computer science. This has been associated with both the socio-cultural and structural factors, which attach masculinity to technology and computers. The effect of this is confident boys and less confident girls. This lack of confidence demonstrated by most girls results in poor motivation, low self-efficacy, and loss of interest to engage with the subject and consequently a career in computer science.

2.3 Intervention strategies and initiatives

A number of strategies and interventions have been explored to address the issue of female under-representation in computer science education and career. The solution(s) applied in any given instance depends on the nature of the problem identified (Galpin, 2002). The key intervention strategies implemented are further reviewed.

2.3.1 Gender grouping, collaborative working, role models and mentoring

A seminal study carried out by Dryburgh (2000) indicated that gender grouping, role models/mentors, school curriculum and organisational policies are important socio-cultural determinants for motivating females into computing. In a review of the importance of mentoring in higher education, Hill et al. (2010) stated, *"it helps address the feelings of isolation and marginalisation".*

Inkpen et al. (1995) and Zhan et al. (2015) show that gender grouping improved performance and attitudes in the computer science education environment more significantly in females than males. Other studies have indicated that the implementation of pair programming is beneficial for all computer science students, especially female students at post-secondary levels (Werner et al., 2005; Carver et al., 2007; Choi, 2013).

Werner et al. (2005) and Watson & Li (2014) further demonstrated that it particularly improves the confidence of females and consequently reduces attrition levels.

2.3.2 Working parties and initiatives

As a result of the disproportionately low numbers of women in computer science education and the workforce, working parties and initiatives have been instigated to improve the awareness of this problem and provide support measures for females.

In the USA, a number of initiatives (Women in Computing Committee, The Kindergarten to 12th Grade, MentorNet etc.) have been set up to encourage women into computing at both the pre-tertiary and tertiary education levels (Klawe et al., 2009; Whitney & Ames, 2014). These groups also seek to ensure that role models are provided; computer science career myths are dispelled and accurate information provided to key influencers of girls (Klawe et al., 2009).

In the UK, many groups have been inaugurated with the aim of recruiting and retaining girls and women in IT. BCSWomen (Chartered Institute for IT) is an example of such a group (BCS, 2016). The TechFuture Girls which encourages girls between ages 10-14 to engage with IT and take up the study of the subject at a higher level is another example (TechFuture Girls, 2016).

Some UK schemes such as Code Bar and Code Club UK provide workshops for computer coding clubs for girls (e-skills in Europe, 2014; Tech Women UK, 2015).

2.3.3 Educational policies

A number of reports have supported the review of educational policies and structure in order to improve the accessibility of computer science study (The Royal Society, 2012; Computing At School, 2012). In England, UK, because of these reports, computer science has been introduced in the national curriculum and was mandatory for delivery in 2014 from Key Stage 1 to Key Stage 4 (Department for Education, 2013). It is anticipated that this initiative may improve female representation in computer science education and subsequently the computer science careers due to improved accessibility of the subject from an early age. According to Armoni & Gal-Ezer (2014), early introduction of computer science to young females in Israel improved the representation levels of females in the subject and careers.

However, the quality of computer science teaching in schools could influence unfavourably on the early introduction of computer science in the national curriculum. As a result, in England, there is a proactive measure to develop teaching excellence in computer science for new and existing teachers. This strategy aims to ensure that confident and effective professionals can motivate learners to engage with the subject (BCS, 2013). The impact of both strategies on the representation of females in computer science education should be reviewed in a few years as the implemented initiative progresses.

2.3.4 Games in society

From the historical context, the first commercial digital entertainment games were adult arcade games, made available in public locations (Williams, 2006). As consoles became available for private use, digital games were marketed as family entertainment.

This meant digital entertainment games could be played in the family home. In the mid-1980s, Nintendo Entertainment Systems (NES) released the Famicom console which was aimed at children and foremost boys in order to find a secure market (Krotoski, 2005). Krotoski further stated that prior to this time digital entertainment games were aimed at men, women, old and young alike. This shift towards young men changed the ideas on digital entertainment game marketing and strategy of production. Consequently, Haddon (1988) commented that during the 1980s and early 1990s, digital entertainment games were seen as boys' toys leading to the marginalisation of female users. This development during the 1980s and early 1990s contributed to the alignment of societal expectations and stereotypes of game designers with the masculine domain as evidenced in the late 1980s onwards (Kiesler et al., 1985; Huff & Cooper, 1987; Huff 2002).

The success of Barbie Fashion Designer for girls in the mid-1990s led to the development of the first *'pink games'* (Leaver & Willson, 2016). This progressed into the development of games for girls in order to encourage girls into gaming and provide technological knowledge (Beavis, 2005; Hayes, 2005). Currently, in the UK, 52% of the digital entertainment gaming audience is comprised of females as compared to 48% male gamers as reported by the Internet Advertising Bureau UK (IAB, 2014).

Consequently, digital entertainment games have become an integral part of our social and cultural environment and have a particular appeal to both children and adolescents (Mumtaz, 2001;Kankaanranta, 2017).

According to Chatfield (2011), digital entertainment games provide engaging and enjoyable activities. These enjoyable activities are active, experiential, problem-based and provide immediate feedback (Boyle et al., 2011). These factors and the ease of access to digital games have been used to engage young people with the use of technology (Davis, 1989; Connolly et al., 2012) and computer science (Papastergiou, 2009; Gilliam, 2017).

2.3.5 Discussion and summary of initiatives and interventions

The review of the initiatives and interventions to get more girls into computer science education and careers indicates that the perception of the subject and the career is a key determinant to improving the representation of females.

This involves the perception of females and key influencers of girls. Other initiatives include the use of role models, workshops, restructuring of educational policies and the use of technology such as digital educational games to engage more young females with computer science.

Sections 2.4 to 2.7 reviews in detail digital entertainment and educational games in relation to gender differences. This review further investigates the use of educational games to engage more young females with computer science considering the success of digital entertainment games with both females and males.

2.4 Digital entertainment games and gender

In addition to the recreational aspects of digital entertainment games, their use has also engaged more girls and boys with the use of technology (Rubin, 1994; Ruggiero, 2000; Sherry et al., 2006; Greenberg et al., 2010; Granic et al., 2014). This has been very successful considering that currently, digital entertainment games are increasingly popular with females as much as males.

Data analysis indicates that an increasing number of females, including the older women (ages 23-40), are also becoming gamers, with the gap between males and females closing rapidly (Yee, 2009; ESA, 2015) and females now taking the lead (IAB, 2014). Furthermore, social networking platforms have also become very popular with both genders with a higher representation of females.

According to The Associate Press (2012) there are more than 500 million active users spending about 700 billion minutes a month on the site and sharing more than 30 billion pieces of content each month. Active users are classified as those users who return to the site within 30 days. An analysis of this data reveals that 61.1% of these active users are females (Watkins & Lee, 2010). In addition, 53% of Facebook users (265 Million) play Facebook games and 69% of these gamers are women (Jasra, 2010).

The literature and trend data on the engagement with digital entertainment games by females and males indicates that they are successful with all age groups and both genders. It also indicates that the introduction of digital entertainment games to both genders has actually improved the engagement with different technologies.

Consequently, terms such as *'Net generation'* (Tapscott, 1998) or *'digital natives'* (Prensky, 2001) have been used to describe the immersion in technology exhibited by individuals born between 1980 and 1994.

Additionally, individuals who were born prior to 1980 have also demonstrated impressive levels of adaptation to emerging technologies hence they were also referred to as *'digital immigrants'* by Prensky (2001).

Identifying the empirical evidence of the reasons for the success of most digital entertainment games provides an insight into its cross-gender capability.

2.4.1. Reasons for the success of digital entertainment games with females and males

Since the early 1980s, digital games have been extremely successful with males and then increasingly with females from the mid-1990s. The success of digital entertainment games with females and males is closely associated with what motivates them to play digital games (Boyle et al., 2012). Consequently, if a digital game possesses the qualities that motivate the individual to play, then the game is immersive and successful in meeting player needs (Ferguson & Olson, 2012).

In his seminal article, Malone (1981) identified three reasons: fantasy, challenge and curiosity, for engaging with digital games. Subsequent studies identified other reasons such as competition, storyline, social interaction, competence, autonomy and self-efficacy (Sherry et al., 2006; Ryan et al., 2006; Klimmt & Hartmann, 2006; Lenhart et al., 2008; Yee, 2009; Griffiths, 2010; Poels et al., 2012).

Competence refers to the general need to have fun, be successful and be good at something. Autonomy refers to the players' use of digital games as an outlet where they feel that they have some control (Lenhart et al., 2008; Ferguson & Olson, 2012).

Ferguson & Olson (2013) argued that young males also use digital games to meet the need for fun, challenge, catharsis and socialisation.

The need of girls was identified to be similar to that of the boys. However, boys demonstrate a higher level of endorsement of fun, challenge, catharsis and socialisation elements.

Ferguson & Olson (2013) further argued that this difference was linked to the self-determination theory. This theory highlights the factors, which facilitate or undermine motivation (intrinsic and extrinsic) to engage with digital games.

Seminal articles on self-determination theory with digital games were focused on intrinsic motivation i.e. inherent satisfaction needs for engaging with digital games (Malone & Lepper, 1987; Frederick & Ryan, 1993, 1995; Ryan & Deci, 2000).

Ryan & Deci (2000) indicated that intrinsic motivation can be supported or thwarted by other contextual factors such as game autonomy and player competence. The impact of these factors on intrinsic motivation has been supported in related work (Bartle, 2004; Ryan & Brown, 2005). In addition to both autonomy and competence factors, the game presence has been identified as key in supporting intrinsic motivation (Lombard & Ditton, 1997; Rigby, 2004; Ryan et al., 2006). Game presence refers to the sense that one is within the game world as opposed to experiencing the game from the outside. This concept has been adapted in the virtual world of games to feel real by creating a compelling storyline, graphic environment and making controls user-friendly (Ryan et al., 2006).

Ryan et al. (2006) further commented, *"game features that conduce to increased perceptions of autonomy, competence and relatedness enhance motivation to play."* More recent studies support this statement as an improved perception of games enhances the motivation to play digital entertainment games thereby making them more appealing to the audience (Ryan et al., 2006; Klimmt., 2009; Przybylski et al., 2011; Wu et al., 2011; Connolly et al., 2012; Powell et al., 2012).

In conclusion, the fundamental reason for the success of some digital entertainment games with females and males could be associated with the appeal of the digital games. The appeal of these games is dependent on the perceptions of the game features or characteristics which can either support or thwart motivation. Good levels of motivation results in improved self-efficacy and interest of players (Powell et al., 2012).

Digital educational games have been used in a similar manner as digital entertainment games to engage young females and males with computer science. The use of digital educational games with females and males is reviewed in the next section.

2.5 Digital educational games and gender

Research shows that the intrinsic motivation demonstrated towards digital entertainment games provides the opportunity for their use as a learning tool (McFarlane, 2002; Kafai, 2006). This is because studies have shown that young people's intrinsic motivation towards games often contrasts their lack of interest in curricular contents (Facer, 2003; Prensky, 2003; Joiner et al., 2011).

The motivation of games combined effectively with curricular content to create what Prensky (2003) referred to as "*Digital Game-Based Learning"* (DGBL). This has resulted in the creation of digital educational games for geography, engineering, biology, computer science etc. (Tüzün et al., 2009; Ebner, & Holzinger, 2007; Annetta et al., 2009; Papastergiou, 2009).

Research on the use of digital educational games as a learning tool has investigated their use within a computer science curriculum and its impact on young females and males. In a Greek school context, Papastergiou (2009) investigated the use of a digital educational game and a non-gaming educational application for learning computer memory concepts. The aim of the study was to assess the learning effectiveness and motivational appeal of digital learning games for computer science. The outcome showed that digital educational games for learning computer science could be exploited as a motivational learning environment regardless of student gender.

The reason for the conclusion was that the students that were provided with the digital educational game were more enthusiastic, absorbed in the task, demonstrated a keen interest in the task and had higher levels of engagement, compared to the non-gaming application group. This finding supports earlier outcomes from Klawe (1999), Rosas et al. (2003) and Ke & Grabowski (2007).

Papastergiou (2009) further reported that there were no gender differences in the motivational appeal of educational games also supported by Ke & Grabowski (2007).

However, these findings contradict the outcome of a similar investigation conducted by De Jean et al., (1999); Young & Upitis (1999) which reported that there are gender differences in the motivational appeal of educational games.

Studies by Klimmt (2009), Przybylski et al. (2011), Wu et al. (2011), Boyle et al. (2012), Powell et al. (2012) Huang et al. (2013) and Ferguson & Olson (2013) confirm that there are gender differences in the motivational appeal of digital educational games depending on the perceptions of the game characteristics which can either support or thwart motivation. The absence of gender difference as suggested by Papastergiou (2009) with digital educational games for learning computer science would occur when the game characteristics provide similar motivational appeal to young females and males.

Consequently, a major challenge in the use of digital educational games to engage girls from an early age is ensuring that the game characteristics support motivational appeal (Gorriz & Medina, 2000; Kinzie & Joseph, 2008; Kankaanranta, 2017).

2.5.1 Challenges in engaging girls with computer science using digital educational games

Digital educational games are designed to promote learner engagement through motivational appeal. However, research into their impact on girls has raised concerns over the content of games. This could be restricted gender roles, gender identity issues and other game characteristics that are unsupportive of the motivational appeal for girls (Hartmann & Klimmt, 2006; Lynch, 2016).

These factors have been shown to encourage gender stereotyping leading to problems with gender identity by associating a gender i.e. the boys with games (Dietz, 1998; Margolis & Fisher, 2002; Boyle et al., 2011).

The issue of gender identity which arises from the stereotypic nature of the game content can lead to a *“reconstruction of identity,”* influence the social perspective of the game and perception of one’s ability (Chee, 2007). As a result, it has been reported that digital educational games can promote low self-efficacy and gender-linked roles with females in the computing environment (Huffman et al., 2013; Beyer, 2014).

This finding has led to further reflection on the role of educational software in the under-representation of females in computer science education and careers (Huff, 2002; Stoilescu & McDougall, 2011; Misa, 2011; Scott & White, 2013; Sanders et al., 2013). It has been acknowledged that embedded gender stereotypic content in educational software could be negative to educational and occupational choices of females (Wu et al., 2006; Powell et al., 2012).

It has also been reported that educational software designed for *“children”* and *“students”* (gender unspecified) was the same as educational software designed specifically for *“boys”* (Huff, 2002; Heemskerk et al., 2009) due to the embedding of gender stereotypic content. This has been noted to result in a difference in attitudes towards educational software, with males exhibiting a more positive attitude than females (Bulkeley, 1994; Simsek, 2011; Huffman et al., 2013).

In addition, more women and girls suffer from computer anxiety as compared to males (Huff, 2002; Wu et al., 2011; Celik & Yesilyurt, 2013) due to the gender stereotypic nature of educational software. The issue of gender stereotypic content was initially addressed by the development and use of both gender neutral and gendered games.

2.5.2 Gender neutral educational games

Gender neutral or equitable educational games are designed to reduce or remove *“male type”* or *“female type”* representations from the software. This includes representations of violence, competition, explosions, war scene etc. Gender neutral games have been argued to provide girls and women better opportunities to explore systems and arrive at solutions (Cooper & Weaver, 2003). However, there are opposing arguments about the most appropriate representations of gender neutral characteristics. For example, the uses of non-gendered characters such as cute animals can be considered condescending and unrealistic for both genders (Ferguson-Pabst et al., 2003).

Another controversy with gender neutral games is that gender neutral representations have little appeal to both female and male audiences as both genders are more familiar with gendered representations as compared to gender neutral representations (Cherney et al.,2003; Cherney & London, 2006).

Cherney & London further argued that boys prefer gendered games and that girls are in need of games that appeal to them. The need for games that appeal to girls was also supported by Van Reijmersdal et al. (2013) and Black et al. (2014).

2.5.3 Gender specific educational games

In contrast to gender neutral games, gender specific software has different versions for females and males. This approach is based on the evidence that gender specific preferences exist (Raney et al., 2006; Salisch et al., 2006). In the design of the games, an attempt is made to include the characteristics of preference to the target gender.

A typical male gendered game (i.e. games with representations that specifically appeal to males) includes a weak female protected or rescued by powerful male, visual portrayals of females highlighting physical attributes, exaggerated sexuality, competitive structure and an abundance of violence (Beasley & Standley, 2002; Downs & Smith, 2005; Vordere et al., 2006).

Other descriptions of boy games by Huff (2002) suggested that boys like games with time pressure, eye-hand coordination, and most importantly, competition. Games designed for girls looked like *"tools"* for learning with conversation and goal-based learning.

A number of disadvantages have been linked to gendered games. Downs & Smith (2005) and Behm-Morawitz & Mastro (2009) maintained that gendered games can lead to more gender stereotypic designs of games and promote undesirable representations of both genders. Hartmann & Klimmt (2006) asserted that gendered games can repel participation and even cause annoyance. Furthermore, the goal-oriented learning model as favoured by designers of female gendered games (i.e. games with representations that specifically appeal to females) has been identified to reduce self-efficacy and development of competence in most instances as the focus of the learner is on the outcome and not the actions that lead to the outcome.

A focus on the outcome results in a learning process that is not sufficiently self-regulated impacting on the development of competence and self-efficacy (Dweck, 2008). Beckwith et al. (2006), suggested that high self-efficacy is critical in problem-solving because it influences the use of cognitive strategies.

Considering that computer science educational materials are predominantly software based, the proliferation of gender stereotypic content and their effects are far reaching to learners of all ages.

To improve the motivational appeal of digital educational games, they have to be created to include game characteristics that appeal to the target audience (Barab et. al., 2005; Barab et al., 2010). The use of digital educational games frameworks has to be incorporated into this process to provide guidelines for the effective combination of game characteristics (Amory, 2007; Gunter et. al., 2008; Wilson et. al., 2009; Bedwell et al., 2012).

2.6 Digital educational game frameworks

A number of digital educational game design frameworks have been proposed and used over the years for creating digital educational games. Each design framework specifically focuses on the user experience by using the appropriate representations and embedding the learning outcomes in the game environment (Amory et al., 1999; Garris et. al., 2002; Salen & Zimmerman, 2004; Kiili, 2005; Maragos & Grigoriadou, 2005; de Freitas & Jarvis, 2006; Song & Zhang, 2008; Yusoff et al., 2009; Ibrahim & Jaafar, 2009; Aleven et al., 2010). Significant to all educational game frameworks is the learning outcome, which fundamentally differentiates educational games from entertainment games.

From the review of the available frameworks, differences between the frameworks include the conciseness of the guidelines on the use of representations or characteristics to improve motivation, immersion and user reflective attributes. From the list of reviewed frameworks, Aleven et al. (2010); Garris et al. (2002) and Amory et al.(1999) frameworks focused on the use of game representations to improve the motivational appeal of digital educational games. Consequently, these three proposed frameworks for the design and development of digital educational games were chosen and further reviewed for the purpose of the study.

2.6.1 Aleven et al. (2010)

This framework presents an insight into the design of digital educational games that achieve two main objectives: fun and education through the effective use of instruction design principles.

This framework, consisting of three components, is used to analyse and design educational games. It is also used for effectively combining the game components which are: 1) Learning Objectives; 2) Game Mechanics, Design and Aesthetics (MDA); and 3) Instructional Design Principles.

The learning objective as the first component of the framework should be effective. To achieve this, the player must have some prior knowledge of the learning objective. In addition, a definitive learning outcome should be identified for the player and the development of transferable skills and knowledge during gameplay.

The game mechanics, design and aesthetics as the second component of the framework provides the taxonomy for the game mechanics which are the basic rules on which the game is built defining the materials, rules, explicit goals, basic moves and control options available to the player. The Dynamics of the game are the behaviours that result when applying the game mechanics with player input during gameplay. Some of the taxonomy of the aesthetics includes sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission.

This taxonomy of aesthetics is commonly referred to as the "*fun"* generated by the game. The framework of the game mechanics, design and aesthetics are decided by the analyst and designers depending on the target audience and the learning objective of the game. The fun element of a game is dependent on the success of the aesthetic goals. The game mechanics and dynamics are the tools for achieving both the fun and educational objectives.

The Instructional principles as the third component of the framework support the designers in deciding how the game would support learning and the consistency of the system with established learning science findings and recommendations. It is also possible within this component to extend the principles with the aim of improving the game to support a more effective way of learning. The instructional principles work predominantly at the level of the game mechanics and dynamics to ensure that the learning occurs while the users are having fun. This might require design decisions to trade off educational objectives and fun objectives.

2.6.2 Garris et al. (2002)

This framework was designed to support designers in developing educational games that motivate learners both intrinsically and extrinsically. The framework has its fundamental outline from the Input-Process-Outcome model. The input components are the instructional content and game characteristics. The game characteristics are identified as the component that ensures that the instructional component is effective. However, the element of the game characteristics that is essential to its success in disseminating instruction varies depending on the learning outcome and the target audience/users (Aleven et al., 2010).

At the process stage, the framework explores the tactical combination of the instructional content and game characteristics, which trigger a cycle referred to as the *"game cycle."* The cycle comprises the user judgement because of the interaction of the instructional and game characteristics and consequent user behaviour resulting in the system feedback.

The defining characteristics of the framework are such that the game cycle ensures that the users are engaged in repetitive play and continually return to the game activity. This is a central hallmark of gameplay and its successful use as a learning tool (Garris et al., 2002).

It is the effectiveness of the game cycle that enables designers to embed instructional applications in educational games using this framework. This process, as a result, encourages the construction of knowledge through an experiential learning approach (Duffy & Jonassen, 1992; Gredler, 1996; Boyatzis & Mainemelis, 2000).

The debriefing process provides a link between the game cycle and the achievement of the learning outcomes which is essentially the link between the gaming experience and the real world. This process may include the description of events that occurred during gameplay and analysis of why they occurred. This would be further explored by the user to identify mistakes that occurred and corrective actions required identified. This process is a fundamental link between game experiences and learning. The debriefing process occurs before the identification of the learning outcome(s) of the gameplay.

The learning outcome(s) is the output of the conceptual framework and has been identified to be a multidimensional construct. Based on the commonality of the attempts to classify types of learning outcome(s), three main types have been identified: skill-based which addresses technical or motor skills, cognitive based which comprises three subcategories – declarative, procedural and strategic knowledge. The third category of learning outcome(s) is the affective learning outcome which refers to attitudes towards learning (Garris et al., 2002).

2.6.3 Game Object Model (GOM I & GOM II)

The game object model (GOM I) was originally presented by Amory et al. (1999). It describes a relationship between the game learning content and game representations. The game object model is loosely based on the object-oriented programming concepts such as encapsulation, inheritance and polymorphism because it can be used to analyse the development of complicated designs. The GOM could also be used to understand complex situations. The components of the model are referred to as "*objects,"* each of which is described through abstract (pedagogical and theoretical constructs) and concrete (design elements) interfaces. Educational game designers make use of the abstract interfaces in the conceptual phase of game design while game developers embed pedagogical aspects as concrete interfaces into game software and gameplay (Amory, 2007).

The *objects* in the game object model are either freestanding or part of other *objects*, in which case they inherit all the parent interfaces. The structure of the model is such that inner objects inherit all of their parent interfaces that are mainly concrete interfaces. The outer objects are more abstract. The theoretical construct of the game object model is such that the Game Space encapsulates the Visualization Space which in turn encapsulates two other objects - Elements Space and Problem Space.

The Element Space encapsulates only the Actors Space that has two concrete interfaces (Gestures and Interaction). The Problem Space encapsulates the communication, literacy, memory and motor objects. These objects inherit all of the concrete interfaces of the Problem Space.

The concrete interfaces of the communication object are reading, writing and speaking; literacy are visual, logical, mathematical and computational; memory (short-term and long-term). Lastly, the motor objects include the manipulation and reflex concrete interfaces.

The Element Space is polymorphic as it contains a combination of concrete (graphics, sound and technology) and abstract (fun) interfaces.

Furthermore, the Visualization Space is also polymorphic due to the combination of concrete (story-line) and abstract (critical thinking, discovery, goal formation, goal completion, competition and practice) interfaces. The Game Space includes four motivational abstract interfaces - play, exploration, challenge and engagement (Rieber, 1996; Thomas & Macredie, 1994; Schank & Cleary, 1995; Amory et al., 1999).

This framework has been used to successfully design academic adventure games (Amory, 2001; Foko & Amory, 2004; Seagram, 2005, Ke, 2016). This framework was further enhanced by Amory in 2001 to a more inclusive version the game object model II (GOM II) by the introduction of the Social Space Object. A further modification includes the shared inheritance of the Problem Space by the Visualization Space. The Social Space is introduced in GOM II to support on-line communities and make effective use of emergent technology – based social interaction.

From the review of the three educational game frameworks, their application during games design can facilitate the evaluation of the digital game for educational effectiveness and ensuring that the game is motivationally appealing to the target audience as these frameworks support the use of game representations for this purpose.

The game customisation process ensures that these requirements are met in a game design life cycle as the game is created to meet specific user needs while retaining its educational effectiveness, thereby improving the user experience.

2.7 Digital game customisation

Digital game customisation is the modification of some aspects of an interface to a certain degree so as to increase personal relevance (Marathe & Sundar, 2011). Digital game customisation can involve the alteration of game representations or characteristics for fulfilling task-based goals e.g. enhancing font sizes for readability (i.e. functional customisation) or altering characteristics that affect the media experience e.g. changing the colour of a graphic image (i.e. aesthetic customisation). Both forms of customisation systematically affect both senses of control and autonomy (sense of identity) of the user which are critical to game enjoyment (Kim et al., 2015). Digital game customisation is used in games design to provide game immersion, which can improve player motivation (Yee, 2006; Teng, 2010; Billieux et al., 2013) and learning (Gee, 2005, Ku et al., 2016).

Digital game customisation can be provided by game creators or implemented in-game by users and ensures that an existing game includes the specific game characteristics that make it appealing to the target audience (Bond & Beale, 2009). According to Magerko et al. (2008), the customisation process of such games by creators takes into consideration the key characteristics that make a game appealing to the target audience.

The in-game customisation provides the player with the autonomy to control the customisation process while engaging with the digital game (King et al., 2010; Dardis et al., 2012). Examples of in-game customisation include MMORPGs and SIMs games. In digital educational games, customisation has been used to improve user engagement (Elsenheimer, 2003) and immersion (Yee, 2006) for all age groups.

2.8 Discussion and summary

The earlier sections of this review presented the related literature on the issue of female under-representation in computer science education and careers. A comparative report on the STEM disciplines indicated that increases in the representation of females for all other disciplines have occurred in recent years with computer science making minimal improvements at both secondary and higher educational levels.

A comparative analysis of female academic performance with their male counterparts was reviewed to identify if poor academic achievement is responsible for the progressive under-representation of females in computer science education. The data and literature indicated excellent achievement levels of females relative to the males. This further prompted a further review of the causes of under-representation of females in computer science education and careers.

The literature suggests that three arguments have been presented as possible causes of female under-representation in computer science education and careers. Recent investigations indicate that combinations of sociocultural and structural factors are most likely to influence the representation of females in computer science education and careers.

Considering the complex nature of the causes, a range of intervention strategies implemented over the years to tackle this problem was reviewed. Given the history and the multiple approaches that have been taken, there has been little effect on the overall representation of females in computer science education and careers and the position continues to decline. It is unclear that a single solution will solve the problem, making it imperative to further explore a breadth of possible solutions.

A scrutiny of digital educational games has revealed that their motivational appeal is unfavourable to girls as they often include gender stereotypes that can influence their interest to engage both with the game(s) and subsequently with computer science. However, to ensure that the design of digital educational games is motivationally appealing and educationally effective to the target age group of the study, the use of digital educational games frameworks in the design of learning games was reviewed.

Common to the frameworks is the need to ensure that digital educational games provide a fun experience while achieving the learning outcome of the game. To achieve these objectives, the customisation of game characteristics that can improve user autonomy and control of the game is key to enjoyment and immersion in the gaming environment.

Consequently, this study focuses on addressing the gap in the knowledge of how to make digital educational games motivationally appealing to girls of age 11-14, considering the success of digital entertainment games with girls of this age grou

CHAPTER 3

RESEARCH METHODOLOGY

(EXPLORATORY AND MAIN STUDY)

3.0 Introduction

The review of the literature suggested that digital entertainment games are increasingly popular with females as much as males of all age groups (children, teenagers and adults) because of the motivational appeal of games. However, there is a gap in the knowledge regarding the nature of games that appeal to the target group of 11-14 year old girls. In order to answer the research questions which are:

(1) *"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"*

(2) *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

An effective technique for eliciting this information from a representative sample of 11-14 year old girls needed to be identified and used to capture the required information.

Section 3.1 provides an overview of the structure of the research methodology, which comprises two phases. This section also discusses the rationale for the structure of the methodology.

Section 3.2 describes in detail the requirements and techniques chosen for the first phase of the study. The section concludes with the rationale for the choice of technique for this phase of the study. Section 3.3 discusses how data was collected and analysed.

Section 3.4 presents an outline of the aims and rationale for the choice of techniques used in the second phase of the study. Section 3.5 reviews how the data collected in the second phase of the study would be analysed. The chapter concludes with a discussion and summary in section 3.6.

3.1 An overview and rationale for the structure of the research methodology

To provide an a response to the research question, information on the nature of the games (i.e. characteristics that appeal to the target group) had to be identified. The knowledge acquired from this investigation was applied to digital educational games for the target group of 11-14 year old girls. The gap in the knowledge about how to create digital educational games that are motivationally appealing to specific age groups was also suggested by Greenberg et al. (2010). To achieve this, an effective information elicitation technique was used to capture and analyse this information. This first phase of the study is referred to as the exploratory study in this thesis.

The requirement of the exploratory study was to obtain empirical information about the reasons why some digital entertainment games appealed motivationally to 11-14 year old girls as this information is missing from the current body of evidence. The exploratory study needed to enable participants to articulate the reasons why some digital entertainment games are appealing and identify the associated characteristics in digital entertainment games. Furthermore, participants led the information elicitation process to ensure that the information elicited was based on participants' understanding of digital entertainment games as opposed to obtaining the information from the researcher or a games design expert. The information elicitation process also needed to be completed in the time the participants were able to devote to the experiment. The information elicited from this process needed to be meaningful to the researcher.

The information captured during this phase of the study was analysed and outcomes obtained from the investigation in order to answer the first part of the research question – "*Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"*

To provide a response to the second part of the research question –*"Can we use this knowledge to create computer science learning games that appeal to this audience?"* the second phase of the study, referred to as the main study, was conducted. The output of the exploratory study was significant in influencing how the main study was designed and conducted.

The main study applied the knowledge obtained from the exploratory study on digital entertainment games in the context of digital educational games for studying computer science with 11-14 year old girls.

The requirement of the main study was to confirm if the findings of the exploratory study and literature can be successfully incorporated in digital educational games to appeal to the target group.

According to Zhai et al. (2003), empirical evaluation has its problems; however, it is far superior to merely asserting that a technology is valuable. Zelkowitz & Wallace (1998) and Glass et al. (2004) both argue that computing disciplines validate their technologies too infrequently. As a result, for this study, the main study was designed to confirm the findings of the exploratory study and provide a response to the research question.

The literature on the potential techniques for the exploratory and main study are reviewed and discussed in sections 3.2, 3.3 and 3.4, 3.5 respectively. The rationales for the chosen techniques are also reviewed in these sections.

3.2 Exploratory study – review of information elicitation techniques

The problem of information elicitation from users is not the lack of techniques (Denzin & Lincoln, 1994; Maiden & Rugg, 1996) but choosing and applying a technique appropriate to the purpose (Rugg & McGeorge, 1999). The aim of the exploratory study was to identify the individual preferences responsible for the appeal of digital entertainment games to participants. The findings from this part of the study should inform the next stage of the study and provide the empirical evidence in response to the first part of the research question.
The information obtained from individuals was analysed to determine the preference of the group by gender i.e. 11-14 year old girls and boys. Obtaining individual preferences to fit a group profile is often a challenge. Therefore, an appropriate technique has to enable the researcher to capture an extensive range of information required for the study with good measures of accuracy (Garcia et al., 2012).
Recent literature have suggested a number of information elicitation techniques that can be used to include interview (Seidman, 2013; Brinkmann & Kvale, 2015), workshops and feedback (Nisar et al, 2015).

Rugg & McGeorge (1999) provide an overview of the main information elicitation techniques and the issues associated with each technique. Some of these techniques were applied in more recent information elicitation studies by Tan & Hunter (2002), Rugg et al. (2002) and Curran et al. (2005)**.** These techniques are discussed below with a view to understanding how they could be applied to this phase of the study.

The *ethnographic approach*, which can be disclosed or undisclosed, to participants, involves spending extensive amounts of time with a group being studied to gain a first-hand understanding of how their physical and conceptual worlds are structured.

The *observational approach* could be participant observation (ethnographic approach without direct involvement in the process), or the direct observation (the activity is observed with direct involvement by the observer e.g. shadowing) and indirect observation (only the by-product of the target activity is observed e.g. the effect of violent digital games on boys).

The use of *reports* involves participants verbally reporting on the target activity. The report could be participants describing their own action when it is taking place (on-line action) or after the action has taken place (off-line action). Participants can also provide reports that describe the actions of others on or off-line.

The most common and widely used elicitation techniques are *interviews* and *questionnaires.* Interviews can be structured (the elicitor has a series of prepared questions) or unstructured (the elicitor does not prepare questions prior to the interview). In the case of questionnaires, lists of questions usually in written or spoken form are used with participants. A distinction in questionnaires is the use of open questions (participants may use their own words in response) and closed questions (participants have to choose from possible responses as indicated by the elicitor).

Finally, the *personal construct theory techniques* were also considered for use with participants. George Kelly developed the personal construct theory in 1955 as a constructivist approach to learning, knowledge, resource and information acquisition. The basis of the theory is that people continually construct their own models of the world and these models are tested against reality (Rugg & McGeorge, 2002). The personal construct theory includes repertory grids, laddering and card sorts.

Repertory grid is a technique based on a grid that usually contains numbers for Likert–type semantic scales and has been used extensively in knowledge acquisition (Shaw, 1980; Shaw & Gaines, 1989). According to Whyte & Bytheway (1996), Tan & Hunter (2002) and Alexander & van Loggerenberg (2005), the advantages of the repertory grids are the lack of interference from the researcher and the speed with which they can be completed.

The identified challenge with repertory grids is the computation of nominal values without scalar quantities (Yorke, 1983, Rugg and Shadbolt, 1991). In the context of the information elicited from participants, they consist of statements that are not measured by semantic scales. Hence, the analysis of information can be challenging using repertory grids.

Laddering is a structured interviewing technique used to collect rich data on participant reasoning and preferences (Peffers et al., 2007). According to Schultze & Avital (2011), it is rarely used for information acquisition in information system design but used extensively in architecture (Honikman, 1977), advertising research (Reynolds & Gutman, 1988) and marketing research (Peffers et al., 2007). Laddering is rarely used for information systems design due to limitations associated with the tedious nature of content analysis of information elicited from participants hence time-consuming and high cost (Botschen et al., 1999).

Rugg & McGeorge (2005) described the challenges associated with each of the sorting techniques i.e. Q-sort, Hierarchical sort, *"All in one sort"* and the repeated single-criterion sort. The Q-sort involves the use of a large set of cards, each of which bears a different statement or phrase. Participants are required to fit the cards into a normal distribution predefined by the investigator. For example, the cards may each bear a description of a participant's preferences, and their task may be to fit each card onto a scale ranging from '*strongly agree'* to '*strongly disagree'*, with only a few cards being used at each end of the scale and most cards being placed somewhere near the middle (Rugg & McGeorge, 2005). Q-sort has its limitation with the computation of semantic distribution and the speed to complete statistical analysis.

The Hierarchical sort is based on cards used as entities to represent different semantic levels.

For example in human biology, the organisation of cards representing systems (e.g. the digestive system) organs (e.g. the stomach), tissues and cells. The participant's task would be to organise these cards into this hierarchical organisation. The challenge is the process of choosing cards as different entities and their hierarchical organisation might distort the knowledge elicited from the process.

The *"All in one sort"* explores the range of overlapping attributes or similarities from the analysis of the participant's constructs. An example of this would be to ask participants to sort a set of cards bearing the names of games into groups. It is likely that the participants would categorise certain games as similar based on experience, although the games might differ widely across some individual attributes (e.g. game platform). The challenge with this technique is the inability to elicit participants' individual attributes systematically. Rugg & McGeorge (1997) further indicated that Q-sort, Hierarchical sort, and *"All in one sort"* techniques lack speed of completion, meaningfulness and resource efficiency.

The repeated single-criterion sort technique requires participants to sort the same entities repeatedly into groups using different criteria each time (Rugg & McGeorge, 2005). Rugg & McGeorge (2005) suggested that this technique is flexible and easy to manage. In addition to the repeated single-criterion sort technique, the closed card sort was considered for the study. The criteria for this sort process are determined in advance by the researcher (Hudson 2005). The closed card sort is useful when adding new content or gaining additional feedback after a repeated single-criterion sort (Spencer, 2009). The application of both the repeated single-criterion and the closed sort techniques should provide the empirical evidence of the key criteria required for the success of digital entertainment games with 11-14 year old girls.

3.2.1 Rationale for the choice of information elicitation technique

For this study, the entities are the different games represented using the cards. The cards were sorted repeatedly into groups using different criteria each time by the participating girls and boys.

In order to determine the most suitable knowledge elicitation technique for the exploratory study, the framework designed by Maiden & Rugg (1996) and Rugg & McGeorge (1999) for categorising information elicitation techniques was adopted.

This framework initially classified participants' *"internal representations"* (i.e. types of memory, knowledge and communication filter that can affect the quantity and quality of information which can be elicited) as *"new"* knowledge and *"existing"* knowledge. *"New knowledge"* refers to knowledge about things which do not yet exist and "*existing knowledge"* refers to things which do exist or have already existed.

The framework further classifies existing knowledge into tacit, non-tacit and semi-tacit knowledge.

According to Panahi et al. (2013), tacit knowledge is usually acquired by individuals or groups through active participation which is guided by both the cognitive (e.g. viewpoints, gut feelings, routines etc.) and technical dimensions such as hands-on experience, skills, problem solving etc. (Nonaka & Takeuchi, 1995).

Non-tacit knowledge is the opposite of tacit knowledge, as it is formal knowledge, which is guided by only cognitive dimensions (Polanyi, 1966).

Semi-tacit knowledge includes knowledge that is hard to recall without cues which include taken-for-granted knowledge (knowledge that is assumed to be held by others) and concealed knowledge which is deliberately withheld knowledge (Gacitua et al., 2009).

Other forms of semi-tacit knowledge according to Rugg & McGeorge (1999) include short-term memory (i.e. limited capacity of about seven items plus or minus two and a duration of a few seconds), recall versus recognition, where recall is the active memory from which information can be deliberately retrieved without cues. Recognition is a more powerful memory structure based on deliberate recall of information using cues.

In the context of the study, the information to be elicited are the reasons why some successful digital entertainment games appeal to 11-14 year old girls. This information can be classified as existing knowledge. This is because participants would already know the reasons why some successful digital entertainment games appeal to them. This knowledge would have been acquired by participants through active engagement with digital games and then developing an opinion of the games. However, this knowledge might be hard to recall and recognise without prompts or cues, considering the numerous experiences of participants over time.

This knowledge might also have been taken for granted, concealed or reside in short-term memory.

Participants can, however, recall this knowledge without cues in some instances and in other instances, they would require cues to recognise the acquired knowledge.

Interviews and reports can be used for information elicitation for semi-tacit knowledge, it requires careful management of the process (Rugg & McGeorge, 1999). The careful management of the process should minimise or eliminate the possibility of the researcher leading the information elicitation process. If this occurs, the outcome of the exploratory study would not be representative of the participants' understanding of the reasons why some digital entertainment games appeal to them.
From the review of the elicitation requirements as shown in section 3.1 and the techniques proposed by Maiden & Rugg (1996) and Rugg & McGeorge (1999) in section 3.2, the personal construct techniques i.e. repertory grid, card sort and laddering were considered the most suitable for the study because participants can lead the information elicitation process to ensure that the outcome is based on their understanding of digital entertainment games.
However, due to the identified challenges of the various techniques within the personal construct theory techniques (repertory grids and laddering) as discussed earlier in the section, the card sort was identified as the most suitable technique. Within this technique, the repeated single-criterion was the most appropriate considering the challenges of the other sorting techniques also discussed previously and the requirements of the exploratory study.

Other advantages of the repeated single-criterion sorts are outlined below:

- The most suitable technique for participants' recall of information and recognition exercises in comparison to interviews and questionnaires (Rugg & McGeorge, 1999);
- An appropriate technique when there is emphasis on participants'' categorisation of information (Rugg & McGeorge, 1999; Slegers & Donoso, 2012);
- Effective for use as an exploratory and main technique (Goffman, 1955; Slegers & Donoso, 2012; Sakai & Aerts, 2015). For this research, the exploratory study forms the basis for the main study;

- The repeated single-criterion sort technique can be used to analyse nominal data that has semantic levels such as bright colours, dark colours and not too bright or dark colours. Other sort elicitation techniques considered for the exploratory study presented limitations in this area. (Osgood, Suci & Tannenbaum, 1964; Rugg & McGeorge, 1992);
- The reasons for the appeal of some digital entertainment games to the target audience are semi-tacit knowledge, which requires a suitable methodology that can be used to elicit this type of information. The repeated single-criterion sort is a suitable technique for the elicitation of this type of information, which is based on participant understanding, not the researcher (Fincher & Tenenberg, 2005; Maiden & Rugg, 1996; Gervasi, 2013). Traditional interviews and questionnaires fail to access this type of information (Upchurch et al., 2001);
- This card sort technique also provides the participants with the opportunity to generate their own constructs (terms) in naming criteria and categories rather than the researcher. Hence, it is a user centred technique (Fincher & Tenenberg, 2005; Slegers & Donoso, 2012).

For the reasons outlined above and the suitability for the exploratory study requirements, the repeated single-criterion sort was identified as the main technique for identifying the game constructs for further investigation. The information obtained from the repeated single-criterion sort can identify game constructs that are common to participating girls but might not provide further information on the how the target audience view these constructs. For this reason, a closed card sort was required to obtain this additional information to the outcome of the repeated single-criterion sort.

Furthermore, the sorting technique should be applied in one-to-one sessions by the researcher. The rationale for the one-to-one sessions as supported by Spencer (2009) are as follows:

- The effect of group behaviour could be detrimental to the quality of data collected. Sometimes a dominant member of a team might impose his or her opinion on the group and the outcome reflects the ideas of only one member;

- In some instances, teams make compromises instead of working through their differences. Consequently, the final outcome might not be representative of the team members;
- *"Think-aloud"* protocols can be gathered during the one-to-one sessions to obtain explanations for the information elicited from participants. This also provided qualitative insight into the information elicited during the analysis of data collected;
- The one-to-one technique excluded constraints associated with the expertise of gameplay and rather focuses on the constructs generated by the participants from engaging with session materials and previous experiences of gameplay.

The one-to-one structure of the exploratory study also ensured that the main requirement of identifying how participants conceptualise digital entertainment games was achieved.

3.2.2 The repeated single-criterion sort technique terminology

In order to describe how the repeated single-criterion sort technique was applied in the exploratory study, some of the terminology associated with this technique is defined:

Construct – This is defined as an attribute used by an individual to describe an entity or object (Kelly, 1955). A simplified definition by Bannister & Fransella, (2013) is: "*a construct represents the view a person has created about the world as they experienced it and at the same time indicates how they are likely to see the world as they continue to experience it."* Both definitions indicate that it is an individual's perception based on experience. A similarity of construct between individuals indicates that there is a level of similarity in the experiences of the group that is studied. Examples of a construct may be '*easy to use'* or '*expensive*'.

Criterion - This is the attribute used as the basis for sorting entities or objects when using sorting techniques. An example could be '*how easy to use'.* The criterion provides the basis for sorting objects or entities into categories (Rugg & McGeorge, 2005).

A **category** is a group into which entities or objects are classified using a criterion (Rugg & McGeorge, 1997). An example, '*very easy to use',* '*not very easy to use'* and '*not easy to use'.*

3.2.3 The closed card sort technique terminology

A common terminology associated with the closed card sort and the repeated single-criterion sort is category. For the closed card sorts, the researcher identifies the name and number of the categories in advance of the sorting process by participants (Hudson, 2005).

Finally, the terms game *"characteristics"* and *"constructs"* are used more or less interchangeably in the thesis. The term *"construct"* is used where reference is made to participants' description of entities or objects. This technical term comes from the sort technique used in the study. Elsewhere, excluding the questionnaires used for the main study, the term *"characteristics"* is used. In the main study questionnaires, the term game *"features"* is used instead of game *"characteristics"* because this was felt to be more meaningful to the young participants.

In section 3.3, the techniques that were considered for analysing the data collected during the exploratory study are reviewed and the rationale for the chosen data analysis technique is discussed. To understand the chosen technique for data analysis, a further review of relevant literature is presented in the section

3.3 Techniques for analysing data collected from card sorting

The type of analysis used for card sort depends on the purpose of the study (Rugg & McGeorge,2005). The purpose of the card sort in this study was to collect data that would be used in obtaining the empirical evidence in response to the first part of the research question. From the review of the literature, there is evidence that some digital entertainment games are successful due to the appeal of the game characteristics used in the creation of the games. However, there is no empirical evidence of these characteristics for 11-14 year old girls.

To provide a response to the first part of the research question, the analysis of the data collected from the card sort should identify the key criteria which can contribute to the appeal of digital entertainment games. This should be achieved using the card sort techniques as the cards which represent the games used for the study are repeatedly sorted into groups or categories by participants using a different criterion each time. Based on the most frequent category elicited from participants for each criterion, the appeal of the criterion was obtained from correlating this information with the result of the closed part of the card sort.

The analysis of the card sort data should apply both qualitative and quantitative approaches to interpreting the results (Paul, 2014).

Two preliminary steps in analysing captured data in a repeated single-criterion sort technique were proposed by Upchurch et al. (2001). These steps comprise the traditional semantic analysis procedure referred to as semantic clustering by Hinkle (2008). These steps precede the application of other analytical tools identified by Rugg & McGeorge (2005) and Fincher & Tenenberg, (2005).

The first step is to perform a verbatim analysis of all criteria labels. This enables the investigator to aggregate criteria, which have identical wording. This aggregation procedure is referred to as "*verbatim agreement".*

The next step in the analysis aggregates the verbatim criteria, which are judged to have identical underlying meaning but expressed in different words. For example interpreting *'difficult'* as meaning the same as thing as '*hard*''. This is referred to as *"gist agreement"* and the outcome which is often the most frequently used criterion from the *"gist agreement"* is the *"superordinate construct"* (Nurmuliani et al., 2004). In the example above, '*difficult*' could be the superordinate construct if it is the most frequently used criterion from the *"gist agreement."*

This stage of the analysis can be carried out manually or by the use of software. However, it appears that human ratings of underlying similarities appear to be viewed as a *"gold standard"* for data analysis (Sanders et al., 2005). For example with the aggregated verbatim agreements of *"popular game",* "*what everyone plays*" and "*a lot of people play this game"* can be grouped collectively into *"game popularity".* Both qualitative processes were initially completed by the researcher and agreed with supervisors.

The traditional semantic analysis technique that requires direct researcher interpretation of elicited information was chosen for the study. This technique is different from techniques that are purely syntactic and hence automated. The reasons for this choice of technique instead of automated syntactic techniques are:

- It is a qualitative process that focuses on understanding the criteria and groups participants create (Paul, 2014);

- According to Sanders et al. (2005), human ratings for underlying similarities are viewed as a *"gold standard"* for data analysis;
- The traditional semantic analysis technique provides rich insight into the data collected (Fincer & Tenenberg, 2005);
- Further complex quantitative analysis such as cluster analysis and descriptive statistics using automation can be completed from the result of this technique (Tullis & Wood, 2004; Sanders et al.,2005; Hudson, 2013);
- This technique is effective when there is a reasonable amount of information that can be processed manually (Fincer & Tenenberg, 2005).

Additional qualitative analysis of the data collected was conducted involving content analysis and representation of patterns and trends as graphical presentations. Microsoft Excel is a common application software used for this purpose (Meyer & Avery, 2009). Other secondary qualitative analyses were also conducted. An analysis of the closed card sort data to identify the most likely to play games and cluster analysis were conducted. The result of the analysis should identify the groupings of games used in the study based on the likelihood of participants playing them again.

Quantitative analysis should also be completed using statistical test applications such as Statistical Package for Social Sciences (SPSS) as it is suitable for quantitative analysis of this nature (Pallant, 2016).

A further description of the chosen analysis procedure of the repeated single-criterion is provided in subsequent sub-sections (3.3.1–3.3.2) for a better understanding of the traditional semantic analysis technique and the outcomes of the analysis.

3.3.1 Commonality of criteria

According to Rugg & McGeorge (2005), the number of the same criteria that two or more participants use is referred to as the "*commonality of criteria*" between them. In some instances, most of the participants might use much of the same criteria as each other. Other times, although participants might produce similar numbers of criteria, the criteria identified may differ widely from participant to participant. As a rule of thumb, the higher the commonality of criteria between participants, the easier the analysis process.

3.3.2 The categories

The number of times a particular category was repeated by different participants was also informative. It is instructive to investigate the same categories within the same criteria. An obvious difference or irregularity requires further investigation of the sort process. This is either an indication of human error or variation in participants. The “drying up” point can also be informative. The similarity or differences in the criteria before this point implies the need for investigation and possible systematic change of the sort technique (Rugg & McGeorge, 2005).

This section reviewed how the data collected from the exploratory study would be analysed, using a combination of semantic clustering and content analysis. The qualitative results obtained from this process would further be analysed quantitatively using SPSS to determine the statistical significance of the results. This should provide the empirical evidence in response to the first part of the research question.

3.4 Main study – aims and chosen techniques

As previously discussed in section 3.1, the main study needed to confirm the output of the exploratory study and provide a response to the second research question - *“Can we use this knowledge to create computer science learning games that appeal to this audience?”*

To achieve this aim, the techniques chosen for the main study needed to effectively investigate if the game characteristics identified from the exploratory study can be used to improve the motivational appeal of digital educational games for learning basic computer science concepts with the target audience. This investigation should provide empirical evidence of the influence of game characteristics on the motivational appeal of digital educational games.

To achieve this requirement, the following actions were taken:

1. Identify an approach that can 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 a digital educational game for learning basic computer science concept or the use of an existing game for the investigation. The second approach was considered and used because a number of digital educational games for the study of basic computer science concepts are readily available. Secondly, the use of an existing digital educational

game provides the opportunity to evaluate existing games for their effectiveness as educational tools.

2. 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 of the game. The process produced two experimental games i.e. one that enhances motivational appeal and the other antithetical to the first.

The participants in the main study, comprising of both girls and boys, were required to engage with both games. The reason for this approach was to obtain two sets of data on the impact 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 digital educational games.

3. The data from the investigation were captured and analysed later in the study. This provided the empirical evidence in response to the research question.

A number of 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 (Rugg & McGeorge, 1999).

Based on these requirements, the questionnaire was chosen because it is a common technique for collecting survey data (McLeod, 2014).

It can also be used to collect a range of information with accuracy and a pragmatic approach for the study as it can be used in all locations without the researcher input and all participants asked the same question.

Some other reasons for its suitability as reported by McLeod (2014) were:

- The administration of questionnaires is inexpensive and easy even when gathering data from people spread over wide geographic area. This was useful for this study as the participants were spread across different locations to improve the validity of the study;
- Reduces chance of researcher bias because the same questions are asked of all participants;

- Most participants should be familiar with questionnaires;
- Qualitative and quantitative analysis of responses is easy;
- A combination of open and closed questioning techniques can be used to collect data;
- An effective means of measuring preferences, opinions and intentions**.**

For the main study, information on how participants view and engage with digital entertainment and educational games were collected. This information was used to establish the impact of game characteristics on the motivational appeal of digital games on the target group. This phase of the study was followed by the collection of information based on the impact of the two experimental games used in the study. The purpose of this structure for the information collection was to compare participant perception and experiences before and after engaging with the experimental games. The result indicated how much impact the games with the variants of the game characteristics had on participants. This was required in order to provide the empirical evidence in response to the second research question - *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

Two types of questionnaires were used to capture participant feedback during the main study. In the thesis, this is referred to as the pre and post-study questionnaires. The pre-study questionnaire should capture participants' 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 included the participant's identification number provided by instructors or teachers for anonymity and demographic information such as age and gender. The identification number was also 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, perception and influence of computer games that appeal to the target audience. In addition, the existing knowledge of the influence and perception of digital educational games (referred to as educational computer games in the questionnaire for simplification purposes) was also captured using the pre-study questionnaire.

Three post-study questionnaires were created for the main study. One post-study questionnaire created for each experimental game and an evaluative post-study questionnaire. Two post-study questionnaires were used to capture participant responses about each game after engaging with them. 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 indicated 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.

3.5 Main study - data analysis technique

The data collected using the questionnaires were initially validated for accuracy and completeness. The rationale for the validation of the data collected was to ensure that it satisfied the purpose for the collection, and variables were appropriately identified for statistical analysis (Bazeley, 2013). To validate the data collected, checks for consistency and completeness were carried out e.g. participant identification and gender information on all datasets. Details of the data analysis procedure are discussed in chapter 7

The data captured were also analysed qualitatively to identify the influence and perception of both computer and educational computer games by participants before engaging with the experimental games. The analysis of the pre-study questionnaire data confirmed the empirical evidence from the exploratory study on the reasons some digital games are appealing to the target group of the study. This was required in order to ensure that the outcome of the exploratory study on which the main study was based upon was reliable.

It needed to also provide more understanding of the perception of digital educational games by the target group before engaging with the experimental games designed for the study. This information is useful in understanding the impact of the main study on girls of age 11-14 years old. The analysis of data collected using the pre-study questionnaire should involve the use of qualitative analytical methods such as content analysis and graphical representations to indicate the trend of the data analysed. The result obtained was used to identify the perception and influence of digital games on participants.

Both qualitative and quantitative analyses were conducted on the data captured from the post-study questionnaires. The qualitative analysis involved content analysis and the use of graphical representations to identify the trend of data captured. The result of the qualitative analysis also was expected to identify the game characteristics and game that appealed more to the participants. It also identified the reasons for the appeal of the game.

The quantitative analysis involved the use of statistical tests to identify 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 in response to the research question of the study. It is expected that the results would identify the key criteria why some digital entertainment games appealed to the target group and if the findings could be used to create digital educational games that appeal to 11-14 year old girls.

For the qualitative analysis of data captured using the pre and post-study questionnaires, the requirement for suitable application software involves the computation of data captured from participants and its presentation as graphical representations. A number of suitable application software (Microsoft Excel, MatLab, R and Statistical Package for Social Scientist) for data analysis were reviewed. Microsoft Excel and Statistical Package for Social Scientists were chosen as a suitable application for this requirement. The applications were used to analyse data collected and present trends used to summarise the results of the main study.

To effectively conduct the quantitative statistical tests for the post-study data from the engagement of participants with the games, the Statistical Package for Social

Scientists was chosen as it is a common tool that can support this type of analysis (Pallant, 2016) and it was readily available at the university.

The results of the main study analysis were validated to ensure that the findings from the study were not because of confounding factors, but the effect of the variables of the study.

3.6 Summary

This chapter describes the methodology for the exploratory and main study. An overview of the methodology and the rationales were also reviewed in this chapter. The relevant literature for the potential and chosen techniques were reviewed to understand the rationale for the choices. For the exploratory study, the card sort techniques were used in combination with researcher notes to capture participant feedback. The data captured during the exploratory study would be initially analysed using the semantic clusters. Other secondary automated analysis tools such as cluster analysis were considered and should be implemented to obtain a statistical grouping of the games used for the study. This would be based on the appeal of the games by gender.

For the main study, a combination of pre and post-study questionnaires and two digital educational experimental games, customised on the basis of the findings of the exploratory study would be used. The chapter concluded with a review of how the data collected during the main study would be analysed both qualitatively and quantitatively using suitable application software.

The data analysis should be concluded with a data validity test to ensure that the result of the study can be applied to the target population. This should provide the empirical evidence in response to the research question.

CHAPTER 4

EXPLORATORY STUDY IMPLEMENTATION, DATA ANALYSIS AND RESULTS

4.0 Introduction

The exploratory study was conducted to gain an insight into how 11-14 year old girls (the target group) conceptualise digital entertainment games and to try to find which characteristics of the games appeal to this target group . The elicited information was used to inform the design of the main study.

Section 4.1 is a description of the exploratory study conducted in four locations with 11-14 year old girls and boys. Section 4.2 discusses the data analysis and concludes with a summary of the outcomes. Section 4.3 is a discussion of results and summary of the chapter. The chapter concludes with how the outcome of the exploratory study addresses the research question and sets the scene for the main study.

4.1 Implementation of the exploratory study

This section initially describes the rationale for the selection of locations and study participants. This is followed by a description of the requirement for each card sort session that was carried out at each of the four locations. The second part of this section describes the materials that were created for the card sort and how each session was run. The purpose of the exploratory study was to identify the key criteria responsible for the success of some digital entertainment games with 11-14 years old girls.

4.1.1 Selection of study locations and participants

The exploratory study was conducted in four different locations in southeast England, comprising of two single gender (girl-only) schools and two mixed gender schools. The reason for this selection of schools was to investigate how girls in a single gender school understand and perceive digital entertainment and educational games in comparison to girls in a mixed gender school.

The boys were included in the study from the mixed gender schools to provide comparative data on the similarities and differences in the understanding and perception of digital entertainment and educational games between girls and boys. In addition, the collection of data from different locations improves the ecological validity of the study (Bracht & Glass, 1968; Cao & Braun, 2014).

The participants for the study were nominated by teachers at the chosen schools following the guidance provided by the researcher. The guidance included the requirement for potential participants to read and consent to participation. They were also informed of the anonymity of the data collected and the right not to continue participation at any stage of the study. Furthermore, consent from a parent or legal guardian was requested as a condition of participation. The participant documentation and school guidance can be found in appendix 2.There were no requirements for previous experience of digital entertainment or educational games. Potential participants were also not required to be studying or have studied computer science. All participants were required to be between the ages of 11-14 years old.

The sessions were conducted by the researcher in a quiet room at the school premises with access to a laptop, a desk and two or more chairs. There was no requirement for an internet connection as the study materials required for the sessions with the participants were downloaded onto a laptop and an external memory drive prior to the session. Due to child protection issues, a member of staff from the participating school was present during the sessions with the students in all schools. A quiet location was required for the session as it involved dialogue between the researcher and the participant. The sessions were one-to-one and lasted about 35 minutes for each participant. The rationale for this structure was discussed in section 3.2.

4.1.2 Materials, participants and implementation

The exploratory study was conducted using an adapted repeated single-criterion and a closed card sort. The rationale for this choice of technique was discussed in section 3.2. The single-criterion card sort technique was adapted to include ten gameplay video clips selected from a variety of game types.

The gameplay video clips were used so that the participants could know what the game was like. The selected games were from ten different game types, which are non-exhaustive as some games are not limited to one type (Lindsay, 2005). The ten chosen game types comprised of the basic i.e. action, adventure, role play, simulation & puzzle and non-basic i.e. maze, arcade, music & casual games types (Lindsay, 2005; Arsenault, 2009). The selections of games from both groups with ten games provided a variety of game types. The games were listed in the top five games as published on various games review websites in 2013 (Metacritic, 2013; Slantmagazine, 2013). The other basis of the selection of the gameplay video clips was their appropriateness for 11-14 year old participants. The Pan European Game Information (PEGI) rating was used to guide the age appropriateness of the selected games. Only games belonging to the ratings 3+, 7+ and 12+ were selected. In addition, the availability of gameplay videos also determined what games was selected. Ten gameplay video clips were selected to represent each game type. In addition, since these games were also represented as picture cards, a manageable number of picture cards were required for the card sort. Rugg & McGeorge (1997) recommend a minimum of eight and a maximum of 20 to 30 cards as a statistically manageable number.

A picture card was created to represent each game. A list of the selected games and card numbers is illustrated in table 4.1. The rationale for the use of picture cards for the card sort was to provide cues for the recall and recognition of information by participants as the cards include images and summary description of the games.

Card#	Game Type	Game Title
#1	Action	Lego City
#2	Maze	Pac-Man
#3	Adventure	Luigi's Mansion
#4	Role Play	World of WarCraft
#5	Simulation	SimCity
#6	Strategy	Fire Emblem
#7	Arcade	Super Mario
#8	Music	Just Dance
#9	Puzzle	Toki Tori
#10	Casual	Angry Birds

Table 4.1. The card number, game type and game titles used for the picture cards

Figure 4.1 is an illustration of a sample gameplay video shown to participants.

Figure 4.1. A sample gameplay video of Toki Tori © 2013, Two Tribes.

A sample picture card is illustrated in figure 4.2. The picture card included an image of the game, the card number and key information about the game such as the plot, platform, player mode (single or multiple) and how scores are awarded where relevant. The picture cards (see appendix 1) were of a similar size to ensure participants did not consider any one card more important than the other (Rugg & McGeorge, 1997).

Figure 4.2. A sample of the picture cards with text (Adapted from Toki Tori).

As previously mentioned in section 4.1.1, each session lasted about of 35 minutes per participant. In total, 24 girls (eight from each of the single gender schools and four from each of the mixed gender schools) participated in the sessions. For the boys, eight participants (four from each of the mixed gender schools) took part in the sessions. As this was an exploratory study, the outcome from this smaller number of participants was further investigated in the main study, using a larger sample size. A selection of eight girls from the single gender school and four from each gender for the mixed gender schools, provided participants from both gender and ages 11-14 year old. Nielsen (2004) recommended fifteen participants and less than thirty for a card sorting test due to increasing diminishing returns and correlations with increase in the number of participants. Consequently, 24 girls and eight boys participated in the exploratory study, with the data from the boys' indicative, as the girls were the focus of the study.

Each one-to-one session started with the researcher allocating a unique number to the participant. The researcher then demonstrated the exercise. He showed each participant how to view the video clips and then explained and demonstrated the process of sorting the cards into groups according to criteria. The researcher told the participant that he would like them to think aloud during the sorting process and that he might sometimes ask them questions to clarify the names of the groups. Each participant was also informed that the researcher would take notes of the sorting outcomes and the dialogue with the participants about their reasons for their criteria and grouping the cards i.e. *"think-aloud protocol".*

Participants were also told that they would be prompted if there was an early *"drying up*" and that groupings such as *"other", "I do not know", "not sure*" and "*not applicable*" should be avoided.

Furthermore, participants were advised not to lump two criteria together in one sort e.g. "*fun and colourful*". These should be in two sorts i.e. *"fun"* and *"colourful*". The examples used in the demonstration could introduce some bias to the study as participants could have been influenced to use these criteria during the exploratory study. However, the findings from this part of the study were confirmed in the main study. Finally, participants were informed that the numbers on the cards are for convenience in recording the sorting as shown by Rugg & McGeorge (1997).

The demonstration period lasted between 5-10 minutes. This duration of time provided the researcher sufficient time to demonstrate the process and answer questions from each participant.

At the end of the demonstration, the participant was informed that at least ten minutes would be given to view the gameplay videos. The allocated time was sufficient for participants to view each video. This decision to allocate at least a minute to viewing each video clip was a pragmatic decision that would ensure that the sessions were concluded within a reasonable amount of time since participants had to take time from lessons. In addition, a review of the average human attention span has been shown to decrease from 12 seconds in 2000 to 8.25 seconds in 2015 (Statistic Brain, 2016). Consequently, media commercials which were usually 30 seconds are now mostly 15 seconds to align with current average human attention span (USA Today, 2010). This factor was also taken into consideration and one minute was judged as sufficient time for the viewing of each gameplay video.

After watching the videos, the participant carried out the card sort. They repeatedly sorted the cards into groups using different criteria each time until they dried up.

The length of the sorting exercise averaged between 20-25 minutes. However, some took less as the participants dried up and even with prompting could think of no more criteria. At the end of each session, participants returned to their lesson and the next participant was brought in by the teacher. A pictorial example of the sorting is shown in figure 4.3.

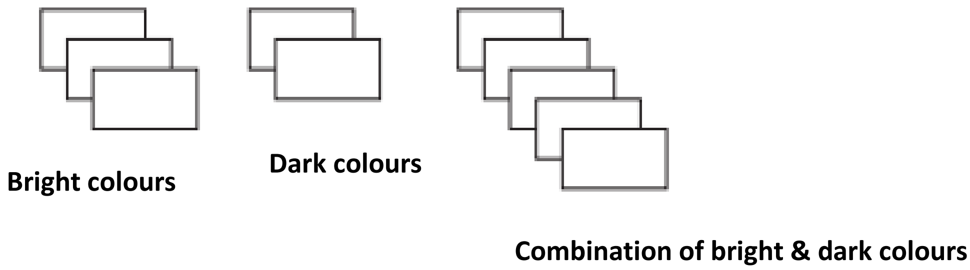


Figure 4.3. A sample set of picture cards after sorting

An example of a record of a sort as noted by the researcher during the session is shown in figure 4.4.

Criteria #1

Criteria: Colours used in games

Bright colours	Dark colours	Combination of bright and dark colours
2,5,6	3,4	1,7,8,9,10

Figure 4.4. A record of a sort

Finally, participants were requested at the end of the session to sort the cards into groups of *"most likely to play," "likely to play"* and "*never likely to play"* to indicate how likely they felt they would play that game in the future. This was the closed part of the card sorting process. The pattern for sessions described above was repeated with all participants in all four locations.

4.2 Exploratory study data analysis

This section discusses the purpose of the data analysis and the procedure for completing the analysis. The analysis of data captured during the exploratory study should provide the evidence to support the key criteria that make some digital entertainment games successful with girls of age 11-14 years old.

4.2.1 Purpose of the data analysis

The data analysis was designed to answer the following questions:

1. Which digital entertainment game characteristics are significant i.e. influence motivational appeal of games to girls of age 11-14 years old?
2. Are there similarities and differences in the game characteristics that are significant to girls and boys participants?
3. What are the similarities and differences between genders in the appeal of significant game characteristics?

The answers obtained to these questions informed the design of the main study. For the purpose of the data analysis, different terms are used to distinguish between the card sorting process which involved the elicitation of information from the participants and the data analysis stage where the information was reviewed to obtain results. The term "*criteria"* is used to describe the attributes of the games as elicited from participants during the card sort as shown above. However, during the analysis of the data collected, the term "*construct*" is used in the next section and henceforth in the thesis to describe the result of the analysis i.e. the attributes used by participants to describe the games based on their experience (Kelly, 1955; Bannister & Fransella, 2013).

4.2.2 Procedure of the analysis of data

The analysis of the exploratory study data involved an initial qualitative analysis of the data using the commonly used semantic technique of semantic clustering. Semantic clustering was reviewed in detail in section 3.3.The output from the implementation of this technique was initially analysed by location and then by construct and gender. The analysis by location provided information about the understanding and perception of digital games based on the different location dynamics i.e. single gender and mixed gender schools.

The analysis by gender and construct provided evidence about how, as a group, girls and boys understand and perceive digital games. The outcome of this analysis also indicated if the findings are representative of the gender.

Each analysis is summarised with a discussion about how it contributed to providing a response to the research question.

From the application of the semantic clustering technique by the researcher, the constructs elicited from participants were organised into *"verbatim constructs"* using verbatim analysis. This process involved the aggregation of the criteria that have identical wording as one construct. An example of this procedure was the aggregation of all criteria *"popular game"* as a criterion *"popular game*".

The next stage of the semantic clustering was to aggregate the verbatim constructs from participants with identical underlying meaning as a single construct. This is referred to as the *"gist analysis."* An example of the gist analysis was the aggregation of *"a game everyone plays,"* and *"what everyone plays"* as the *"superordinate construct"* "*game popularity"* (Nurmuliani et al., 2004). A similar analysis of the categories within constructs was conducted where verbatim categories were aggregated into one category and gist categories aggregated as superordinate categories.

After the semantic analysis, quantitative analysis was applied. This included descriptive statistical analysis of the data such as the mean, median, mode, standard deviation values and statistical significance tests. This analysis provided the comparative values within the sample group for each location. In addition, a hierarchical cluster analysis of the appeal of the games by gender was also completed. The outcome of this analysis also provided a comparative indication of the appeal of the games within groups i.e. gender. A detailed review of each type of secondary analysis conducted is shown in section 4.2.4 of this chapter.

The semantic clustering and the descriptive statistical analysis were completed for all locations and aggregated into one result. For simplification, the detailed analysis by location is included in appendix 3. A summary of the results by location is discussed in section 4.2.3.

4.2.3 Discussion of results by location

A total of 131 constructs were initially generated from the repeated single-criterion card sort conducted at all four locations. A total of 95 constructs were elicited from the girls and 36 from the boys.

After the application of semantic clustering, as described above the numbers reduced to 47 constructs from the girls and 28 from the boys. A summary of the semantic analysis by location is illustrated in table 4.2.

The analysis of the data collected by location identified game constructs that were most frequently identified by the girls and boys. For location 1, a mixed gender school, the most frequent constructs differed between girls and boys. The most frequent construct for the girls was fun.

This was closely followed by constructs adventure, popularity, scenery, colour used, graphics and number of players. For the boys, fun, action and graphics were jointly the most frequent constructs. These were followed by game popularity, mission, age appropriateness, number of players and movement.

For location 2, which was also a mixed gender secondary school, the most frequent constructs for the girls were character, gaming device and violence. For the boys, it was the storyline, graphics, game control and action.

For location 3, the most frequent constructs were the number of players and graphics. These were followed by age appropriateness and violence. In location 4, the most frequent constructs were number of players, fun and popularity. These were followed by age appropriateness, violence, graphics, complexity and dialogue. The analysis of location 3 and 4 (the single gender girls schools) show more similarities between the girls at the two schools than between the girls at the two mixed gender schools. The similarities between location 3 and 4 were the number of players, age appropriateness and violence.

A possible reason for the similarity in the constructs generated between the single gender girls schools could be the lack of interaction with boys of a similar age group in the learning environment (Simpson et al., 2016). It was noted that the girls from the single sex schools appeared more confident and produced more game constructs (location 3=51 and location 4=62 respectively) as compared to the girls from the mixed gender schools (location 1=29 and location 2=34 respectively). No data was collected from single gender boys school for this stage of the study. However, there were no obvious differences between the boys in the mixed gender schools at both locations.

Construct No	Superordinate construct	Location 1		Location 2		Location 3	Location 4
		Girls frequency	Boys frequency	Girls frequency	Boys frequency	Girls frequency	Girls frequency
1	Number of players	2	2	2	1	5	5
2	Fun	4	3	1	1	3	5
3	Age appropriateness	2	2	2	0	4	4
4	Violence	1	1	3	1	4	4
5	Graphics	2	3	0	3	5	4
6	Colour used	2	1	2	0	3	3
7	Popularity	2	2	1	0	0	5
8	Storyline	2	0	2	3	2	3
9	Gameplay levels	1	0	0	0	2	3
10	Gaming device	0	1	3	2	2	1
11	Character	0	0	4	1	0	2
12	Scenery	2	0	0	0	1	2
13	Movement	1	2	1	0	3	0
14	Complexity	0	0	1	0	0	4
15	Role play	1	1	1	1	1	2
16	Audio	1	0	0	1	0	2
17	Game objective	0	0	0	0	1	3
18	Dialogue	0	0	0	0	0	4
19	Rewards	0	2	1	1	1	1
20	Control	1	1	1	2	1	0
21	Challenge	0	0	0	0	1	2
22	Adventure	2	0	0	1	0	0
23	Gameplay creativity	0	1	0	0	2	0
24	Gender based	0	0	1	0	1	0
25	Software platform	0	0	1	0	0	1

26	Feedback	0	0	0	0	1	1
27	Player involvement	0	0	0	0	1	1
28	Mission	1	1	0	1	2	0
29	Use of animals and creatures	1	0	0	0	0	0
30	Layout	1	0	0	0	0	0
31	Competition	0	0	1	0	0	0
32	Brand	0	0	0	1	0	0
33	Progression	0	0	1	0	0	0
34	Game type	0	0	1	1	0	0
35	Internet	0	0	1	0	0	0
36	Price of game	0	0	1	0	0	0
37	Software update	0	0	1	0	0	0
38	Appeal	0	0	0	1	0	0
39	Ease of use	0	0	0	0	1	0
40	Educational content	0	0	0	0	1	0
41	Rebellion	0	0	0	0	1	0
42	Theme	0	0	0	0	1	0
43	Title	0	0	0	0	1	0
44	Action	0	3	0	2	0	0
45	Duration	0	1	0	0	0	0
46	Environment	0	0	0	1	0	0
47	Fonts	0	1	0	0	0	0
48	Graphics view	0	1	0	0	0	0
49	Quality	0	1	0	0	0	0
50	Play location	0	0	0	1	0	0
51	Game series	0	0	1	0	0	0

Table 4.2. The semantic cluster analysis by location

A statistical test was conducted to determine if there is an association between gender and the frequency of the construct generated and the significance of the association. This statistical analysis was required in order to identify if the difference in gender or study locations was responsible for the difference in the frequency of the constructs generated between participating girls and boys.

The Pearson Chi-square test was used for this analysis, as it is a suitable tool for the evaluation of the distribution of sets of categorical data. It is also a test of association and the significance of the association (small, moderate, or large).

The null hypothesis for the test was established before the test was run.

H_0 = There is no significant association between the gender of participants and the frequency of constructs generated

H_1= There is a significant association between gender of participants and the frequency of constructs generated

If $P => 0.05$ accept H_0.

Table 4.3 illustrates the statistical test. The result indicated that $p=0.010$, hence H_1 is accepted for this test. This implies that there is a significant association between the gender of the participants and the frequency of constructs generated.

Chi-Square Tests Between Gender (girls & boys) and construct frequency

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	76.392	50	.010
Likelihood Ratio	81.508	50	.003
N of Valid Cases	234		

Table 4.3. Statistical test for the association between gender and the frequency of construct generated

A further cross-tabular analysis was conducted to determine the strength of the association. Table 4.4 illustrates the level of association between gender and the frequency of constructs generated. The *phi value (0.571)* indicated that the association is moderate to strong between gender and the frequency of constructs generated.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.571	.010
	Cramer's V	.571	.010
N of Valid Cases		234	

Table 4.4. Strength of association between gender and the frequency of the constructs generated

In summary, from the results of the analysis by location, there is an indication that the difference in the frequency of the constructs generated between girls and boys is because of the gender difference. The result of the statistical analysis was reviewed by a statistician for validity. The strength of association between gender and the frequency for the girls was valid. However, the association for the boys was indicative due to the unbalanced boy-to-girl ratio. As mentioned previously, the target group and focus of the study are the 11-14 year old girls. Consequently, the analysis of the result of the exploratory study was evaluated by gender and construct. This should support the investigation in identifying the reason for the appeal of some digital entertainment games to the target group.

Section 4.2.4 presents further analysis of the data by gender and construct. The section also illustrates the secondary analysis conducted and a discussion of the results.

4.2.4 Data analysis by construct and gender

The analysis of the data by gender and construct was conducted to identify the constructs that were identified more frequently by each gender. This is taken to be a measure of the significance of the construct i.e. the construct that was identified most frequently is considered as the most significant. To identify the constructs significant to girls and boys, the construct by gender matrix was used to establish the frequency values. Table 4.5 presents the construct cumulative frequency values by gender. Figure 4.5 presents the same data in graphical form.

Construct No	Superordinate construct	Girls cumulative frequency values	Boys cumulative frequency values
1	Number of players	14	3
2	Fun	13	4
3	Age appropriateness	12	2
4	Violence	12	2
5	Graphics	11	6
6	Colour used	10	1
7	Popularity	8	2
8	Storyline	9	3
9	Gameplay levels	6	0
10	Gaming device	6	3
11	Character	6	1
12	Scenery	5	0
13	Movement	5	2
14	Complexity	5	0
15	Role play	5	2
16	Audio	3	1
17	Game objective	4	0
18	Dialogue	4	0
19	Rewards	3	3
20	Control	3	3
21	Challenge	3	0
22	Adventure	2	1
23	Gameplay creativity	2	1
24	Gender based	2	0
25	Software platform	2	0

26	Feedback	2	0
27	Player involvement	2	0
28	Mission	3	2
29	Use of animals and creatures	1	0
30	Layout	1	0
31	Competition	1	0
32	Brand	0	1
33	Progression	1	0
34	Game series	1	0
35	Game type	1	1
36	Internet	1	0
37	Price of game	1	0
38	Software update	1	0
39	Appeal	0	1
40	Ease of use	1	0
41	Educational content	1	0
42	Rebellion	1	0
43	Theme	1	0
44	Title	1	0
45	Action	0	5
46	Duration	0	1
47	Environment	0	1
48	Fonts	0	1
49	Graphics view	0	1
50	Quality	0	1
51	Play location	0	1

Table 4.5. Construct cumulative frequency values by gender

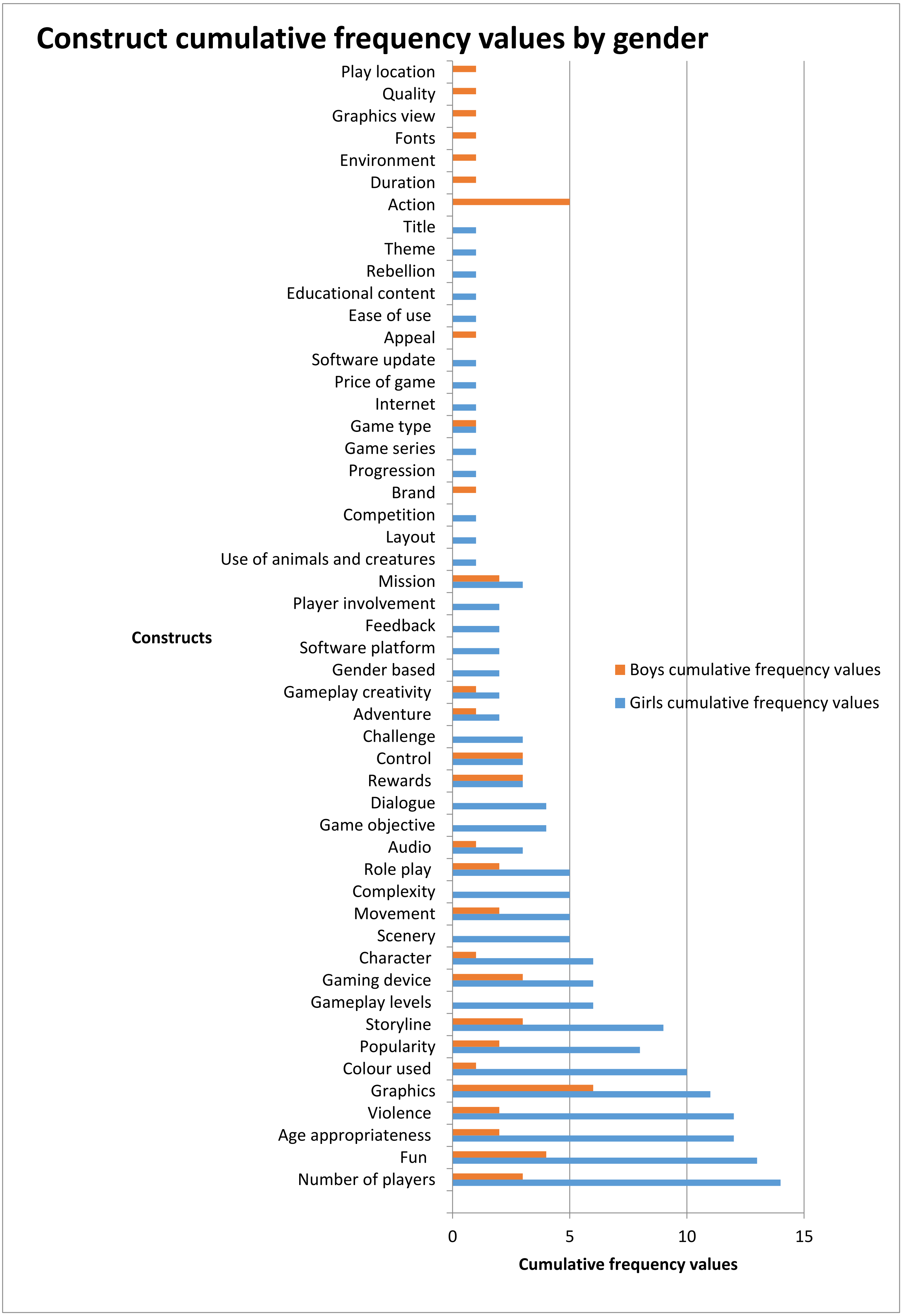


Figure 4.5 Construct cumulative frequency values by gender

From the analyses, as shown in table 4.5 and figure 4.5, the number of players, fun, violence, age appropriateness, graphics and colour used can be seen to have the highest frequency values for the girls. Other constructs with relatively high frequency values for girls included the popularity of the game and the storyline of the game. For the boys, graphics, action, and fun have the highest frequency values. Other constructs of relative high frequency values for the boys include control, device, rewards, storyline, and the number of players. A comparative review of the results from girls and boys identified the number of players as the construct with the highest frequency value for the girls and graphics for the boys. Furthermore, storyline and the number of players were also of high frequency values between both genders. A comparative game construct frequency count for girls and boys is summarised in table 4.6. The table illustrates the game constructs with the highest frequency values which are referred to as the *'significant game constructs'* in this study.

No	**Girls game construct (frequency %)**	**Boys game construct (frequency %)**
1.	Number of players (30%)	Graphics (21%)
2.	Fun (28%)	Action (18%)
3.	Age appropriateness (26%)	Fun (14%)
4.	Violence (26%)	Control (11%)
5.	Graphics (23%)	Gaming device (11%)
6.	Colour used (21%)	Storyline (11%)
7.	Popularity (17%)	Number of players (11%)
8.	Storyline (17%)	Reward (11%)
9.	Gaming device (13%)	Age appropriateness (7%)
10.	Character (13%)	Mission (7%)
11.	Gameplay levels (13%)	Violence (7%)

Table 4.6. Comparative game construct frequency percentage for girls and boys

The think-aloud comments captured during the card sort were also analysed for additional qualitative insight. During the card sort sessions, participants were encouraged to verbalise their thought process while generating criteria and the categorising the cards. In spite of encouragement, most participants did not say much during the card sorting process and so the volume of comments was not large.

A general analysis of the comments recorded was initially conducted to identify the broad meaning of the comments as recorded against different constructs. This was then refined to include only comments about the significant constructs. The rationale for this approach was to gain more insight into the reasons why these constructs were significant to participants.

The comments were then analysed to identify the relationship between the participant’s comments and constructs. Table 4.7 illustrates some of the think-aloud comments for some of the significant constructs identified during the study. The selection of the comments was based on the game constructs with the highest frequency for the girls and the comments were used to gain more qualitative information on these constructs.

Game construct	Participant comments (Girls)	Participant comments (Boys)
Number of players	“The number of players in a gaming environment determines the level of communication which is important in a game”;	“Multiplayer games are fun”;
	“When there are a number of players, it becomes educational in a way as we can share ideas”;	“I prefer a game many people can play”;
Fun	“How involving the game is must have levels of play and can be played by a number of people. It must not be too difficult as well”;	“Rewards and being able to complete the game makes it fun”;
	“It provides the opportunity to interact with other people and this creates more fun”;	“There is an urge to return to a fun game”;
	“Learning something new makes playing games fun”;	
Age appropriateness	“There is not a lot of appeal in a game if the age is not right for me”;	“If the game is not at my age it may be too easy or difficult to play”;
	“It (the game) becomes unchallenging if the age is not right as the game would be too easy to play”;	“I would not play a game that is not for my age group”.
	“This game has the features I would like but it is too easy to play”;	
	“Unappealing if the age is not right as it might be difficult and require a lot of thinking and movement”;	
Violence	“I do not mind some violence, but a lot of it becomes off putting”;	“I like extremely violent games”;
	“…boys game”;	

	"I do not mind playing games with some violence, but I will not play one that is extremely violent";	
Graphics	"The graphics are similar to that for little children of age 3-9 years of age";	"The game graphics affects the game design";
		"The game graphics is how the game looks like";

Table 4.7. Girls and boys think-aloud comments

The analysis progressed to identifying if there were any similarities or differences in the appeal of each significant game construct by gender identified during the study. The think-aloud comment discussed above provided some insight. The '*Likely to play'* data collected at the end of each session provided more evidence for the investigative analysis. A detailed review of how *'The Likely to play*' data was used to investigate the variation in the appeal of significant game constructs is described in the next section.

4.2.4.1 The appeal of constructs generated

At the close of each session, the participants performed a closed card sort, which was used to obtain more qualitative information from the outcome of the repeated single-criterion sort. The outcome of the correlation of results from both card sorts was the appeal of the constructs generated by the participants. They sorted the picture cards into three categories *'Most Likely to Play', 'Likely to Play*' and *'Never Likely to Play*'. The analysis of the data collected from this activity which involved the correlation of the *"Most Likely to Play"* result from the closed card sort with the categories generated during the repeated single-criterion card sort was used to generate information about the appeal of the frequently occurring game constructs which are then referred to as the significant game constructs. The appeal of a game in this study was analysed based on the categories recorded for each construct during the repeated single-criterion card sort. The data was analysed to create a '*likelihood data table'* in Microsoft Excel.

The data table was used to rank the constructs and categories based on the selection of the games as identified by the card number. Table 4.8 illustrates the summary of the game constructs and the most re-occurring category from the analysis, which is referred to as the '*significant category*'.

From the analysis, each construct has a number of categories. This is labelled as the *'No of categories'* in the table. The '*significant category'* has the most significant effect on the appeal of the construct. This is obtained from the correlated data from the "*Most Likely to Play*" data from the closed sort, obtained from the calculated values of likelihood percentage and weighted likelihood (see appendix 4 - Likelihood data table). For example from the table 4.8, for the girls, the construct graphics has three categories with cartoons (significant category) having the most effect on its appeal.

	Girls (N=24)		**Boys (N=8)**	
Game construct	**No of categories**	**Significant category**	**No of categories**	**Significant category**
Graphics	3	Cartoons	3	Photographs
Fun	3	Lot of fun	3	Lot of fun
Game control	4	Moderate control	3	Full control
Gaming device	4	Any device	3	Specialised
Number of players	2	Player interaction	2	Non-interactive
Rewards	3	Progression	5	Points
Storyline	3	Include a definite storyline	3	May or may not include storyline
Age appropriateness	10+	All ages/ everybody	3	Teenage games- suited for age group
Mission	2	Not based on character mission	2	Based on character mission
Violence	3	No violence	3	Very violent
Popularity of game	3	Very popular	3	Popular games
Colour used	6	Bright colours	2	Dark colours
Character	4	Human with real scenarios	4	Animals in fantasy scenarios
Action	-	-	5	Lots of action
Game levels	2	Game with levels	-	-

Table 4.8. Girls and boys construct and category pairing.

Table 4.9 summarises the result from table 4.8. It shows the significant constructs and category pairing for girls and boys that result in appeal.

Game construct	**Construct category with appeal (girls)**	**Construct category with appeal (boys)**
Graphics	Cartoons	Photographs
Fun	Lot of fun	Lot of fun
Control	Moderate control	Full control
Gaming device	Any device	Specialised
Number of players	Player interaction	Single player
Rewards	Progression	Points
Storyline	Include a definite storyline	May or may not include storyline
Age appropriateness	All ages /everybody	Teenage games-suited for age group
Game mission	Not based on character mission	Based on character mission
Violence	No violence	Very violent
Popularity	Very popular	Popular games
Colour used	Bright colours	Dark colours
Character	Human with real scenarios	Animals in fantasy scenarios
Action	-	Lots of action
Gameplay levels	Game with levels	-

Table 4.9.Significant game construct categories with appeal to participating girls and boys

Further analysis was conducted to identify how the games are grouped based on the *'Likely to play'* responses from the participants using a hierarchical cluster analysis. The result of this investigation is included in appendix 5 - Cluster analysis results. The results indicated that the construct categories appear to influence the groupings of the games.

4.2.4.2 Construct category pairings for further investigation

From the list of significant game constructs that appear to appeal to the girls, seven constructs category pairings were identified for further investigation, which determined if the inclusion or exclusion of these constructs had an impact on how 11-14 year old girls engage with digital educational games for learning computer science. The constructs were selected from the list of significant game constructs identified during the exploratory study (see table 4.6).

Furthermore, the selected constructs were among the top 15 constructs identified from the analysis. In some instances, they presented a considerable variation between girls and boys. For example, while the girls found bright colours appealing, the boys indicated that dark colours are more appealing. In other instances, the differences were not distinct and hence required further investigation. For example, girls prefer non-violent games but would play games with moderate violence. Some related work argues otherwise.

Other pragmatic reasons for the selection of these constructs for further investigation included the availability of resources. Technical expertise was also a key factor that determined the constructs for further investigation.

The constructs category pairings for further investigation are presented in table 4.10.

No	Female game constructs	Categories
1.	Age appropriateness	All ages/everybody
2.	Game violence	No violence
3.	Game graphics	Cartoons
4.	Colour used	Bright colours
5.	Game character	Human with real scenarios
6.	Number of players	Player interaction
7.	Storyline	Include a definite storyline

Table 4.10. Selected construct /category pairing for further investigation.

To investigate the impact of these construct category pairings, two experimental digital educational games for learning basic computer science concepts were created for the main study. Both games set similar tasks but were customised such that one incorporated construct category pairings shown to appeal to girls, for example, construct: colour used, category: bright colours. The other game included an antithesis of the category that is not the most appealing for each of the chosen constructs.

4.5 Discussion and Summary

This chapter described the implementation of the exploratory study conducted with 11-14 year old girls and boys from four secondary schools in southeast England. A total of 32 participants were involved in the study. The analysis of the data captured during the survey indicated there are game constructs that are significant to each gender as shown by the cumulative frequency values. The result of the analysis also indicated that these constructs appeal differently to the girls and boys depending on the construct category pairings.

Gameplay levels and action were shown from this study to be highly gender specific. Game action was peculiar to the boys, as there seems to be an appeal for high hand-eye coordination requiring quick-paced interactions (Gorriz & Medina, 2000).

For the girls, the appeal for gameplay levels can be associated with the requirement for a game to be purposeful and show progress. It also encourages a non-competitive structure, exploration, less time pressure and failure threats (Lucas & Sherry, 2004).

Another group of game constructs were significant to both genders but differed in their appeal. Examples of such game constructs include graphics, character, violence, control, gaming device, storylines, mission and the number of players. For example, the girls preferred cartoon images while the boys preferred photographic images. This difference was supported in related work on computer graphics for girls and boys by Jakobsdóttir et al. (1994).

Fun was significant to both girls and boys participants. However, the think-aloud comments reveal that the range of game characteristics that create fun vary between genders.

Gameplay levels, number of players, exploration, progression, complexity, and interactivity contribute to the fun of the game for girls. For the boys, it included violence, action, number of players, reward and challenge. The number of players was also significant to girls and boys participants. The think-aloud protocol comments (see fun and number of players in table 4.7) indicated that a game that allows interaction between players improves the appeal of the game for girls. Consequently, it is beneficial to ensure that the appropriate multiple player tools and a social interaction platform are included in games designed for girls of age 11-14.

Game violence was significant to girls and boys but varies in appeal depending on the amount of violence. Girls find games with non-violent content more appealing as compared to games with violent content. However, the result also indicated that girls would play games with moderate violence in preference to very violent games. This was further supported by the think-aloud comments.

The more appealing colours also differ significantly between girls and boys. Girls find bright colours more appealing and the boys, dark colours. Related work on the effective use of colours and graphics in applications for children of age 7-14 by Naranjo-Bock (2011) and Nielsen et al. (2013) support this finding. Girls were identified to find bright colours appealing and boys' dark colours.

Game popularity can also greatly affect the appeal of games to both genders. Girls find games that are very popular more appealing. However, boys find games that are moderately popular more appealing. Finally, there was a difference in the preference of the game character for girls and boys. Girls find more appealing a human character set in real life scenario while the boys an animal character set in a fantasy scenario. Kafai (1996) reported that there were differences between gender with regard to the fantasy-reality dimension of the worlds of girls and boys games. The girls' were identified to use real-life settings for games they designed and the boys' fantasy settings. An argument to support the difference in the appeal of human characters to girls and animal characters to boys could be associated with the need for realistic roles that they can identify with as compared to fantasy roles (Kafai,1996; Cassell & Jenkins, 1999).

In relation to the research question "*Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"* The exploratory study indicated that a range of significant game characteristics can contribute to the motivational appeal of digital entertainment games. To confirm this understanding, seven significant game constructs with categories that appeal to girls were identified at the end of the exploratory study.

These constructs were applied in the customisation of an educational game used to teach basic computer science concepts. The customised versions of the games were used in the main study to provide empirical evidence in response to the second part of the research question *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

CHAPTER 5

CREATION OF EXPERIMENTAL GAMES

5.0 Introduction

In chapter 4, the data collected from the exploratory study was analysed and digital entertainment game characteristics that are significant to 11-14 year old girls were identified. The study further investigated the appeal of the significant game characteristics to the target group of 11-14 year old girls. The result of this investigation identified the variations of the game characteristics, which can make them appealing to the target group. The chapter concluded with the selection of a variation of seven significant game characteristics in digital entertainment games for further investigation in experimental educational games for studying computer science. The conclusion of the exploratory study provided the evidence, which suggested that variations of significant characteristics in digital entertainment games could make them appealing to 11-14 years old girls. This chapter discusses the process of implementing the findings from the exploratory study to produce two experimental digital educational games for the study of basic computer science concepts.

Chapter 5 initially reports on how an existing digital educational game for learning basic computer science concepts was chosen and then customised to create two experimental games for the main study.

The purpose of creating the two experimental games which included variations of game characteristics identified from the exploratory study to be significant to girls of age 11-14 were:

1. To confirm the results of the exploratory study to the first part of the research question - "*Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"*
2. To provide the empirical evidence in response to the second part of the research question - *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

The first experimental game included the variations of the significant game characteristics that positively appeal to the girls and the second the antithesis of the characteristics selected for the first game. The rationale for the variation of the game characteristics as identified from the exploratory study was to investigate 1) if the selected game characteristics would also be appealing in digital educational games and 2) the impact of the variants of the significant game characteristics on the girls.

The customised games are initially referred to as '*experimental games'* because they are used to investigate the selected significant game characteristics. For the rest of the thesis, they are referred to as *'games'* for ease of understanding.

Section 1 describes the process of choosing an existing digital education game for customisation. Section 2 describes the procedure for customising the existing game, using a suitable digital educational game framework to evaluate the effectiveness of the existing game and ensure that the customisation process does not compromise the educational effectiveness of the game. Section 3 reports on how the process of customisation was implemented. Section 4 is a summary of the chapter.

5.1 Choosing a suitable digital educational game

This section describes in detail how the existing digital educational game was chosen for customisation. The process involved identifying the requirements for the educational game, the available options and then choosing with justifications a game suitable for customisation. The chosen game should satisfy a number of technical and educational requirements, which includes the following:

1. An educational game that supports the learning of basic computer science concepts. This is a requirement for the existing digital game because the research question investigates the creation of computer science learning games that appeal to 11-14 year old girls. The game should provide some form of feedback to enable participants to improve their knowledge and understanding of the computer science concept(s).

   The game challenge should be differentiated to enable participants engage at different levels and build their understanding and knowledge in the course of gameplay. This should then enable the participants to take on more challenging tasks. As a learning game, this requirement ensures that the game supports a range of abilities of participants;

The game should also provide participants with the opportunity to transfer the knowledge and understanding within and outside the gaming environment. This requirement should enable participants to apply the knowledge and understanding gained from one task in another scenario. These are basic requirements for an effective digital educational game that facilitates constructive learning;

2. The existing digital educational game should be set in a visual environment, which does not require competence in computer science concepts as participants are not required to have prior knowledge of computer science;
3. A game set in a visual environment would also be preferable as it is fun and easy to engage with;
4. The game should be accessible on most software platforms as restrictions to a specific platform that is not easily accessible would be a limitation to the study. Participants are selected from different locations and they needed to access the same games and submit feedback online from study locations;
5. An open source game building environment that would support the customisation of the game to create two variants. The successful creation of two experimental games is fundamental to the main study.

To meet requirement 1, only educational games that support the learning of computer science concepts were considered. For requirements 2 and 3, digital educational games set in a visual environment such as Scratch, Alice, Google Blockly were considered as experienced and the inexperienced participants can engage with them easily. These game environments are fun and non-threatening to players (Kelleher et al., 2007). The Google Blockly game was chosen due to the availability of existing educational game that supported the learning of basic computer science concepts. For requirement 4, web-based games were considered as these could be accessed easily by participants from all locations of the study. The Google Blockly game was accessible on the web.

Requirement 5 indicated that the game must be open source to ensure that it can be customised to include the variants of the significant game characteristics identified from the exploratory study. The other requirements of the game included feedback, challenge, and transfer of knowledge.

The Google Blockly maze game was the only option available from the Blockly games at the time, hence it was considered for customisation as it met all the requirements. This game supports the learning of basic computer science algorithm concepts. The game is set in a visual programming environment, web-based and open-source. Other pragmatic reasons for choosing this game included the technical expertise of the researcher to customise this game and no cost in acquiring the software.

As a result, this game was chosen for customisation to create the two games for the main study. A detailed description of the Google Blockly maze game is reported the next section.

5.1.1 The Google Blockly maze game

The Google Blockly maze game is an open source program deployed in a web-based visual programming environment (Kumar, 2014). The visual programming environment provides learners with the opportunity to stack blocks of programming constructs to form a set of instructions. The environment is graphical and enables the users to manipulate instructions with little or no prior computer programming knowledge (Halbert, 1984; Kumar, 2014). Learning how to program and understand the concepts of programming is challenging for many learners. This is because programming is cognitively challenging and involves a number of inter-related skills such as syntactic, conceptual and strategic knowledge (McGill & Volet, 1997; Naidoo, & Ranjeeth, 2007).

Baldwin & Kuljis (2001) and Ko, Myers & Aung (2004) indicated that an effective aid to developing lacking or incomplete skills when learning to program is the use of visual support for learners. Visual programming environments facilitate the development of software in a context that is fun and non-threatening (Kelleher, Pausch, & Kiesler, 2007).

The learning objective of the game was to design instructions that would implement some or most of the basic programming constructs used in computer science algorithms. For this game, the player is required to instruct a lost character (*Pegman*) on how to get to the home position *(The marker*) by navigating through a maze. If the instructions are correct, the objective is achieved and the player is prompted to progress to the next level, which presents a more complicated maze problem. If the instructions are incorrect, the game issues prompts on how to get to the home position.

A successful completion of a set of instructions can be translated into the JavaScript programming language. Figure 5.1 illustrates the original game prior to its customisation.

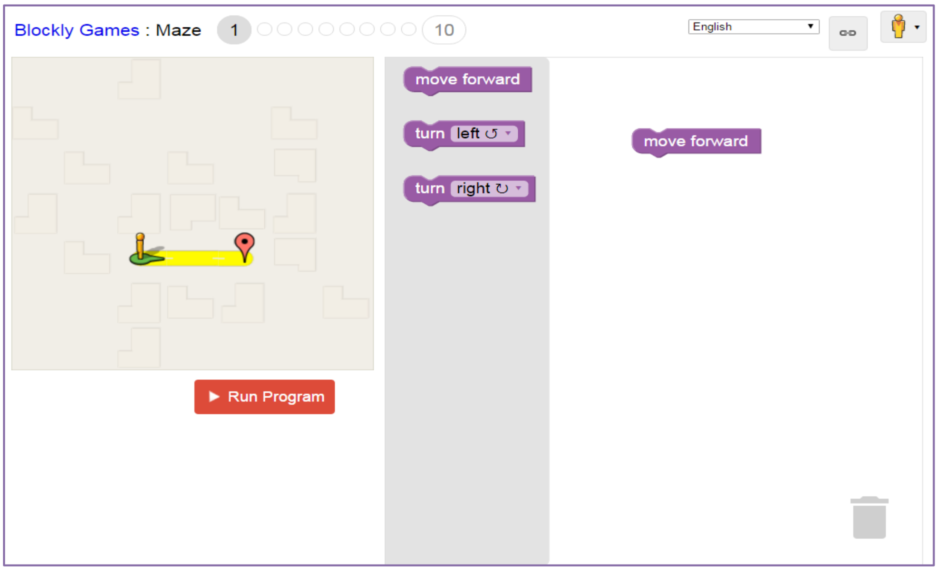


Figure 5.1. The Google Blockly maze game

There are 10 levels of play in the gaming environment, each focuses on the use of different programming constructs:

Level 1 – This level focuses on SEQUENCING of instructions. This level also allows the user to use an unlimited number of blocks to get to the home destination successfully.

Level 2 – This level considers a combination of SEQUENCE and DECISION instructions. The sequence provides a linear direction along the maze while the decision determines at the end of a linear path if the maze required 90^{o} turn to the Left or Right. This level was also allocated an unlimited number of blocks.

Level 3 – This level further considers the use of similar multiple instructions in a linear sequence. However, lesser number of blocks were made available to the player. To successfully complete this level, the user is expected to use the single REPEAT block in addition to the other instructional blocks provided. This level enables the player to understand the use of REPEAT (LOOP) in program constructs.

Levels 4 & 5 – These levels consider a combination of SEQUENCE, DECISION and REPEAT statement blocks. The number of blocks required to successfully complete this level is limited. Hence, the repeat block is also provided for both levels. Both levels are allocated a maximum of four blocks respectively.

Levels 6, 7 & 8 – These levels consider a combination of SEQUENCE, DECISION, REPEAT and IF statement blocks. The player is also provided a limited number of blocks. This ensured that the repeat and if statements blocks are used accurately in the visual programming environment. Both levels 6 and 7 are allocated a maximum of four blocks respectively. Level 8 is allocated a maximum of nine blocks.

Levels 9 & 10 – These levels consider a combination of SEQUENCE, DECISION, REPEAT, IF and IF-ELSE statement blocks. The player is also provided a limited number of blocks. This ensures that the repeat, if and if-else statement blocks are accurately used. A total of six blocks is allocated to level 9 and nine blocks to level 10.

In addition to the levels and the blocks, the player is able to choose the colour of the main character from a menu. The game refers to this as selecting "*your favourite player.*" This is an opportunity for the player to demonstrate a preference for colour schemes. There is a recycle bin for reusing statement blocks. There are also feedback messages and prompts to guide the player in the programming environment. On the successful completion of a level, a congratulatory message and instructions to proceed to the next level are displayed on screen.

5.2 Procedure for customising the Google Blockly maze game

This section describes the procedure of customising the existing Google Blockly maze game. The process initially involved the evaluation of the chosen existing digital educational game to confirm its educational effectiveness and identifying the aspects of the game that can be customised without compromising the effectiveness of the game. The evaluation of the game involved the use of a digital educational game framework for the design and creation of digital educational games. This was then followed by a review of how to implement the variants of the significant game characteristics in the two games was created.

5.2.1 Evaluating the Google Blockly game using a digital educational game framework

In section 2.6, a number of digital educational games design frameworks were reviewed to ensure that the integration of game design technology with educational content achieved the intended outcome of fun and educational objectives. Three proposed frameworks by Aleven et al. (2010), Garris et al. (2002) and Amory et al. (1999, 2001) were further reviewed because of their conciseness on the use of game characteristics to enhance the motivational appeal provided by digital educational games.

For this study, the requirements for choosing an educational game framework which was applied to the existing game were to:

1. Confirm the suitability of the design of the existing game for learning:

   From the research question, the primary objective of creating the games was to support the learning of computer science concepts. Consequently, an existing game that was customised for the purpose of the study should be designed adequately to meet educational objectives. If the chosen game was not an effective choice, similar games that meet the basic requirements would have been reviewed.

2. Apply the design guidelines of the framework to improve the appeal of the existing game:

A key outcome of the research question is the improvement of game appeal based on the application of variants of significant game characteristics to a game. A suitable framework should provide guidelines on aspects of the game that can be customised to improve the appeal without compromising the educational effectiveness of the game.

From the list of three frameworks above, the framework proposed by Aleven et al. (2010) was considered the most suitable framework, which satisfied the requirements stated above for the following reasons:

1. This framework has met requirement one i.e. can be used to confirm the suitability of the game for learning. Two of the three components of the framework support the design and evaluation of digital educational games for their effectiveness. Both the learning objectives and instructional design principles guidelines of the framework can be used to evaluate the educational effectiveness of digital educational games.
2. The MDA (Mechanics, Dynamics and Aesthetics) component of the framework satisfied requirement two. The guideline reviews the interrelationship between the game rules and the behaviours that result from applying the game rules to create fun. This component of the framework further provides taxonomy of fun, which is indicated to be non-exhaustive (Aleven et al., 2010). This offers both designer and player perspective of the game design process and the relationship between both. The MDA provides the opportunity to review how changes from one perspective during design affect the other perspective (Hunicke, LeBlanc & Zubek, 2004). Furthermore, the MDA component provides guidelines on how to customise aspects of the game (game materials) without compromising the effectiveness of the game (rules goals, moves and control option).

On this basis, the framework proposed by Aleven et al. (2010) was chosen and used to confirm the educational effectiveness of the Google Blockly maze game and customise it without compromising its effectiveness.

This framework was used to analyse the game from three perspectives: the learning objectives, the instructional principles and the game mechanics, design & aesthetics (MDA) of the game. The three components of the framework support the analysis of important design choices during the design of digital educational games. A review of how the three components of the framework were used to evaluate the Google Blockly maze game and design the experimental games is reported below.

5.2.1.1 Component 1: Learning objectives

A clear specification of the learning objectives supports the use of the game as an educational tool to meet educational goals. The framework suggests that the specification of the learning objectives must satisfy three key questions:

1. What knowledge or skills do players require before starting the game?
2. What knowledge or skills can players be expected to learn from the game?
3. What knowledge and skills might players learn that go beyond what they actually encountered in the game.

In response to the first question, the player must have some *prior knowledge* of how to decompose information into blocks of instructions. For example, to move from point A to B, three linear steps are required. However, this knowledge can also be constructive as the player progresses through the game. The game commences with a simple task on how to decompose the problem into blocks of linear instructions which can be used to create a solution to the problem.

The higher levels of the game require the player to decide if they need to turn 90^{O} left or right in order to get to the destination. Consequently, the player must have a basic understanding of relative left or right depending on the reference point of the destination. The player must also possess some prior knowledge or construct the knowledge progressively by making decisions depending on the goal to be achieved. Other aspects of the game such as the use of REPEAT, IF and IF-ELSE statement blocks build on the prior knowledge of sequencing and decisions. This is extended in the game from level 3-10.

Question two can be used to evaluate the learning that occurs while playing the game and the retention of knowledge that should occur.

By playing the maze game, the player is likely to acquire a better understanding of how to decompose instructions and use this skill to attempt to compose complex instructions. In the game, the initial task is focused on the use of sequences to create direct or linear instructions. The player is then challenged to use this skill and knowledge to create instructions that are not linear, as decisions have to be made depending on the reference point of the destination. Some of the levels further extend the player to use fewer blocks to arrive at a solution.

With respect to question three, the transfer of knowledge and skill is evaluated in the game. It can be speculated that the game supports the players to develop an understanding of why instructions need to be precise and accurate. It extends the player to understand why REPEAT, IF and IF-ELSE statement blocks are used when creating instructions. This knowledge further extends to how instructions are translated to JavaScript programming language. By engaging with the game, the knowledge and skill can be learned and used in a different context.

5.2.1.2 Component 2: Instructional Principles

According to Aleven et al. (2010) framework, a key assumption is that instructional design principles that have been established in other types of learning environments will carry over to the design of educational games and can support the creation of games that are educationally effective.

This framework considers four instructional design principles:

1. Multimedia principles (Mayer & Moreno, 2003);
2. Cognitive tutor principles derived from research on intelligent tutoring systems (Anderson et al.,1995);
3. Life-Long Learning Principles based on the compilation of 25 principles from learning research science;
4. Gee’s (2007) 36 principles of game-based learning.

Aleven et al. (2010) further stated that there is an overlap between the four principles, however, their focus is different. In analysing games using the principles, it is important to identify the principles a game might violate or ignore.

To indicate the source of the learning principle, the following abbreviations: MM= Multimedia Principles; CT= Cognitive Tutor Principles and Gee = Jim Gee's Principle of Game–Based Learning have been used in this review.

The Google Blockly maze game implements a number of principles from the sources listed above. Gee#12: *"Learners get lots and lots of practice in a context where the practice is not boring".* The game provides the player opportunities to practice getting the solution correct without time pressure. During this process, there is feedback and hints on how to arrive at the correct solution. As a result, the game implements CT#6: *"Provide immediate feedback on errors".* The feedback system is extended to include cues on the most appropriate blocks to use to make the instructions more concise or prompts when the player has taken too long to respond to the game. This information is provided just in time, when the player needs it or at the point when the information can be best understood and used in practice. This reflects the Gee#27: *"Explicit information on-demand and just-in-time principle*".

Finally, the game gets more challenging as the player progresses through the levels. This reflects the Gee#14: "Regime *of Competence Principle: The learner gets ample opportunity to operate within, but at the outer edge of his or her resources so that at those points things are felt as challenging but not undoable".*

According to Habgood & Ainsworth (2010), the analysis of an educational learning game should present a coherent story of supported principles and not a complete coverage of all the associated learning principles. Based on this measure, the Google Blockly maze game met the instructional principle requirements of a digital educational learning game.

5.2.1.3 Component 3: MDA

The third component of the framework is focused on three mutually-dependent layers of the game: Mechanics, Dynamics and Aesthetics. The MDA component, which is also a framework in its own right (Hunicke et al., 2004) and provides a taxonomy for the game mechanics and aesthetics. The game analyst or designers should invent the terms and concepts that characterise the dynamics of a given game (Aleven et al., 2010).

Furthermore, Aleven et al. (2010) suggested that although the MDA framework provides a taxonomy of eight aesthetic elements which includes sensation, fantasy, narration, challenge, fellowship, discovery, expression and submission, they are non-exhaustive as it is a guide to explaining the aesthetic components of a game. The MDA framework establishes the game components from a player perspective and its design counterpart from the analyst or designer's perspective and the relationship between them. The player perspective starts from what makes a game "*fun".* The "*fun"* associated with a game from the player perspective are the emotional responses evoked in the player when they interact with the game system. This is the aesthetic component from the designer or analyst perspective which is achieved by manipulating the aesthetic elements discussed above.

In addition as shown in figure 5.2, the MDA informs the designer of elements that can be customised to improve the appeal of the game without compromising the effectiveness of the game. The framework identifies the taxonomy of the game mechanics, which can be customised to improve the aesthetics elements of the game.

Based on the selected variants of the game characteristics from the exploratory study for further investigation, the MDA framework was used as a guide to review the existing game aesthetics taxonomy. The framework presents the player and the design counterparts respectively (figure 5.2). The outcome of the application of the framework was used to identify the aspects of the Google Blockly maze game that could be improved aesthetically to provide *"fun"* in the player perspective. The taxonomy provided within the aesthetic component of the framework was used to implement the customisation process. A detailed account of how the customisation was achieved using the taxonomy is described in section 5.2.2.

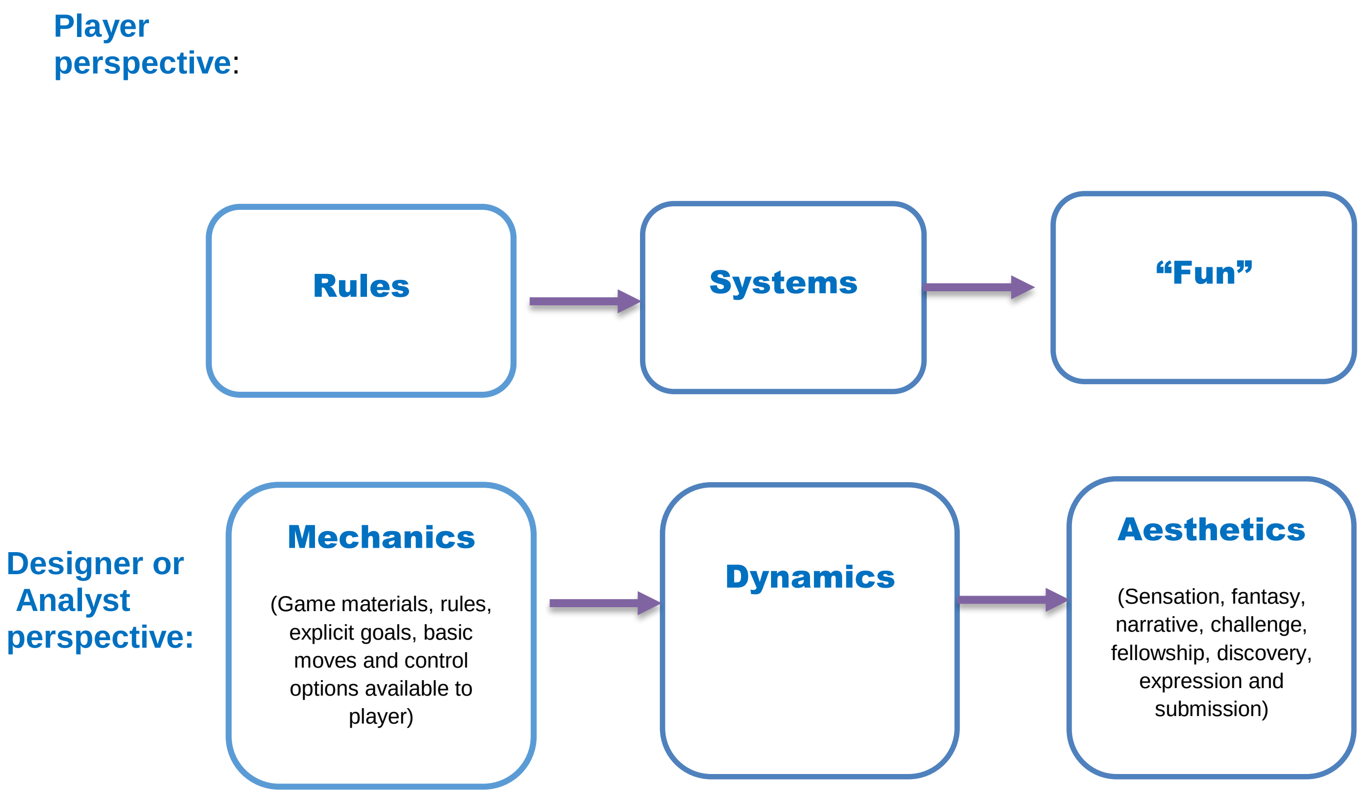


Figure 5.2. The MDA framework perspectives from Hunicke et al. (2004)

According to Hunicke et al. (2004), a review of a game from both perspectives is important in order to understand how changes in one layer affect the other. Furthermore, a consideration of the player encourages an experience–driven design which has been suggested to improve the player reflection and exploration (Ke, 2014).

Of the eight aesthetic elements in the MDA taxonomy, challenge is the most clearly associated element with the Google Blockly maze game. Challenge is associated with getting the *pegman* to the marker point at each level. The learning content also adds to the feeling of challenge provided by the game. The player is required to use linear instructions initially to get to the marker point. At higher levels, a combination of SEQUENCES, DECISION REPEAT, IF and IF-ELSE statement blocks are required for the solution to the problem. The game rule such as the use of fewer statement blocks adds to the challenge provided by the game. A secondary aesthetic element associated with the game is fantasy.

The player assumes the role of the *pegman*. In addition, the narrative of the game was inherent as it involves *pegman's* journeying through the maze.

The game dynamics create the aesthetic experiences. For example, the challenge is created by the game mechanics in getting the *pegman* to the marker and the use of fewer statement blocks as a rule within the game environment. There is no time pressure associated with this game.

Finally, using the MDA framework to evaluate the Google Blockly maze game indicated that the game has implemented mostly the aesthetic elements of challenge, fantasy and some narrative to achieve the learning objective of the game. This should enable the player to acquire the knowledge or skill, which can improve retention and the transfer of knowledge and skill.

5.2.2 Procedure for implementing the variants of the significant game characteristics

In section 4.2, table 4.10, the construct category pairings that were used to identify the seven variants of the significant game characteristics for further investigation were presented. These variants of significant game characteristics were included in one game and the alternative variants in the second game.

It is important to note that some of the variants were “*meta-constructs”* by definition as a number of game variants were implemented to achieve the desired outcome.

For example, to implement the game characteristic of age appropriateness, graphics, colour, font sizes, character type etc. has to be considered. Also, the implementation of the variants of the graphics also involves colour and type of image. Table 5.1 illustrates the game characteristics for implementation, description of the game characteristics and the appeal of the characteristics.

No	Game characteristic	Description of characteristic	Variant of the characteristic
1.	Age appropriateness	Whether or not a game is appropriate for my age group.	Games that appeal to my age group
2.	Violence	The amount or level or violence in a game	No violence included
3.	Graphics	The combined use of images, colours and scenery to provide the graphical component of the game	Bright cartoon graphics
4.	Colour used	A range of colours used in the game	Bright colour scheme
5.	Character	The characters used in a game are the objects which can be controlled by the player or the game program.	The use of timeless human character.
6.	Number of players	The number of players that can engage with a game at a specific time.	A gaming environment with social interaction e.g. chat room facility.
7.	Storyline	The narrative of a game, which could be audio, media, or graphics.	Include a definite storyline (Narrative)

Table 5.1. Game characteristics from the exploratory study used in the customisation process

5.2.2.1. Game characteristic No. 1 – Age appropriateness

Studies on usability issues suggest that when designing for children, age appropriateness of design is crucial to young learners (Catherine, 2001; Nielsen, 2010). This characteristic includes a number of visual elements in the gaming environment such as the colours, graphics, game layout and characters used (Nielsen, 2010). The existing game was age appropriate.

However, elements such as colour and character used were customised in game two to make it less age appropriate and enhanced in game one to make it more age appropriate for the purpose of the study.

Game one - *The Lost Astronaut* game used a range of bright colours for the game graphics and background. The game background was also a cartoon graphic. An up-to-date main character i.e. an astronaut in a realistic scenario was used in this game.

Game two - *The Lost Hippo* game included alternative variants of the significant game characteristics. The game background was a real image of space whilst the main character of a Hippo and dark background colour were not age appropriate for the target audience. This customisation should intentionally make this game less age appropriate for 11-14 year olds as the use animal characters such as Hippos, Crocodiles, Frogs, and Monkeys are usually found in educational resources for 2-8 year olds.

5.2.2.2 Game characteristic No. 2– Game violence

Some studies have shown that girls do not like games with violence (Weaver & Sargent, 2000; Denner et al., 2005; Möller et al., 2014). However, other studies appear to demonstrate that game violence is tolerated by this group if it is moderate or mild (Subrahmanyam & Greenfield, 1998; Bussey & Bandura, 1999). Our exploratory study supports the latter finding that moderate violence in a game is acceptable to girls although non-violent games are preferred. The two games were customised as follows.

Game one - *The Lost Astronaut* did not include any violence as the exploratory study result indicated that 11-14 year old girls find games without violence appealing.

Game two - *The Lost Hippo* game was customised to include some moderate violence showing the fantasy Hippo exploding in space. This was included in game two as the alternative to the games without violence are games with violence.

5.2.2.3 Game characteristic No. 3–Graphics

The graphics for the games consisted of graphics that appeal which were included in game one and alternative graphics in game two. From the exploratory study, the preferred graphics for girls were shown to be characters, designed as a cartoon.

The variation to this would be the use of a main character that is not up-to-date and the use of real images as part of the game graphics.

Game one - *The Lost Astronaut* game included the image of an astronaut as the main character. The background image was brightly coloured scenery.

Game two - *The Lost Hippo* included an image of a Hippo and a dark real image of space as the background image.

5.2.2.4 Game characteristic No. 4–Use of bright colours

Studies show that girls find games with bright colours appealing (Cassell & Jenkins, 1999; Denner et al., 2005). Neilson (2010) in his work on graphics and colours that appeal to young children also indicated that 11-14 year olds find bright colours appealing. The exploratory study supports this observation.

Game one - Bright colours (yellow, red and white) were used in *The Lost Astronaut* game.

Game two - Dark colours dark brown, dark grey and greyish brown were used in *The Lost Hippo* game for similar reasons as game one. However, the block stacking environment is light coloured to ensure that the stacks are visible. It also makes it easy for the hints and feedback dialogues to be seen.

5.2.2.5 Game characteristics No. 5-Game character

Girls prefer the use of a human character as identified from the exploratory study and other studies have indicated that girls find games with realistic scenarios and human characters appealing (Kafai 1996; Nakamura & Wirman, 2005). The possible relationship between the reality of the scenario and use of humans, which the girls can identify with is an argument for this combination. The result of the exploratory study also supported this finding. Consequently, an Astronaut was used as the character for game one and an antithesis of this was the use of an animal in a fantasy scenario for game two. Additional reasons for the use of the Hippo character were explained in section 5.2.2.1.

Game one - *The Lost Astronaut* used the image of an astronaut as the main character and the realism of the scenario was improved with a storyline.

Game two - *The Lost Hippo* used the image of a hippo as the character for the game. As described in section 5.2.2.1, the use of the hippo character was to improve the fantasy aspect of the game and reduce the age appropriateness.

5.2.2.6 Game characteristics No. 6-A gaming environment with social interactivity

Social interaction provides opportunities to share information and collaborate. For example information about the gameplay levels, the game environment and experience. From previous studies, it has been noted that females focus more on developing relationships online (Baxter & Wilmot, 1983; Nakamura & Wirman, 2005). The exploratory study indicated that the preferred mode of interaction varies between the genders. The boys prefer interactions that involved challenge and competition. However, the girls preferred a purposeful collaborative environment that encourages sharing ideas and information.

Game one - *The Lost Astronaut* game included a chat facility for participants. This was moderated by the instructor of the session. The players can set-up their profile in the chat room using the personal identification number provided at the beginning of the session.

Game two - *The Lost Hippo* did not include any social interaction facility.

5.2.2.7 Game characteristics No. 7-Games with storylines

The findings from the exploratory study indicated that girls preferred digital games with a storyline. The importance of a game storyline to girls has also been identified in other studies (Kelleher, 2008 ; Nakamura & Wirman, 2005; Robertson, 2012) and further suggested as a means of getting girls involved with technology (Daly, 2003; Robertson, 2012). From the exploratory study, the boys did not demonstrate any preference for this game characteristic. This was supported by an earlier study by Robertson (2012).

Game one - *The Lost Astronaut* included a storyline about the game. This narrative (a short video clip) provided a background to the purpose of the game.

Game two - *The Lost Hippo* did not include a storyline.

5.3 Customising the Google Blockly maze game

The framework proposed by Aleven et al. (2010) was used to confirm that the Google Blockly game was educationally effective and identified aspects of the game that could be customised to create two games that are differentiated in their appeal without impacting on the effectiveness of the experimental games. This would involve the customisation of selected game materials, which includes the game characteristics in the game mechanics. The framework was also used to identify aspects of the game mechanics that should not be customised i.e. the game rules, goals, control and options available to the player as these would impact the effectiveness of the game.

The finding from the exploratory study was used for the customisation process to produce two games. The first game included the variations of the selected game characteristics that appeal to girls of age 11-14. The second game incorporated different variations of the same game characteristics, which were not found to appeal to the girls.

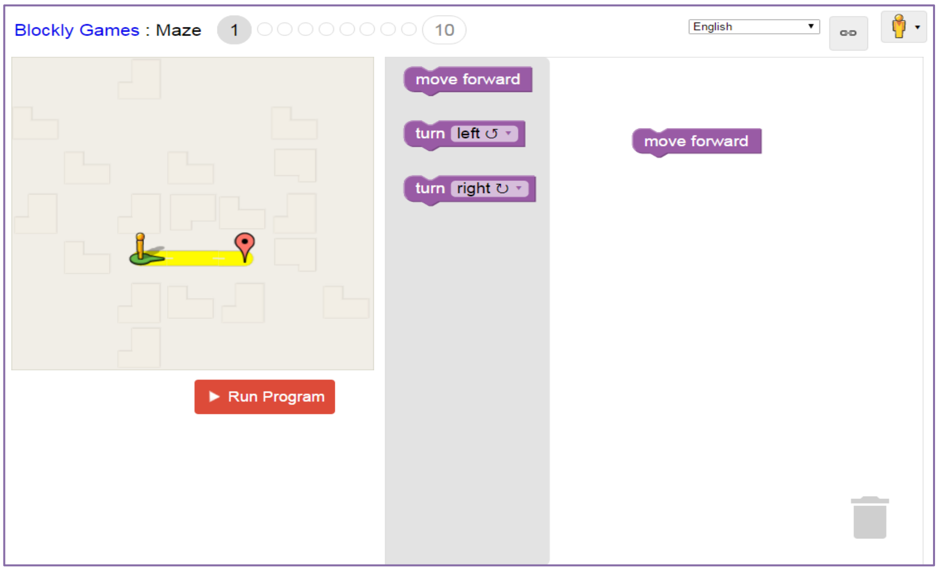
5.3.1 Implementing game customisation

The two games created have a number of similar characteristics such as the audio, feedback, dialogue, layout, mission, gameplay levels, fonts and single player mode which are not investigated in the study. These game characteristics were identified to be significant in the exploratory study.

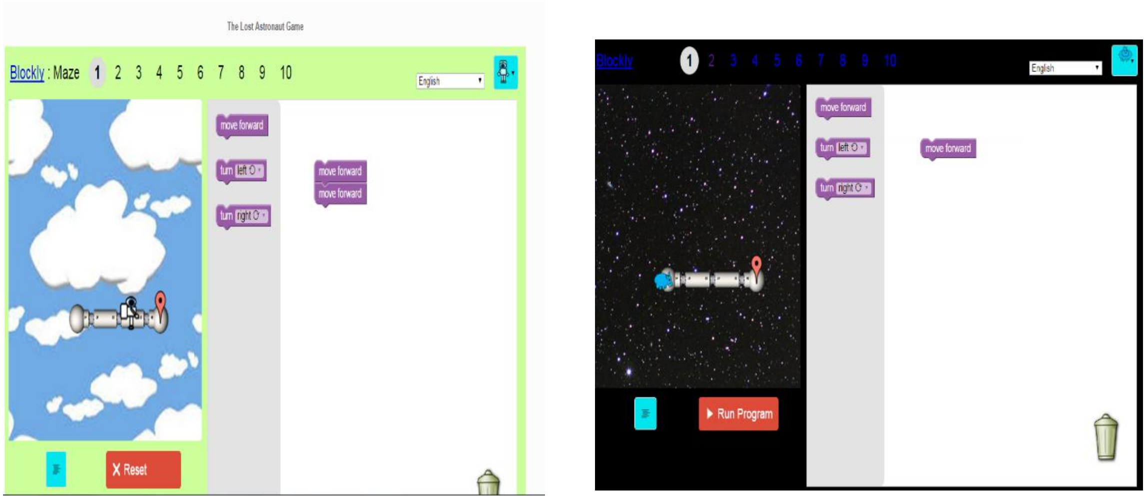
Blockly is free and open source. In order to customise the maze game the Blockly project code was downloaded from GitHub and the Blockly code changed to implement the customisation.

The aspects of the existing game that were customised are as follows:

1. **Age appropriateness of the game.** To achieve this, a number of elements were customised. The background colour of the game layout and the type of graphics used were also altered. For *The Lost Astronaut*, a bright background colour and a cartoon image of an astronaut in space were included. An alternative of a dark background colour and the use of a fantasy Hippo character in space was included in *The Lost Hippo.* Figure 5.3 illustrates the customisation comprising of the existing game (a). *The Lost Astronaut* (b) *The Lost Hippo* (c). The illustrations show how the main character was changed from a *pegman* to the Astronaut or Hippo of 3 colour variations. The illustrations also show how the background of the game was changed from the original plain coloured background to the cartoon or real image of the bright and dark sky.



(a)



(b) (c)

Figure 5.3. An illustration of the age appropriateness customisation

2. **Game violence.** The customisation involved the inclusion of mild explosion when the Hippo moves inaccurately within the maze in *The Lost Hippo game* only.
3. **Game graphics**. As illustrated in figure 5.3, the cartoon graphic of an astronaut in space with a bright background was included in game one and the use of a hippo with a real image of a dark coloured background was implemented in game two.
4. **Use of bright colours.** A selection of bright colours yellow, white blue and red were used in *The Lost Astronaut*. Alternative dark colours dark brown, dark grey, greyish brown and black were used for *The Lost Hippo.*
5. **Game character.** An up-to-date character of an astronaut in a real-life scenario was used for game one and the hippo character as a fantasy character in space was used for game two.
6. **Gaming environment with social interaction.** *The Lost Astronaut* game included a chat room facility which was absent in the existing game and the customised game two. This is illustrated in figure 5.4.

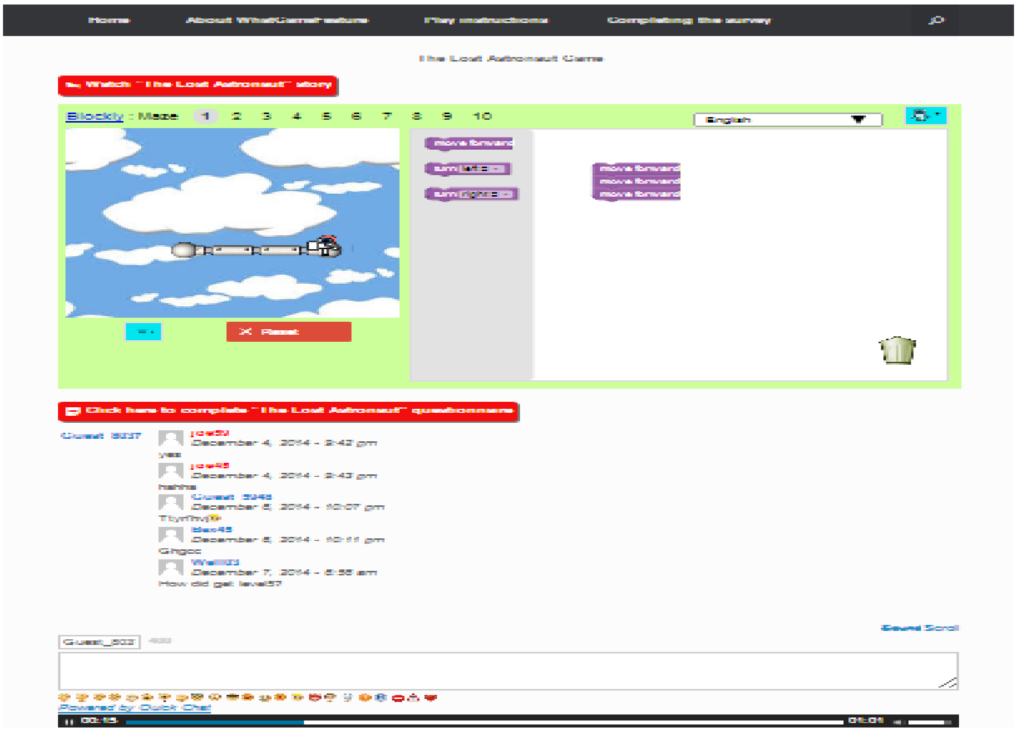


Figure 5.4. An illustration of the chat room facility

7. **Game with storyline.** *The Lost Astronaut* game was customised to include a short video of the storyline. This was not included in the alternative game two. Figure 5.5 illustrates the storyline of *The Lost Astronaut*.

Figure 5.5. The storyline for The Lost Astronaut game

The games, survey questionnaire and instructions on how to play the game can be accessed online (*http://www.WhatGameFeature.com*).

5.4 Summary

This aim of this chapter was to describe how the existing game for customisation was identified, evaluated using the framework proposed by Aleven et al. (2010) and then customised. The framework guidelines were used to confirm the educational effectiveness of the chosen game and also supported in identifying aspects of the game that can be altered to produce two variants that are differentiated in their appeal. The purpose of the game identification, evaluation and customisation was to achieve the objective outlined by the research question i.e. creating a computer science learning game that appeals to the target audience. *The Lost Astronaut* was created as the game that included the variants of the game characteristics that appeal to 11-14 year old girls. *The Lost Hippo* included the antithetical variants of the same game characteristics that were included in *The Lost Astronaut*. Both games were used in the main study to investigate the impact of the variants of the selected game characteristics on 11-14 year old girls, which should provide the empirical evidence in response to the research question.

CHAPTER 6

DESIGN OF RESEARCH EXPERIMENT

6.0 Introduction

This chapter describes in detail the design of the main study. It also reviews the threats to the validity of the study and ethical considerations of the study.

Section 6.1 is an overview of the structure of the main study. Section 6.2 describes the rationale for the structure of the main study. Section 6.3 outlines the key investigations of the main study. Section 6.4 reviews the structure of the comparative game investigation process. Section 6.5 describes the experimental subjects, classification of variables, materials and procedure. Section 6.6 identifies the threats to the validity of the findings of the study and how they can be minimised or eliminated. Section 6.7 reviews the ethical issues for consideration and the steps taken during the study. The final section is a summary of the chapter.

6.1 Overview of the main study

From the exploratory study, game characteristics such as graphics, colour, storylines etc. that are significant to girls were identified from successful digital entertainment games. Further investigation of the characteristics during the exploratory study indicated that there are variants of game characteristics as shown in section 4.2.4.1 that can contribute to the appeal of the digital entertainment games to the target group.

Section 5.3 described how variants of seven significant game characteristics identified during the exploratory study were used to customise the Google Blockly maze game. Two games: *The Lost Astronaut* (which included variants of the characteristics identified as appealing to girls) and *The Lost Hippo* (which included antithetical variants of similar game characteristics) were produced during the customisation process.

The requirement of the main study was to investigate the impact of the games on the target audience of 11-14 year old girls.

To achieve this, an experiment was designed to collect data that was used to empirically identify the impact of the games on the target group. The result of the main study should confirm the findings of the exploratory study and provide the empirical evidence in response to the second part of the research question – *“Can we use this knowledge to create computer science learning games that appeal to this audience?”*

During the experiment, the target group would engage with both games and feedback collected using pre and post-study questionnaires.

6.2 Rationale for structure of the experiment

The main study was a quasi-experiment, as it did not include a control group (National Centre for Technology Innovation, 2012). The rationale for the structure of the experiment is as follows:

- The study is not aimed at measuring the participants’ knowledge and skills in programming constructs. Consequently, a test of prior knowledge of algorithms was not measured in the study;
- There are no correct or incorrect answers to the study questionnaires. The responses are the perceptions of the participants;
- Traditionally, the pre and post-study questions are identical (National Centre for Technology Innovation, 2012). This traditional structure was not used for this study because the aim of the study was not to determine the participants’ knowledge and understanding of algorithms before and after the study. Furthermore, there were no correct or incorrect responses to the questions posed in the questionnaire. The responses captured the perception or opinion of participants during the study.

  In this study, the questions in the pre and post-study questionnaire were not identical. The pre-study questionnaire data were compared with the findings from the exploratory study. The post-study questionnaires focused on the impact of the each game on participants.

  The structure of the main experiment was such that participants engaged with both experimental games. Their perceptions of the games were collected using pre and post-study questionnaires. This structure provided data for the key investigations of the study and the empirical evidence in response to the research question.

6.3 Key investigations of the main study

To obtain the empirical evidence to answer the research question, the investigation should provide data on the following:

- digital game characteristics that are significant to girls of age 11-14 in educational games;
- the differences and similarities in game characteristics that are significant to girls and boys of age 11-14 in digital educational games;
- the variants of the game characteristics that can make digital educational games appealing to girls of age 11-14;
- the perception of digital educational games for learning computer science concepts that appeal to girls of age 11-14;
- the perception of learning using digital educational games that appeal to girls of age 11-14;
- assess whether variants of game characteristics found appealing in entertainment games can be used to make educational games appealing to the target group.

6.4 Structure of the comparative game investigation

The subjects were assigned to both games during the study. The study was conducted at different schools in southeast England. These locations provided access to as many participants as possible for the study. A combination of single and mixed gender schools was also used to collect a range of data, which was used to further investigate any gender-related patterns or trends in the study. The rationale for the selection of location and participants was described in detail in section 4.1.The model of subjects engaging with both games is illustrated in figure 6.1. In both mixed and single gender locations while one group of girls & boys; girls or boys initially engaged with the game (x), other participants engaged with the other game (y). At the end of the first session, the groups progressed to the antithetical game.

The structure of participants engaging with the games ensured that the order of gameplay, which could become a validity constraint (order bias) on the study, does not significantly affect the responses of subjects.

Sample group 1 (Girls & Boys; Girls or Boys)	Sample group 2 (Girls & Boys; Girls or Boys)
Game X	Game Y
Game Y	Game X

Figure 6.1. Graphical representation of investigative models

6.5 Experimental subjects, variables, materials, and procedure

As mentioned in section 6.4, the study was conducted across five locations. Locations 1 and 2 were mixed gender schools. Locations 3, 4 and 5 were single gender schools. Location 3 was a female only school whilst locations 4 and 5 were male only schools. The ages sampled for all locations were 11-14 year old participants. The selection process of the participants was carried out by the teachers at each location independent of the researcher but based on the guidelines supplied by the researcher.

The guidelines for selection indicated that academic capability, interest in computer science or prior knowledge of the subject were not pre-requisites. The requirement similarities with all five locations included the same age group of participants, no requirement for ethnic classification and computer science algorithm knowledge or skills.

All locations required parental consent and the allocation and use of a personal identification number provided by the class teacher.

The estimated duration of the study session for all locations was a maximum of 60 minutes and participant responses was not shared with the school or any third party. Table 6.1 illustrates the differences in requirements between locations.

	Location 1	Location 2	Location 3	Location 4	Location 5
Total number of participants	149	50	50	27	28
Total number of females	76 females	26 females	50 females	0 females	0 females
Total number of males	73 males	24 males	0 males	27 males	28 males
Participants gender	Female and male	Female and male	Female only	Male only	Male only

Table 6.1. Differences in the requirements of survey locations.

6.5.1 Experimental variables classification

Both independent and dependent variables were reviewed in the structure of the experimental design. Hornbeak (2013) described the independent variable of an experiment as the intervention, treatment or condition applied to the subjects. In the context of this study, the game characteristics, which were deliberately varied during the study, comprise the independent variables. The independent variables were consistently applied at all participating locations of the study.

Furthermore, the effects of the intervention were measured as the dependent variables of the study. For this study, the appeal generated from the variants of the game characteristics is a dependent variable. Each variable in the experiment was classified into these two groupings. Table 6.2 illustrates the variable factors and their classification.

Classification of variable	Variable	Comment
Independent variables	Participants age range	This independent variable ensured that subjects between ages 11-14 were sampled across all locations.
	Total number of participants	This independent variable was set as part of the intervention. This varied between locations.
	Estimated duration of study	The maximum duration of the study was 60 minutes and was set by the researcher.
	Participants gender	This independent variable was set as part of the intervention to comprise of young females and males.
	Game characteristics	The researcher set this independent variable. This variable was applied as different game characteristics e.g. game colour and variants of the game characteristics e.g. bright and dark colours during the study.
Dependent variables	Perception of computer science as a subject	These dependent variables are outcomes of the study.
	Attitude to learning computer science algorithms	
	The appeal of game characteristics and their associated variants	

Table 6.2. Classification of experimental variables

The outcome of the intervention on the subjects during the study was assessed based on the key investigative statements identified in section 6.3. The result obtained for each investigation was statistically validated using a set of hypotheses-null hypothesis (H_0) and the alternative hypothesis (H_1).

According to Hornbeak (2013), hypotheses are statements that connect variation in independent variables to expectations about variation in the dependent variables. Table 6.3 illustrates the key investigative and hypothetical statements used for the statistical analysis of the main study data.

#	Key investigative statement	Null hypothesis(H_0)	Alternative Hypothesis (H_1)
1	Are there digital game characteristics that are significant to girls of age 11-14 in educational games?	There are no significant game characteristics to girls of age 11-14	There are significant game characteristics to girls of age 11-14
2	Are there differences and similarities in game characteristics that are significant to girls and boys of age 11-14 in educational games?	There are no differences or similarities in game characteristics that are significant to girls and boys of age 11-14 in educational games	There are differences and similarities in game characteristics that are significant to girls and boys of age 11-14 in educational games
3	Are there variants of the game characteristics that can make digital educational games appealing to girls of age 11-14?	There are no variants of the game characteristics that can make digital educational games appealing to girls of age 11-14	There are variants of the game characteristics that can make digital educational games appealing to girls of age 11-14
4	What is the perception of digital educational games for learning computer science concepts that appeal to 11-14 year old girls?	There is no significant influence of digital educational games that appeal to 11-14-years-old girls	There is a significant influence of digital educational games that appeal to 11-14 year old girls?

5	What is the perception of learning using digital educational games that appeal to 11-14-years-old girls?	Digital educational games that appeal to 11-14 year old girls have no significant influence on their perception of the subject	Digital educational games that appeal to 11-14 year old girls have a significant influence on their perception of the subject
6	Is it helpful to learn computer science concepts using games that appeal to learners?	It is not helpful to learn computer science concepts using games that appeal to learners	It is helpful to learn computer science concepts using games that appeal to learners.

Table 6.3. The key investigative and hypothetical statements used for the statistical analysis.

6.5.2 Materials for the study

As discussed in section 3.4, the materials required for the study are two games and online questionnaires. The first game (*The Lost Astronaut)* comprise of variants of game characteristics that were identified in the exploratory study as appealing to the target group of girls. The second game *(The Lost Hippo)* comprise of alternative variants of the same game characteristics. The online pre and post-study questionnaires were used with the subjects to capture their feedback on the games and submitted to an online database.

The questionnaires collected both qualitative and quantitative data from participants. The qualitative data were typically descriptive data about individual preferences. This would be analysed to establish the statistical significance of the result and if the finding could be quantitatively extrapolated to a wider context of the population.
The research question guided the questions posed in the pre and post-study questionnaires (Lietz, 2010) and the research hypotheses (Vikat et al., 2007).

The focus during the questionnaire design was the application of best practice as described by Williams (2014). This included question length, wording and order.

The questions were kept short (usually less than 20 words) considering the average reading age in the United Kingdom is around 12 years and the average age for the study was 12.5 years. The questions had to be clear, simple, specific and relevant to the study. This is important because more difficult questions either produces inaccurate responses which can affect the validity of conclusions or participants give up and do not complete the questionnaires (Bradburn & Sudman, 2003; Holbrook et al., 2006; Williams, 2014).

The order of questions in the questionnaire was important especially with questions about their attitude and habits. The more general questions preceded the specific questions. A poor order of questions can affect the validity of the results and the generalisability of results to the population (Baker 2003; Lietz, 2010).

The quantitative element of the study involved the number of participants taking part in the study (sample size) and the composition of the male and female population (sample type).

The qualitative data collection process included the empirical identification of the design elements in the game that appeal to girls. Other aspects of qualitative data included the impact of the appeal on the perception of educational games designed to teach computer science.

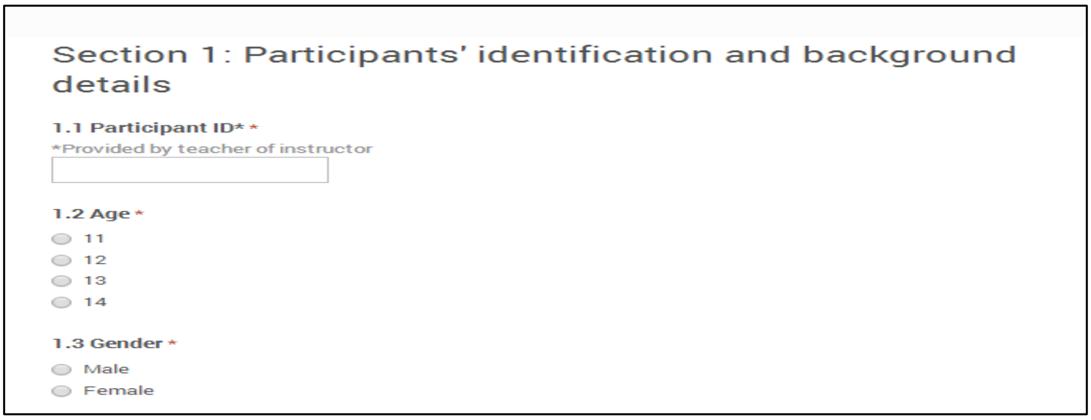
The Likert-scales were used in the questionnaires to elicit information from participants as accurately as possible. A combination of 4, 5,6,7,8 and 10-point Likert-scales were used in the pre and post-study questionnaires. A 4-point format was used where the response to the question might not be fully defined by all participants (Krosnick & Presser, 2010). Furthermore, Foddy (1993) indicated that 5 to 7-point scales are preferred in situations where participants are asked for absolute judgements (most precise response). The 7-point Likert-scale is a preferred format for capturing absolute behavioural or opinionated data (Burns and Grove, 1997). The use of 8 to 10-point Likert-scale, was to further improve the precision of the responses (Cummins & Gullone, 2000). The pre and post-study questionnaires are included in appendix 4 of this thesis. The structure of the questionnaires is explained in the sections below.

6.5.2.1 Structure of pre-study questionnaire

The primary aim of the pre-study questionnaire was to collect participant information, entertainment gameplay habits, compare the digital game characteristics that might appeal to the age group with the exploratory study findings and investigate the impact of game appeal on the perception of digital educational games. The data collected in the pre-study questionnaire was correlated with data from the post-study questionnaire, which was designed to investigate the impact of the game characteristics that appeal to the target group. The impact was measured both qualitatively and quantitatively using statistical tests. The term "*game features"* was used in the questionnaires instead of *"game characteristics*" for ease of understanding for the young target group.

6.5.2.1.1 Participants' identification and background details

The participant information requested in this first section of the pre-study questionnaire were the participants' identification number and demographic data. The instructor or class teacher provided the participant identification. The participant identification number was used to identify the participant that completed the questionnaire and link the pre-study to the post-study responses. It also ensured that participant identity was kept anonymous in line with ethical procedures. Other data collected in this section included participant age and gender. The age of the participants was essential in order to ensure that the correct age group was sampled. In addition, the gender information was used to group the data by gender. The data collected in this section of the pre-study questionnaire was used to link the other information provided in other sections of the pre-study and the post-study questionnaires. Figure 6.2 illustrates the data collected in section 1 of the pre-study questionnaire, which comprised of the participant ID, age and gender.



Section 1 : Participants' identification and background details

1.1 Participant ID* *
*Provided by teacher of instructor

1.2 Age *
- 11
- 12
- 13
- 14

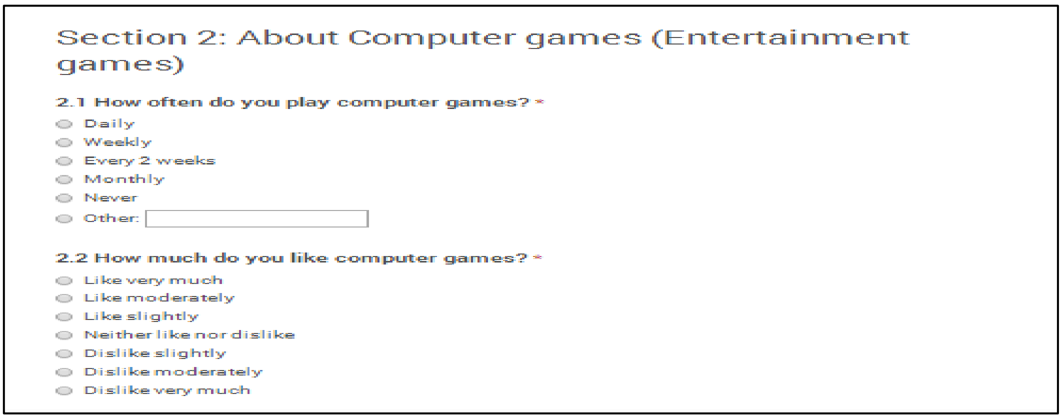
1.3 Gender *
- Male
- Female

Figure 6.2. Collecting participant identification and background details

6.5.2.1.2 About computer games (Entertainment games)

The first two questions of the second section of the pre-study questionnaire as shown in figure 6.3, collected data on the regularity of computer gameplay and how much participants like computer games.

These questions indicated the popularity of computer games with the target group. A 7-point Likert-scale on how much participants like computer games was used in this section.



Section 2: About Computer games (Entertainment games)

2.1 How often do you play computer games? *
- Daily
- Weekly
- Every 2 weeks
- Monthly
- Never
- Other:

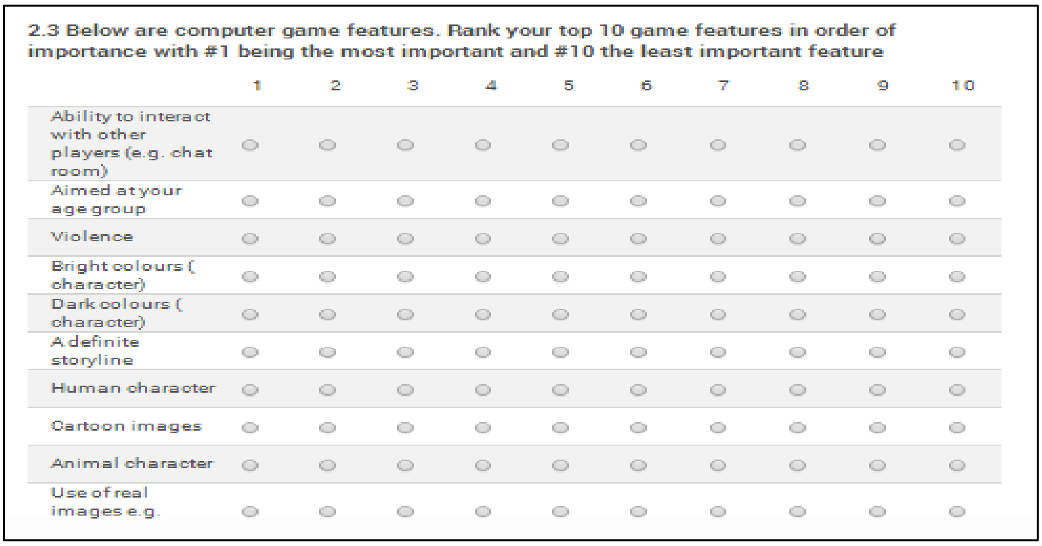
2.2 How much do you like computer games? *
- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much

Figure 6.3. Collecting participant entertainment games play habits and appeal

The third question in the second section as shown in figure 6.4 asked about the importance (significance) of the listed game characteristics to participants. A 10-point rank order was used, with 10 being the most appealing characteristic and 1 the least appealing characteristic. The computer game characteristics identified in the exploratory study were used in this question to elicit this information from participants. The computer game characteristics were rated on a unipolar numeric scale 1-10.

The responses could be in one of three categories i.e. high, mid or low ends of the numeric scale. An even numeric scale, such as 10, could easily capture these three response categories effectively as compared to 6 or 8-point scale (Schwarz et al., 1991).

Furthermore, a positive unipolar scale was used, as participants hesitate to assign themselves to negative point scales (Schwarz et al., 1991). The constructs elicited from the exploratory study were used to design question 2.3. The responses collected from this question were also compared with the findings of the exploratory study.



2.3 Below are computer game features. Rank your top 10 game features in order of importance with #1 being the most important and #10 the least important feature

	1	2	3	4	5	6	7	8	9	10
Ability to interact with other players (e.g. chat room)										
Aimed at your age group										
Violence										
Bright colours (character)										
Dark colours (character)										
A definite storyline										
Human character										
Cartoon images										
Animal character										
Use of real images e.g.										

Figure 6.4. Collecting data on computer game characteristics with the most and least appeal to participants

The fourth question in the second section (2.4) as shown in figure 6.5 was a 7-point Likert-scale that captured data on the frequency of play if a computer game appeals to the participant. The influence of the appeal of the game characteristics on the participants' frequency of gameplay was captured here. This data was correlated with the post-study data to validate responses to the games.

2.4 How frequently will you play a computer game with the features that you like? *

- Very frequently
- Quite frequently
- Moderately frequently
- Neither frequently nor infrequently
- Moderately infrequently
- Quite infrequently
- Very infrequently

Figure 6.5. Collecting data on the influence of appealing game characteristics on the frequency of gameplay by participants

The fifth question in this section (shown in figure 6.6.) further collected data on the extent that including appealing game characteristics in entertainment games influenced participants' perception of computer games. A 4-point Likert-scale was used to capture this data.

2.5 How much will your view of computer games be influenced if it includes game features that you like? *

- A lot
- Some
- Little
- Not A lot

Figure 6.6. Collecting data on the influence of appealing game characteristics on the perception of computer games by participants

6.5.2.1.3 Educational computer games

This section of the pre-study questionnaire collected data on gameplay habits, the appeal and influence of game characteristics on the perception of educational computer games. The participant responses to the questions were correlated with the post-study responses on educational computer games. This section captured the participants' opinion of the created games. The first question in this section shown in figure 6.7 is a 6-point Likert-scale that collected data on the regularity of play of educational computer games by participants.

3.1 How often do you play educational computer games? *

- Daily
- Weekly
- Every 2 weeks
- Monthly
- Never
- Other:

Figure 6.7. The regularity of educational computer gameplay by participants

The second question in this section (figure 6.8) collected data on how much participants' like educational computer games. A 5-point Likert-scale was used to capture the participants' response to this question.

3.2 How much do you like educational computer games? *

- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly

Figure 6.8. Collecting data on how much participants like educational computer games

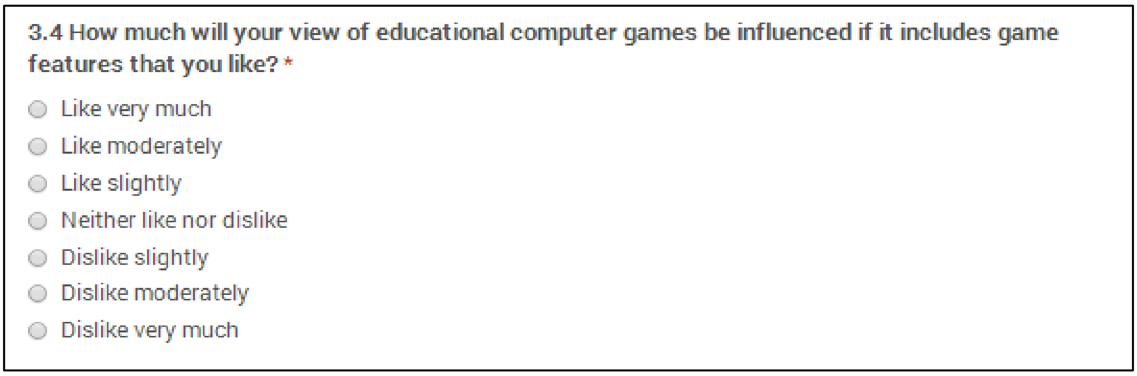
The third question in this section collected data on participants' preference for computer educational games if they were to include game characteristics that are appealing. A 5-point Likert-scale question as shown in figure 6.9 was used to capture this data.

3.3 Would you prefer an educational computer game with features that you like? *

- Strongly prefer
- Somewhat prefer
- No preference
- Somewhat do not prefer
- Strongly do not prefer

Figure 6.9. Collecting data on participants' preference for educational computer games with appealing game characteristics

The fourth question in this section collected participants' responses on the perception of educational computer games if they included appealing game characteristics. A 7-point Likert-scale (figure 6.10) was used to collect this information, which was compared with responses from the post-study survey.



3.4 How much will your view of educational computer games be influenced if it includes game features that you like? *

- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much

Figure 6.10. Collecting data on participants' perception of educational computer games with appealing game characteristics

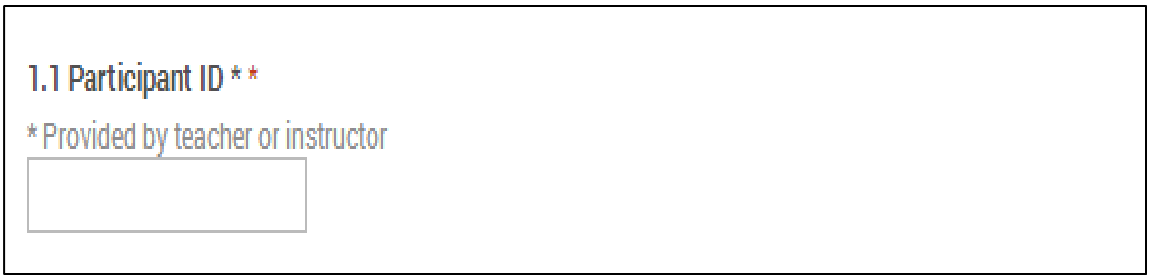
6.5.2.2 Structure of post-study questionnaires

Two post-study questionnaires were created to capture the opinion of participants about each game. A questionnaire was designed for each game i.e. *The Lost Astronaut* and *The Lost Hippo.* This was followed by a third post-study questionnaire that was used to compare participant responses about the two games. The first and second post-study questionnaires included similar sections, which collected participants' information and gameplay experience. The illustrations of *The Lost Astronaut* are used in the explanations in the sections to avoid duplication of information.

The third post-study questionnaire included sections on participants' identification information and an evaluation of the educational computer games used for the experiment. This evaluative post-study questionnaire gathered participants' comparative opinion of both games. The structure of the first and second post-study questionnaires is reviewed in the next section.

6.5.2.2.1 Participants' identification data and gameplay experience

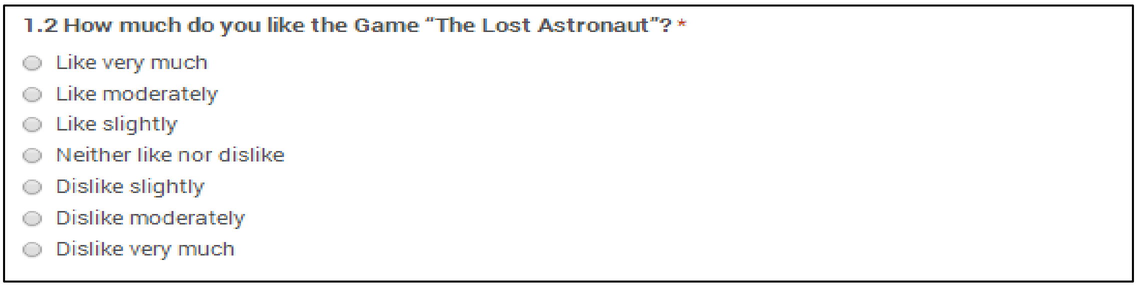
The first question shown in figure 6.11 captured the identification number of the participant used to correlate the pre-study and post-study data. The identification number was also linked to the demographics data from the pre-study survey.


1.1 Participant ID * *

* Provided by teacher or instructor

Figure 6.11. Collecting participants' identification number

The second question in this section as shown in figure 6.12 captured participants' responses on how much they like the respective games. The opinions of the participants were captured using a 7-point Likert-scale question. This question is a general question that preceded a more specific question on the characteristics that would have made the game appealing or less appealing.


1.2 How much do you like the Game "The Lost Astronaut"? *

- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much

Figure 6.12. How much participants like the games

By completing both questions in each questionnaire, participants' opinion of both games could be analysed to determine how much each game appealed to them. The information obtained from the analysis would contribute to understanding the impact of game characteristics that appeal to participants.

The third question in this section specifically investigated the game characteristics that the participants found appealing whilst playing the games. The game characteristics were chosen from the list of significant game characteristics identified from the exploratory study.

The labelled 8-point Likert-scale shown in figure 6.13 was used to collect this information from the participants. The participants answered each question on a 0 to 7 scale for each game characteristic on the basis of the appeal.

The zero point was used to determine if participants were able to identify the presence or absence of the game characteristic in the game and enter their response.

1.3 Using the point scale of 1-7 tell us how much you like the following features used or not used in "The Lost Astronaut": *

	0=Not present	1=Dislike very much	2=Dislike moderately	3=Dislike slightly	4=Neither like nor dislike	5=Like slightly	6= Like moderately	7=Like very much
Interaction with other players e.g. chat room, forum	○	○	○	○	○	○	○	○
Fun to play	○	○	○	○	○	○	○	○
Violent scenes e.g. explosions	○	○	○	○	○	○	○	○
Use of audio (effect and background)	○	○	○	○	○	○	○	○
Definite storyline	○	○	○	○	○	○	○	○

Figure 6.13. How much participants like the game characteristics as used or not used in the games

The fourth question shown in figure 6.14 attempted to collect additional data on game characteristics that made the game appealing.

1.4 List additional game feature(s) used or not used in "The Lost Astronaut" that you like very much
*

Figure 6.14. Additional game characteristic(s) that make games appealing to participants

The fifth question in figure 6.15 collected data on participants' consideration to play this game or a similar game again. The 7-point Likert-scale was used for this question.

1.5 Having played "The Lost Astronaut" game, would you consider playing this game or a similar one again? *

- Very much consider
- Moderately consider
- Slightly consider
- Neither consider nor not consider
- Slightly not consider
- Moderately not consider
- Very much not consider

Figure 6.15. Participant consideration to play the game or a similar game based on current experience

The sixth question in figure 6.16 collected data on how much learning occurred from playing the games. The response to this question was used to evaluate the effectiveness of educational computer games for learning.

1.6 How much did you learn playing "The Lost Astronaut" game? *

- A lot
- Some
- Little
- Not A lot

Figure 6.16. The question captured the responses on the amount of learning using educational computer games

The seventh question in figure 6.17 captured data on how the game compare with other educational computer games. This question assumed that participants would have engaged previously with digital educational games.

1.7 How much do you like the "The Lost Astronaut" game compared to other educational computer games? *

- A lot
- Some
- Little
- Not A lot

Figure 6.17. This question compares the game with other educational computer games

The last question of the post-study questionnaire in figure 6.18 is a free-text format that captured the information on how to improve the respective games so that they are more appealing to the target audience.

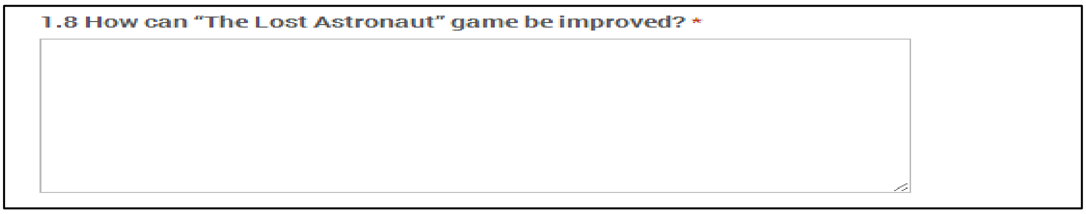

1.8 How can "The Lost Astronaut" game be improved? *

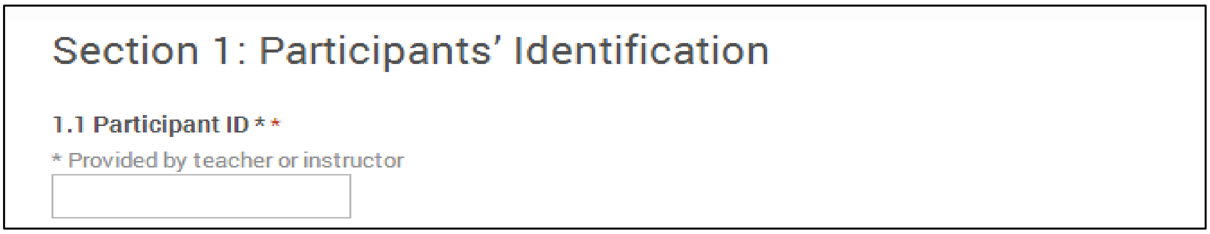
Figure 6.18. The question captured responses on how to improve the game to make it more appealing

6.5.2.3 Post-study questionnaire (evaluative)

The evaluative post-study questionnaire collected comparative data from participants on both games used in the study.

6.5.2.3.1 Participants identification information

The first and only question of the section shown in figure 6.19 captured the identification number of the participants. This information was used to relate the data collected using the pre-study questionnaire and the post-study questionnaires.


Section 1: Participants' Identification

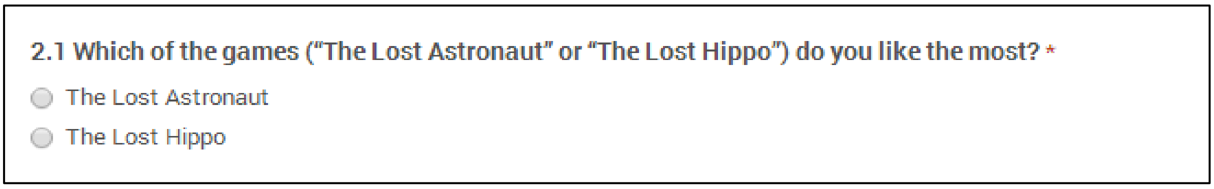
1.1 Participant ID * *

* Provided by teacher or instructor

Figure 6.19. Collecting the participants' identification number

6.5.2.3.2 Educational computer games for learning computer science

The first question in this section (figure 6.20) asked participants to identify their preferred game. The question correlated the game with the game characteristics identified as appealing and if this resulted in the game being the most preferred of the two.

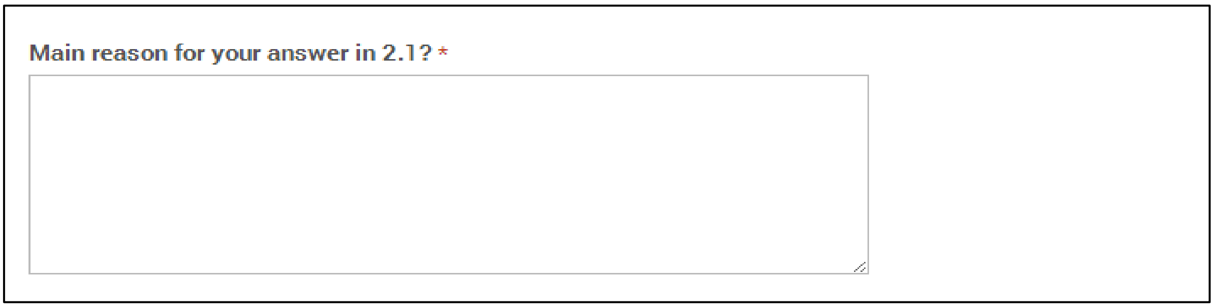


2.1 Which of the games ("The Lost Astronaut" or "The Lost Hippo") do you like the most? *

- The Lost Astronaut
- The Lost Hippo

Figure 6.20. Collecting data on the more appealing game from the study

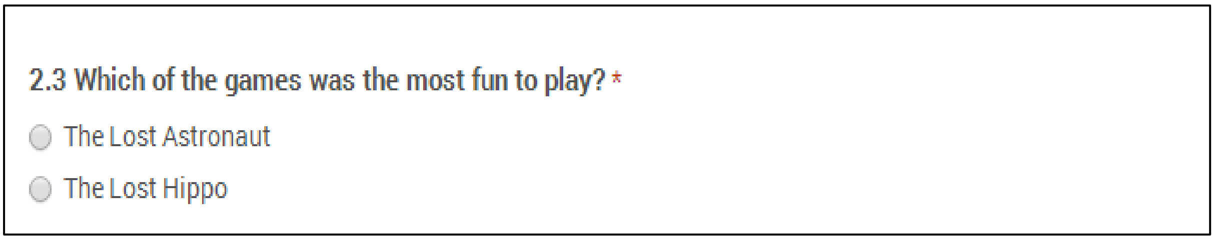
The second question in this section (figure 6.21) asked participant the reason for their preference of the game. It was a free-text question, as it required an open response.



Main reason for your answer in 2.1? *

Figure 6.21. Capturing the reason for the appeal of the game

The third question in this section as shown in figure 6.22 asked participants which of the games they found most fun to play.

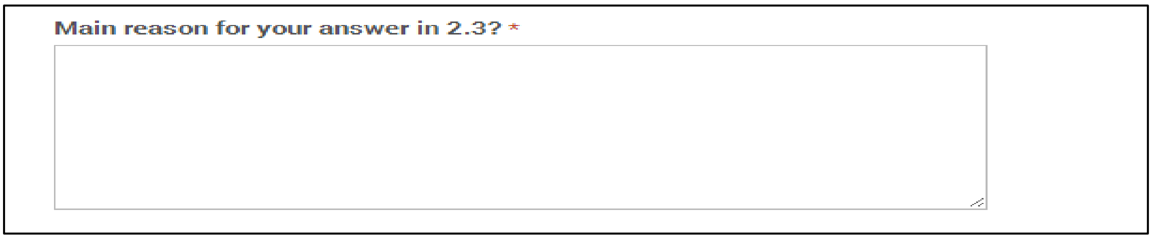


2.3 Which of the games was the most fun to play? *

- The Lost Astronaut
- The Lost Hippo

Figure 6.22. Collecting data on the most fun game to play

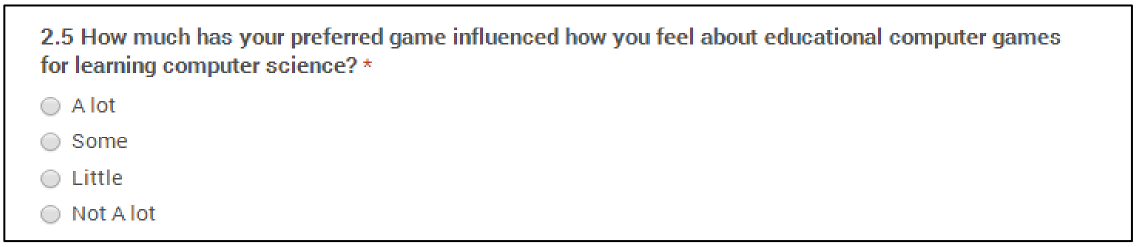
The fourth question (figure 6.23) requested the reason for the response to question 2.3 i.e. the reason for one of the game being more fun to play than the other. This question is a free-text option response.



Main reason for your answer in 2.3? *

Figure 6.23. Collecting information on the reason for the most fun game of the two games

The fifth question in this section as shown in figure 6. 24 collected data on how much the preferred game influenced the participants' perception of educational computer games.

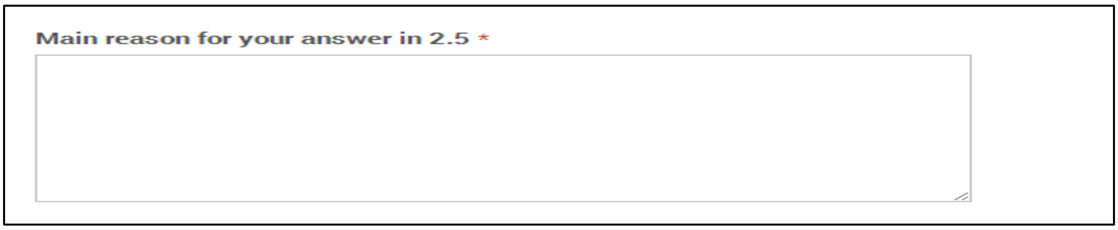


2.5 How much has your preferred game influenced how you feel about educational computer games for learning computer science? *

- A lot
- Some
- Little
- Not A lot

Figure 6.24. Collecting data on how the preferred game influenced the perception of educational computer games

The main reason for the response provided in question 2.5 was captured in this question (figure 6.25). It is a free-text option question.



Main reason for your answer in 2.5 *

Figure 6.25.Collecting information on the main reason for response to question 2.5

6.5.3 Procedure of experiment

Before the experiment commenced, each participant was assigned to a desktop with an online facility. The participants completed the session during their designated lesson duration of 60 minutes. As a result, different class groups completed the session at different times of the day and week. The session comprised of the completion and submission of the pre-study questionnaire, playing game one, completing and submitting the relevant post-study questionnaire for the game. This process was repeated for game two. The session concluded with the completion and submission of the evaluative post-study questionnaire.

Participants completed the exercise and submitted the questionnaires within the allocated duration. The allocated time for each stage of the exercise was sufficient for all participants to complete and submit their responses online. The respective class teachers managed the sessions independently using the guidance information provided by the researcher. The experiment commenced with a short demonstration by the class teacher on how to access and complete the exercise. The participant IDs were distributed and the online pre-study questionnaire, which was designed to take 5-10 minutes, was completed. The procedure for the experiment is illustrated in figure 6.26 and discussed in sections 6.5.3.1 to 6.5.2.6.

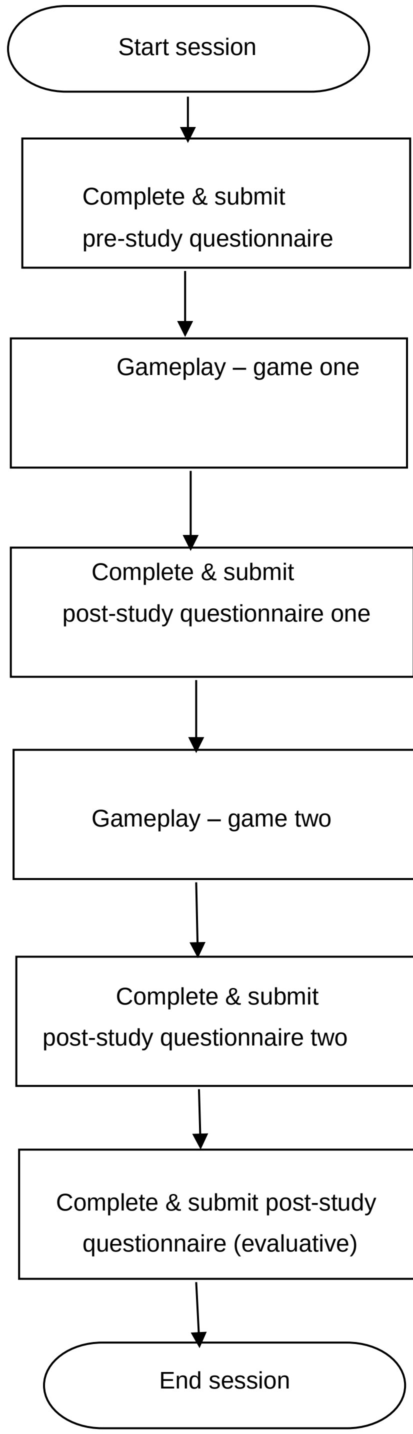


Figure 6.26. Flowchart of the procedure of the experiment

6.5.3.1 Gameplay – Game one

On the completion of the online pre-study questionnaire, participants played their first game. The participants were allowed to play the game for a maximum duration of 20 minutes with each player spending an average of time of two minutes on each level of the game. The game was designed as 10 levels to allow all the major programming constructs (e.g. sequences, decisions, loops etc.) and the combination of the constructs (e.g. sequences and decisions) to be explored in the game. Consequently, the level of challenge provided by the game changed with the levels of play. The feedback from participants indicated that most of them completed the first game past level 5 on average within the time allocated. At the end of the allocated time, participants were instructed to complete the post-study questionnaire for the game they played.

6.5.3.2 Post- study questionnaire one

Participants completed the first post-study questionnaire, which captured information on their opinion of the game. The duration for the completion of the questionnaire was 5-10 minutes. The completed questionnaire was submitted online and participants were instructed by the class teacher or instructor to play their second game.

6.5.3.3 Gameplay – Game two

Participants also played the second game for a maximum duration of 20 minutes.

6.5.3.4 Post-study questionnaire two

On completion of the duration of gameplay, participants completed post-study questionnaire two for the game they played. This questionnaire captured the participants' opinion of their second game. The duration for completion and submission of the questionnaire was 5-10 minutes.

6.5.3.5 Post-study questionnaire – Evaluative

At the completion of post-study questionnaire 2, an evaluative post-study questionnaire was completed by participants to compare both games. The duration for the completion and submission of the evaluative questionnaire was 5-10 minutes.

6.6 Threats to validity of findings

There are a number of factors that might affect the outcomes of the study. In the experimental design, it was imperative that these factors are considered and appropriate measures are taken to eliminate or minimise the effect of these factors. These factors are referred to as "*threats"* in the experimental parlance because they threaten the validity of research findings.

Onwuegbuzie (2000) describes experimental validity: "*An experiment is deemed to be valid, inasmuch as valid cause-effect relationships are established, if results obtained are due only to the manipulated independent variable (i.e., possess internal validity) and are generalizable to groups, environments and context outside of the experimental settings (i.e. possess external validity)*". As a result, the validity of an experiment should be assessed for internal and external validity.

The validity of the findings of a study can be threatened in a number of ways that are not always predictable. Hence, the purpose of the threat analysis in experimental design was to establish the cause–effect relationships during the study and the actions to minimise the effect of confounding variables that can cause bias in the outcome of the studies.

An in-depth understanding of both internal and external validity parameters of an experimental study was essential in the experimental design stage. A detailed review of both internal and external validity factors is reported in chapter 7.

6.7 Ethical issues

Due to the age of the participants (11-14 year old), legal consent was required from the legal guardian or parent(s) of potential participants. Prior to participants participating in the experimental sessions, legal consent documentation, made available to the teacher by the researcher was handed to participants. The form was completed and signed by the legal guardian or parents of the potential participants. In addition, consent was also obtained from potential participants. They were informed of the conditions for participating, the right to withdraw from the experiment at any time and how the data collected would be used and stored. Participants were allowed to participate in the sessions only when both forms were signed and returned.

The forms were designed by the researcher and approved by the University research ethics committee. Copies of the forms are included in appendix 6 of the thesis.

The data collected during the experiment was in conformity with the data protection regulations and was not shared with participant parents/legal guardians, school authority and any third party.

6.8 Summary

The aim of this chapter was to report the structure for the main study, which should enable the participants to engage with the digital educational games designed in chapter 5 and feedback captured. The information captured from the exercise provided the empirical data used in analyses, which provided a response to the research question. The experimental design also ensured that the threats to the validity of the study were considered and their effect significantly minimised during the design of the study. An effective experimental procedure ensured that the data collected for analysis provided the empirical evidence in response to both research questions was valid and reliable.

CHAPTER 7

DATA ANALYSIS, RESULTS AND VALIDATION

7.0 Introduction

This chapter is an analysis and evaluation of data obtained from the main study across five different locations involving 304 participants.

Section 7.1 is an overview of the structure of the data analysis of the main study which comprised of both qualitative and quantitative analysis. Sections 7.2 to 7.6 review the qualitative analysis of the pre-study data by location. Each section concludes with a discussion of the result by location. Section 7.7 is a summary of the pre-study data analysis and how it provided responses to the research question. Sections 7.8 to 7.10 reports on the qualitative and quantitative analysis of data collected in the post-study stage. Section 7.8 is a comparative analysis of post-study data from each game (*The Lost Astronaut* and *The Lost Hippo*) by location and gender. Section 7.9 also provides a comparative analysis of the game appeal by gender. In addition, it describes the correlation between the appeal of the games and the impact on participants' perception. Section 7.10 is a discussion of the internal and external validity factors that may compromise the reliability of the study. These factors are statistically analysed for their levels of significance to the study. The chapter concludes with a summary of findings obtained from the empirical study in section 7.11.

7.1 An overview of the structure of the data analysis

The analysis of data collected during the main study commenced with the analysis of the pre-study data. This included data collected on participants' play habits and perception of digital entertainment and educational games. The participant opinion of both game types was analysed and the qualitative results obtained. The pre-study data analysis confirmed results obtained from the exploratory study and also provided information on how participants perceived digital educational games before engaging with the experimental games designed for the study.

The second stage of the data analysis was the post-study data analysis of each of the customised games by gender and location. Both qualitative analysis and quantitative statistical tests were conducted to obtain results from the data collected. The result obtained from the analysis confirmed the exploratory study findings on digital educational games, pre-study results and the empirical evidence of the influence of each game on participating girls and boys from each location.

The third stage of the analysis reviewed the responses captured from participants on the comparative evaluation of *The Lost Astronaut* and *The Lost Hippo*. This analysis identified the preferred game with reasons and its influence on participants' perception of educational games for learning computer science concepts. The final stage of the data analysis considered the internal and external validity of the study. The result of the third stage of the data analysis confirmed previous results involving digital educational games and the preferred game by the target group of the study with justifications. The result of the validity tests also established how the findings can be applied to a wider population of the study.

The structure of the data analysis procedure ensured that the holism of the analysis was maintained (Cohen et al., 2013); such that qualitative and statistical trends could be correlated to the impact of the variants of the game characteristics identified during the exploratory study and no other confounding factors. The structure of the data analysis also supported in obtaining the empirical evidence in response to the research question of the study.

For the purpose of the survey, "*digital entertainment games"* were referred to as "*computer games"* and "*digital educational games"* as *"educational computer games"* in the questionnaire for simplification purposes with the participants.

The data analysis of the main study should provide the empirical evidence in response to the both research questions –

1) *"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?".*
2) *"Can we use this knowledge to create computer science learning games that appeal to this audience?"*

Sections 7.2 to 7.6 reports on the qualitative analysis of data by location and a summary of the results by location.

7.2 Location 1 – Qualitative analysis of pre-study data

7.2.1 Gender and age distribution

Location 1 is a mixed gender school with 149 participants involved in the empirical study. The gender composition of the sample population was 76 girls and 73 boys of age 11-14 years.

7.2.2 Regularity of computer gameplay

The first question of the pre-study questions was the regularity of play of computer games by participants. An illustration of the result is shown in figure 7.1. The data indicated that more boys play entertainment games on a daily basis than girls. However, girls play more regularly over a weekly, fortnightly (every two weeks) and monthly basis. In addition, more girls' never play computer games in comparison to the boys. An overview of the regularity of play by gender indicated that more boys play digital entertainment games on a daily basis than girls. However, this location goes on to show that girls play more regularly weekly, every 2 weeks and monthly.

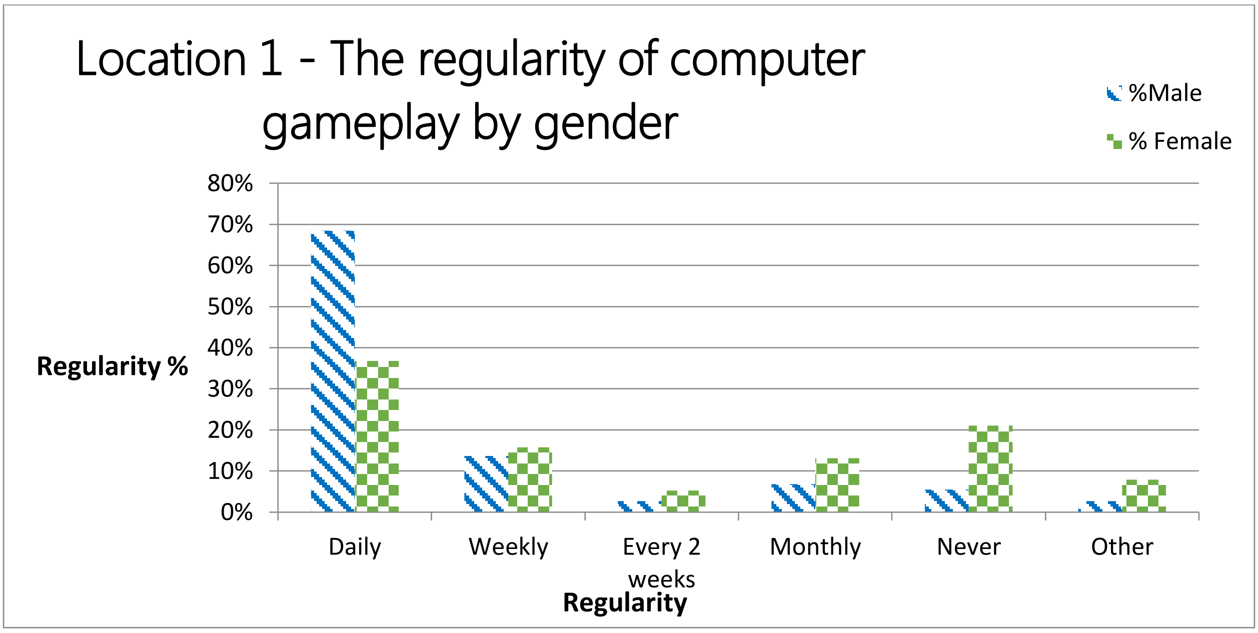


Figure 7.1. Location 1- The regularity of computer gameplay by girls and boys

7.2.3 The appeal of computer games

The result of the data analysis from location 1 as shown in figure 7.2 indicated that more girls in the sample population found computer games appealing as compared to those that find it unappealing. In total 64% of girls from this location found computer games very much, moderately or slightly appealing as compared to 11% that did not find computer games appealing. In addition, 24% were unsure of the appeal of computer games.

In comparison, 95% of the boys found computer games very much, moderately or slightly appealing. Only 1% appeared unsure about the appeal of computer games. It was also clear from the analysis that more girls (11%) than boys (4%) find computer game unappealing.

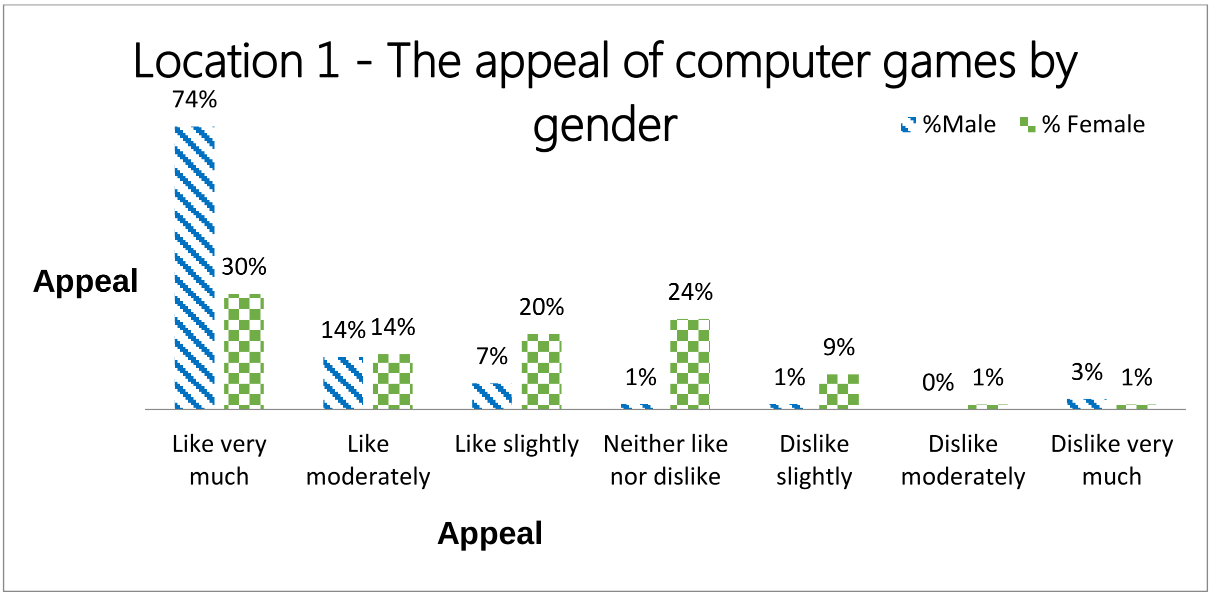


Figure 7.2. Location 1 – The appeal of computer games by gender

7.2.4 Ranking the top 10 game characteristics

During the pre-study survey, participants were also required to rank the game characteristic in order of importance. The most important characteristics ranked as 1 and 10 the least important. Table 7.1 illustrates the analysis of the pre-study data collected from location 1. The top two game characteristics for both genders were game interactivity and multiplayer environments.

This supports the exploratory study finding, where variants of these characteristics resulted in differences in the appeal of games. Girls find the collaborative interactive and multiplayer game environment appealing while in contrast, boys find a competitive interactive and multiplayer environment appealing (Osunde et al., 2015). Other significant game characteristics identified from the analysis also support the exploratory study finding such as reward, violence, graphics, colours, gameplay levels, action and competition.

Game characteristic ranking	Girls	Game characteristic ranking	Boys
1	- Interactive games	1	- Interactive games
2	- Multiplayer games	2	- Multiplayer games
3	- Challenge - Mission	3	- Reward
5	- Reward	4	- Audio (sound effects)
6	- Violence - Dark colours for characters - Storyline - Gameplay levels - Action - Competition	5	- Audio - (background effect) - Challenge - Competition
6		8	- Ability to choose characters - Obvious progression - Good use of available space

Table 7.1. Location 1 ranking of top 10 game characteristics for girls and boys

7.2.5 The regularity of play of computer games with characteristics that appeal to players

This pre-study question also investigated the impact of game characteristics that appeal to participants on the frequency of gameplay. A 7-point Likert-scale question was used to capture the responses of the participants. The analysis of the data by gender is illustrated in figure 7.3. About 67% of the girls target group would play computer games regularly if they included game characteristics that appeal to them.

Only 18% of the girls were unsure of their regularity of play if games were to include characteristics that appeal to them. For the boys, 100% would play regularly if computer games included game characteristics that appeal to them. The analysis also indicated that 22% of girls would play very frequently as compared to 68% of the boys.

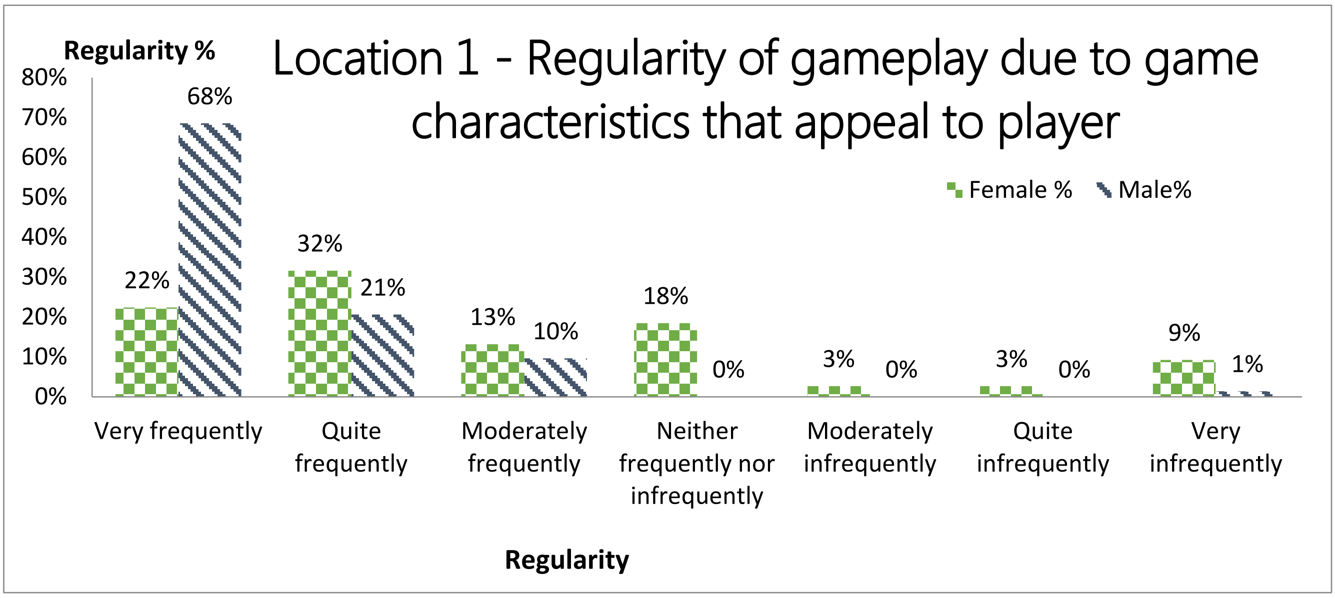


Figure 7.3. Location 1 – The regularity of gameplay due to game characteristics that appeal to player

7.2.6 Influence on players' view of computer games when games included characteristics that appeal

The influence on the players' views of computer games when games included characteristics that appeal was captured and analysed in this question. A 4-point Likert-scale question was used to capture the responses. The result is illustrated in figure 7.4.

From the results, 72% of girls view of computer games would be influenced a lot and to some extent. It would make not a lot of difference to about 9% of the girls. Similarly, 94% of the boys indicated that the influence is a lot and to some extent. Only about 5% indicated that it would make not a lot of difference to how they view computer games.

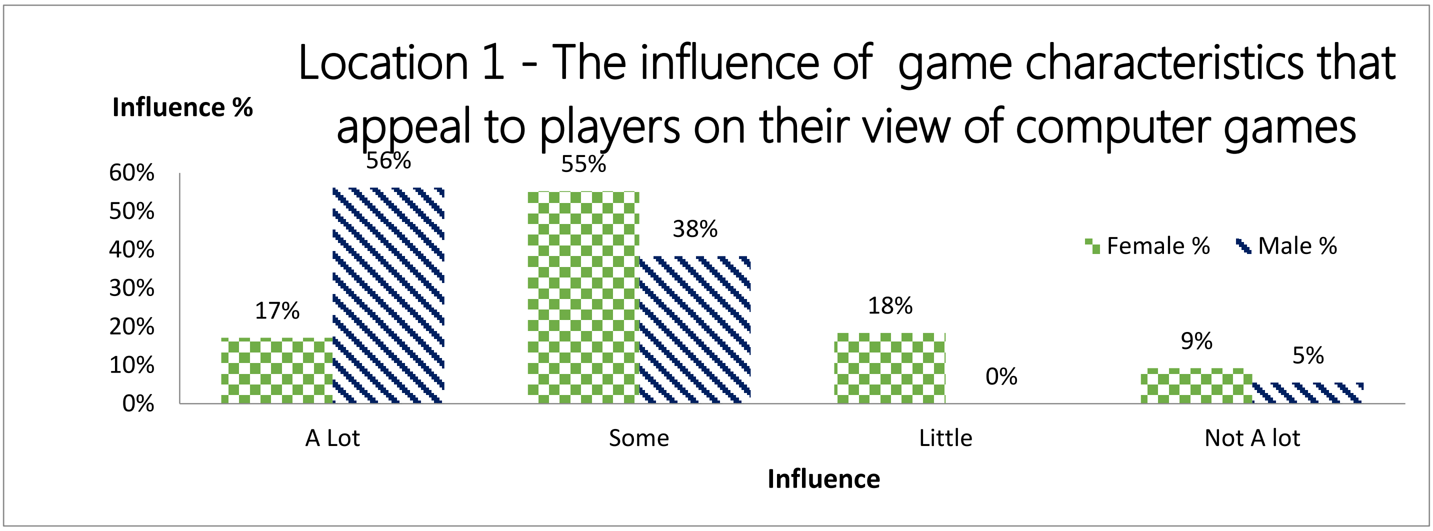


Figure 7.4. Location 1 – The influence of game characteristics that appeal to players on their view of computer games

The other questions in the pre-study questionnaire captured information specifically on educational computer games. The view of the target audience of educational computer games was captured using Likert-scale questions.

7.2.7 The regularity of play of educational computer games

This question captured by gender the responses of participants on how regularly they play educational computer games. The result of the responses is illustrated in figure 7.5. The boys of age 11-14 from this location tend to play educational computer games regularly on a daily basis than the girls. However, on a weekly, 2 weeks and monthly basis, about 36% of girls play educational computer games as compared to 28% of the boys. The analysis also indicated that 50% of girls would never play educational computer games as compared to 41% of boys.

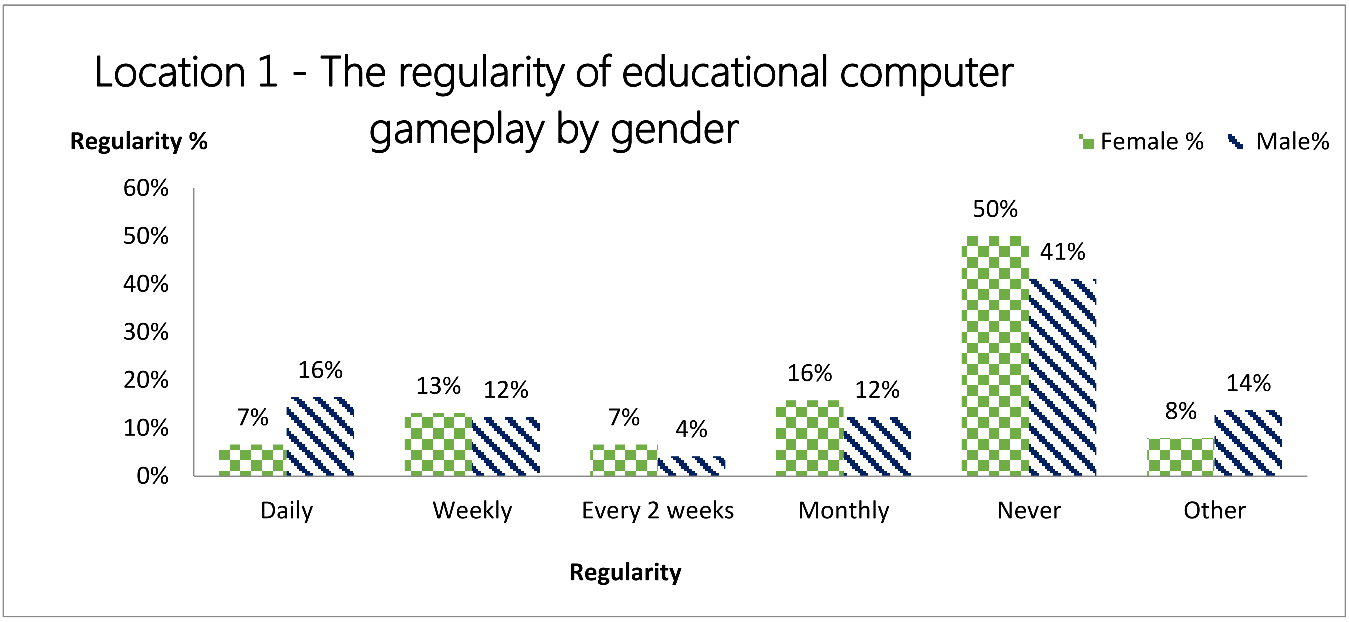


Figure 7.5. Location 1 –The regularity of educational computer gameplay by gender

7.2.8 The appeal of educational computer games

This question captured the information on the how many participants from this location found educational computer games appealing. A 7-point Likert-scale was used to capture the data. The result of the data analysis is shown in figure 7.6. About 50% of girls find educational computer games unappealing in comparison to 51% of boys from this location. In addition, more boys (33%) dislike educational computer games very much as compared to 12% of girls from this location. Similar numbers of girls and boys from the location neither like nor dislike educational computer games. Finally, there was no significant difference in the appeal of educational computer games between the girls (28%) and boys (27%).

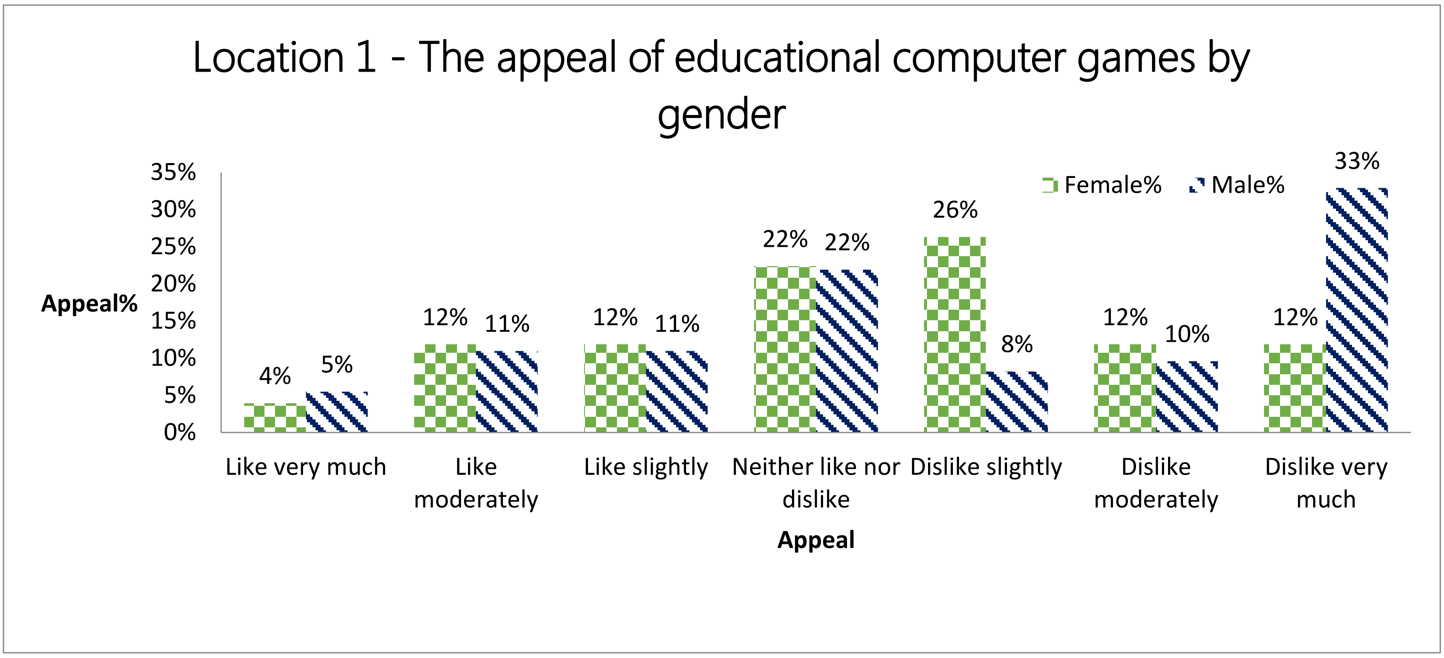


Figure 7.6. Location 1- The appeal of educational computer games by gender

7.2.9 Preference for educational computer games with characteristics that appeal to players

The preference for educational computer games that included characteristics that appeal to the target audience was captured in this question using a 5-point Likert-scale question. The result of the data analysis shown in figure 7.7 indicated that about 37% of the girls from this location strongly and somewhat prefer educational computer games with characteristics that appeal to them. More girls appear to indicate this preference in comparison to the males. Furthermore, about 34% of the boys either somewhat do not prefer or strongly do not prefer educational computer games with characteristics that appeal to them as compared to 23% of the girls from this location.

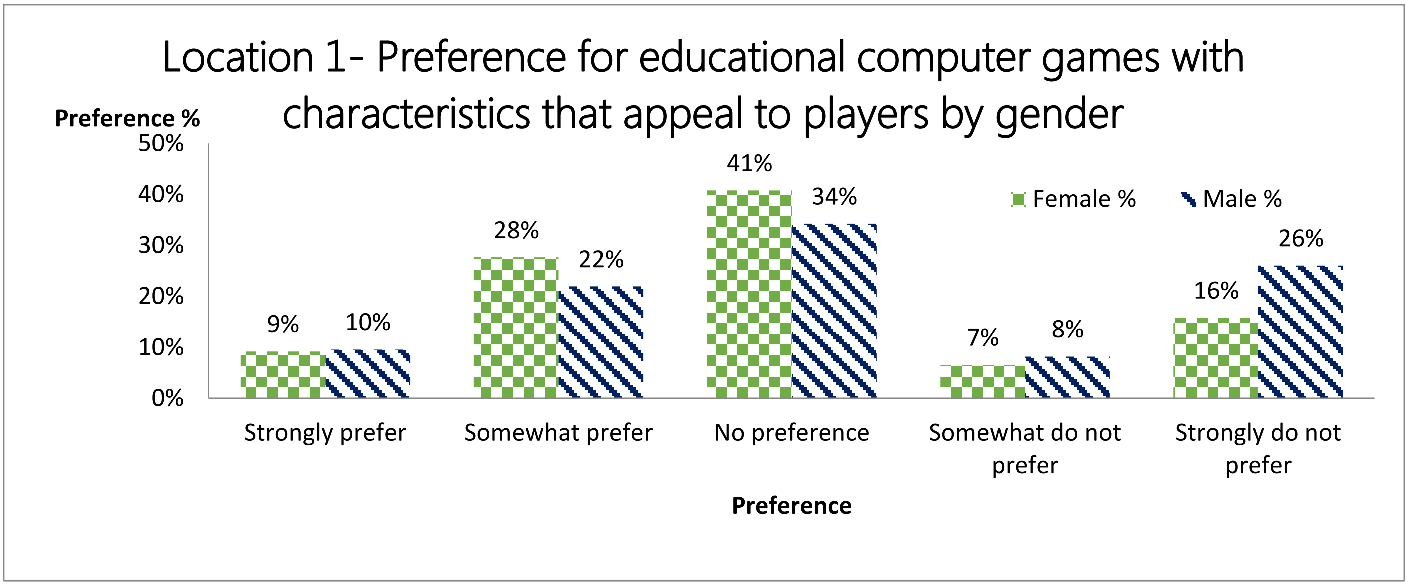


Figure 7.7. Location 1 – Preference for educational computer games with characteristics that appeal to players by gender

7.2.10 The influence of game characteristics that appeal to players on their view of educational computer games

A 7-point Likert-scale question was used to capture the responses of participants for this question. The result of the data analysis is illustrated in figure 7.8.

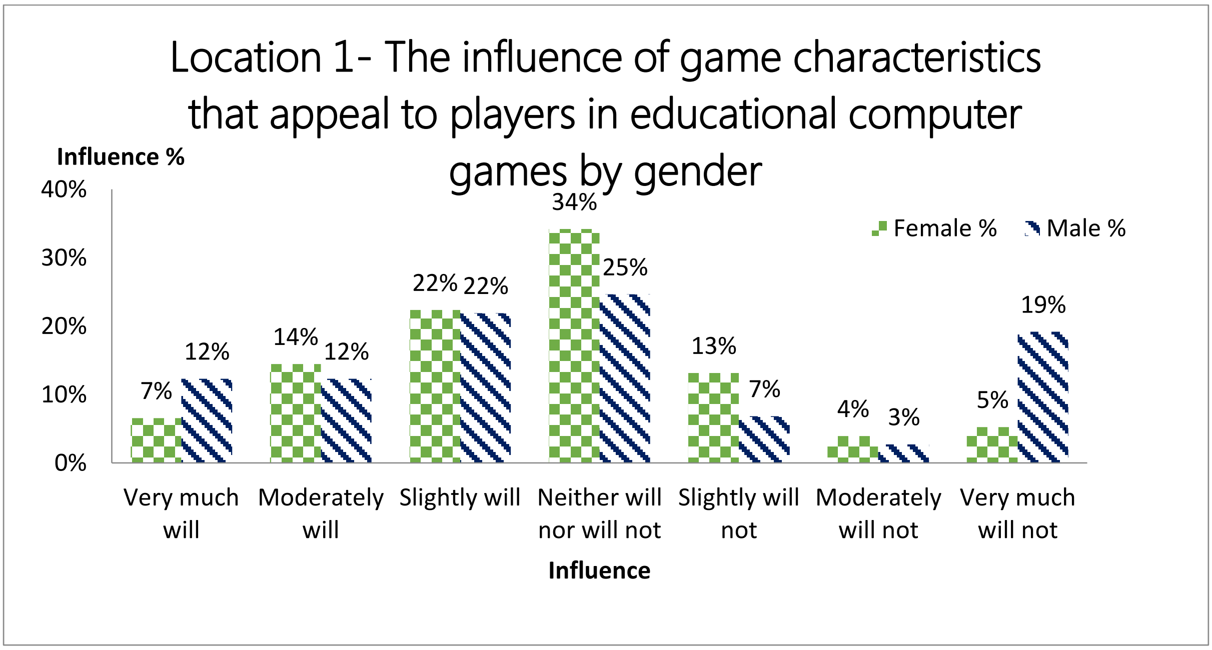


Figure 7.8. Location 1 – The influence of game characteristics that appeal to players in educational computer games by gender

From the result of the data collected, cumulatively, the view of about 43% of girls would be influenced as compared to about 46% of the boys. In addition, the views of more boys as compared to girls from this location would not be influenced if educational computer games included game characteristics that appeal to them. Consequently, from the results, it appears that the views of girls would be more influenced in comparison to the boys.

7.2.11 Conclusion of the results of Location 1

The result of the data analysis for location 1 which is a mixed gender school indicated that the boys from this location play computer games more regularly on a daily basis than the girls. However, the girls play more regularly over a week, fortnightly and monthly basis. Although more boys found computer games appealing in comparison to the girls, more girls found computer games appealing as compared to the proportion of girls that do not find computer games appealing.

The ranking of the top game characteristic for both girls and boys indicated a similarity in the top two ranking of interactive and multiplayer games. Both genders would play computer games more regularly if they included characteristics that appeal to them. In addition, game characteristics that appeal to girls and boys would influence their views of computer games.

The trend for the regularity of play of educational computer games for both gender was similar to computer games. However for this location, more girls would never play educational computer games as compared to the number of girls that play. Almost similar proportions of girls and boys from this location find educational computer games appealing, with the boys disliking educational computer games the most.

Finally, more girls than boys from this location indicated that they prefer educational computer games with characteristics that appeal to them. A fewer number of girls than boys also indicating that characteristics that appeal to them will not influence their views of educational computer games.

In relation to the research question, from the feedback obtained from girls and boys participants from this location, including game characteristics that appeal to them would influence their views of digital educational games.

7.3 Location 2 – Qualitative analysis of pre-study data

7.3.1 Gender and age distribution

Location 2 was another mixed gender school comprising 51 participants. There were 26 (51%) participating girls and 25 (49%) participating boys.

7.3.2 The regularity of computer gameplay

The regularity of playing computer games was similar to location 1 as the boys play more often (daily) as compared to the girls. On a less regular basis, more girls (35%) play than the boys (16%).Most participating girls in this location tend to play more on a weekly basis as compared to the males who play more on a daily basis. It is also significant to note that 27% of the girls never play as compared to 4% of the boys.

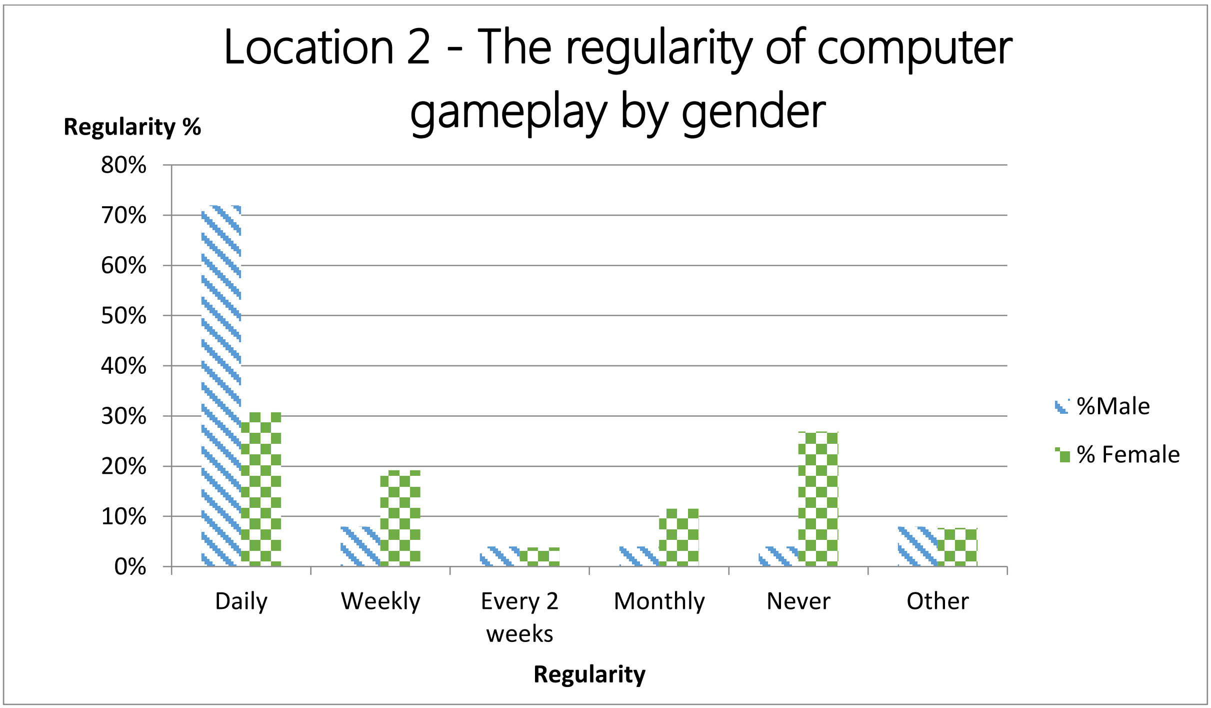


Figure 7.9. Location 2-The regularity of computer gameplay by girls and boys

7.3.3 The appeal of computer games by gender

The boys in this location find computer games appealing more than the girls. From the data analysis, cumulatively 92% of the boys find computer games appealing, with 68% finding computer games very much appealing. In contrast, 58% of the girls find computer games appealing with 23% very much, 12% moderately and 23% slightly appealing respectively. In addition, 32% of the girls cumulatively dislike computer games as compared to 4% of the boys. Figure 7.10 illustrates this result.

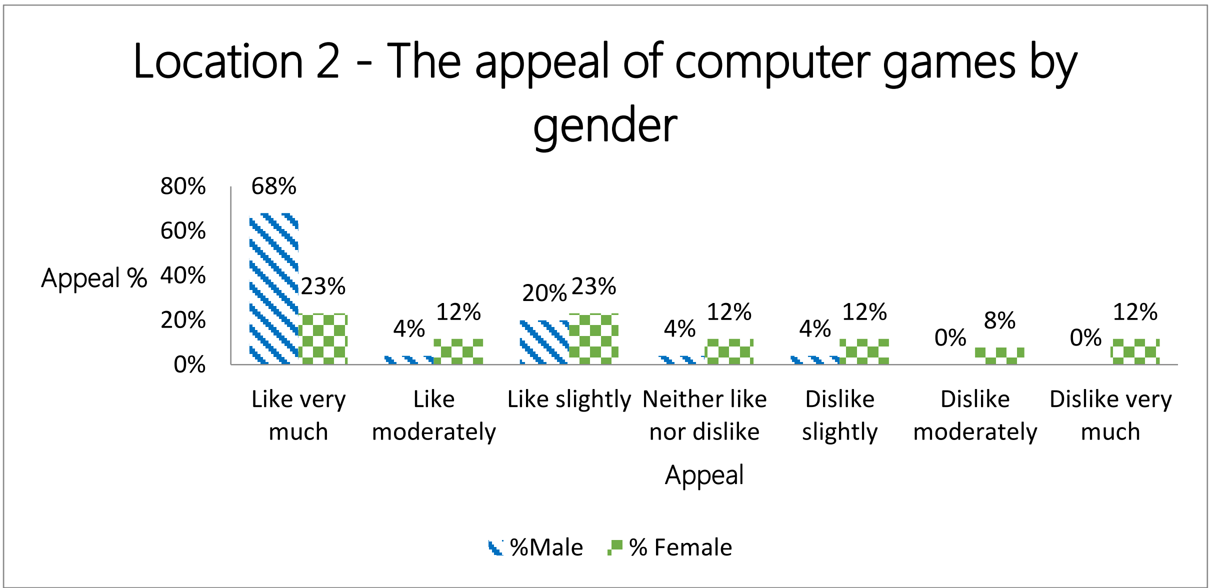


Figure 7.10. Location 2 – The appeal of computer games by gender

7.3.4 Ranking the top 10 game characteristics

The ranking of the game characteristics by gender from this location is shown in table 7.2. There are significant differences and similarities in the top 10 game characteristics between both genders. The similarities in the top 10 game characteristics were audio (background sound), challenge, good use of available space, rewards and ability to choose characters. There were also a number of differences which included storyline, action, rewards, purposefulness, gameplay levels, use of help dialogues and game violence. These similarities and differences were consistent with the findings of the exploratory study.

Game characteristic ranking	Girls	Game characteristic ranking	Boys
1	- Storyline	1	- Multiplayer - Action
2	- Violence - Ability to choose characters - Audio background sound - The use of help dialogues - Obvious purpose of the game - Reward - Challenge - Good use of available screen space	3	- Gameplay levels - Reward
		5	- Audio sound effects
		6	- Competition - Ability to choose characters
		8	- Interactivity - Audio background sound - Challenge - Good use of available space

Table 7.2. Location 2 ranking of top 10 game characteristics for girls and boys participants

7.3.5 The regularity of play of computer games with characteristics that appeal to players

The analysis of the data collected from this location illustrated in figure 7.11 indicated that 68% of boys would play digital games that include characteristics that appeal to them very frequently. The number of boys that play digital games due to the appeal of game characteristics cumulatively (92%) were far greater than the number of girls (50%). Furthermore, only about 4% of the boys were unsure of the effect of the game characteristics that appeal to them in digital games. In contrast, 27% of the girls were unsure of the impact of game characteristics that appeal to them on their regularity of play. Cumulatively, about 24% would play occasionally with 12% playing very sparingly. It was also obvious from the results that most girls in this location are not sure of the impact of game characteristics that appeal to them.

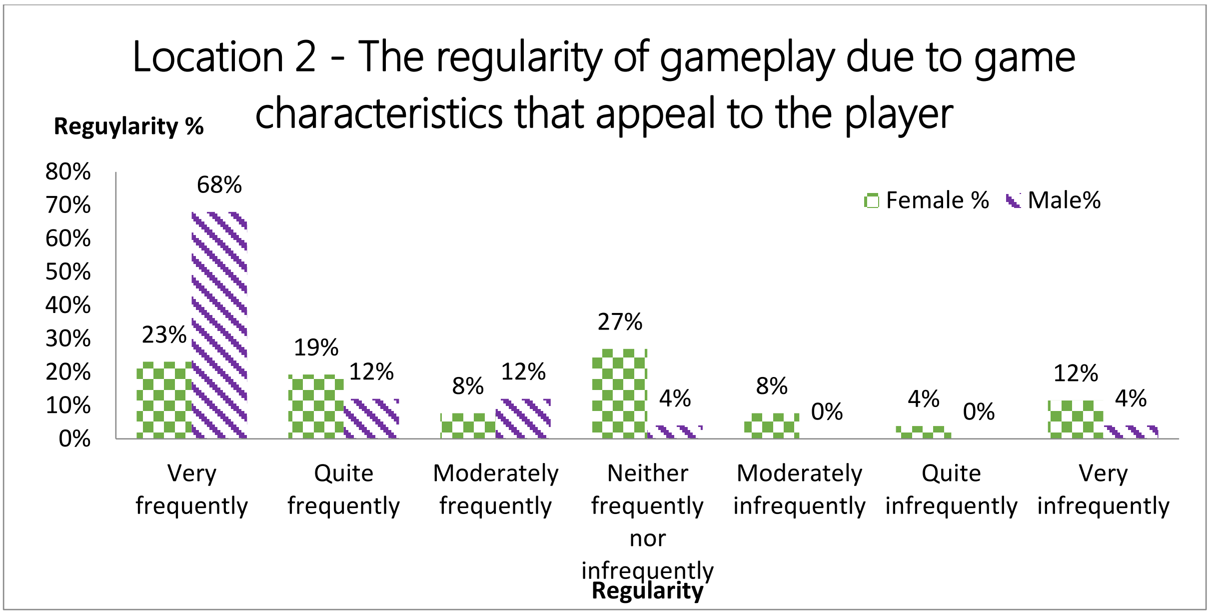


Figure 7.11. Location 2 – The regularity of gameplay due to game characteristics that appeal to players

7.3.6 The influence of game characteristics that appeal to players on their view of computer games

For the girls in this location, 23% indicated that including game characteristics that appeal to them would influence their view of computer games a lot. In comparison to the boys, about 60% of the population would be influenced a lot if they included game characteristics that appeal to them. The broad picture indicated that 73% of girls as compared to 96% of boys would have their views of computer games influenced if they included game characteristics that appeal to them.

This result is illustrated in figure 7.12.

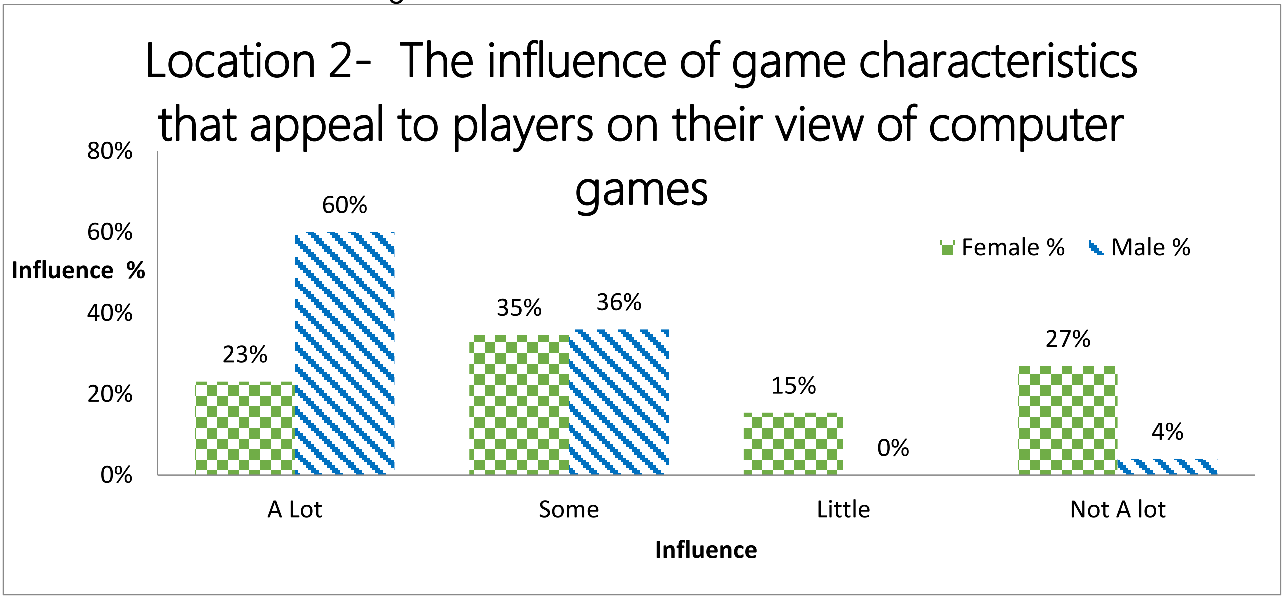


Figure 7.12. Location 2 – The influence of game characteristics that appeal to players on their view of computer games

7.3.7 The regularity of educational computer game play

The result for this location as illustrated in figure 7.13 indicate that more girls (8%) play educational computer games daily than boys (4%). However, the numbers that play cumulatively on a longer duration are almost equal – girls (43%); boys (44%). In addition, more girls (38%) never play educational computer games as compared to boys (32%) from this location.

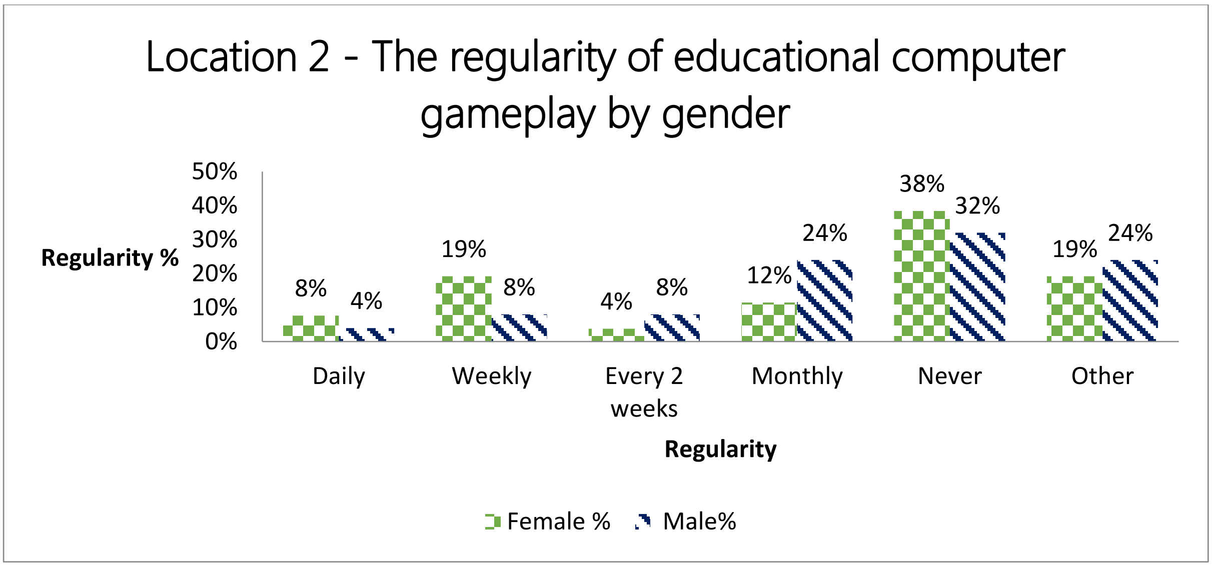


Figure 7.13. Location 2- The regularity of educational computer gameplay by gender

7.3.8 The appeal of educational computer games by gender

The result from this location indicated that cumulatively, 20% of girls find educational computer games appealing. A similar percentage of the boys also find educational computer games appealing. However, 8% of girls as compared to 4% of boys find educational games very much appealing. Conversely, 36% of boys very much dislike educational games as compared to 19% of the girls. The result of the analysis is illustrated in figure 7.14.

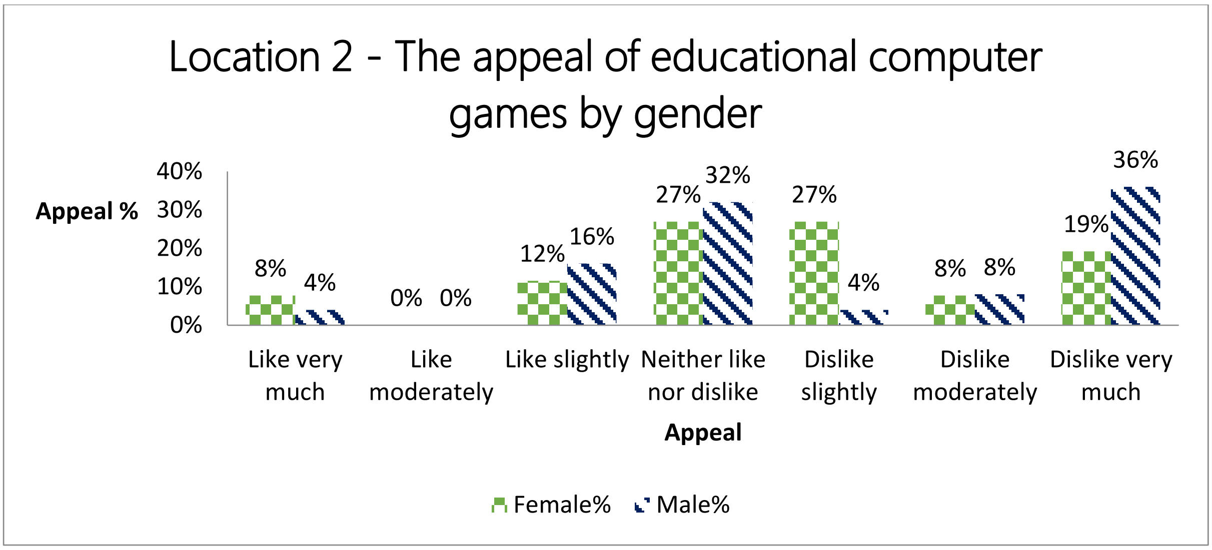


Figure 7.14. Location 2 – The appeal of educational computer games by gender

7.3.9 Preference for educational computer games with characteristics that appeal to players

From the analysis of the preference for educational computer games that include game characteristics that appeal to participants, the boys (48%) from this location prefer educational computer games with characteristics that appeal to them than girls (39%).Generally, it appeared that girls (35%) from this location show no preference for educational computer games that include characteristics that appeal to them as compared to 16% of the boys. Finally, about 36% of boys from this location show a stronger lack of preference for educational computer games in comparison to 23% of girls from this location (Figure 7.15).

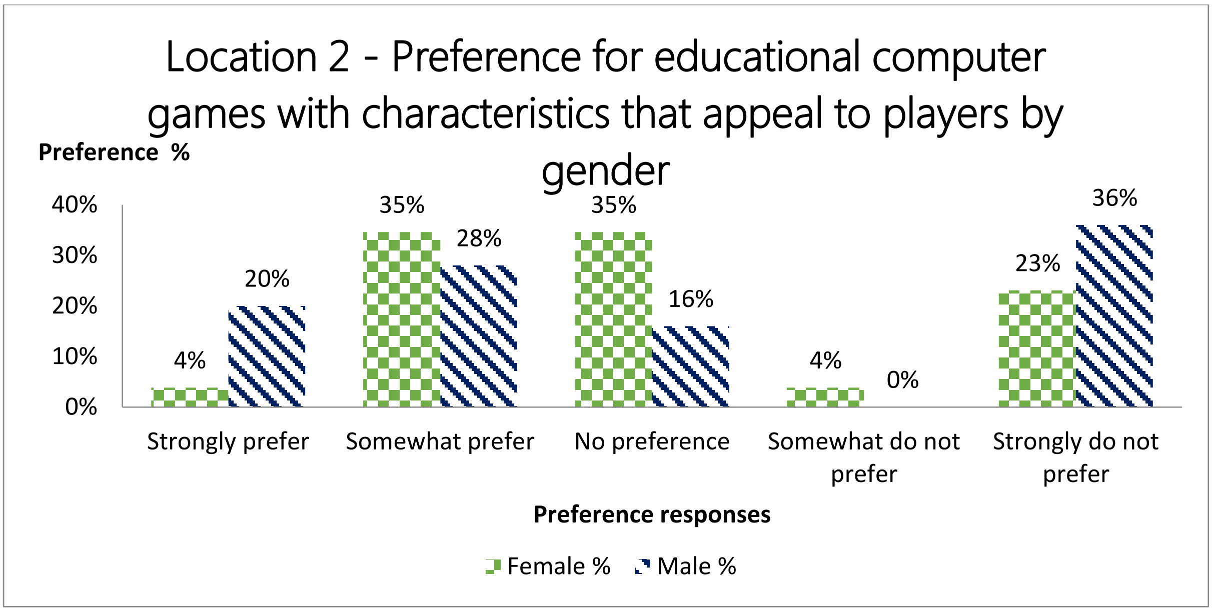


Figure 7.15. Location 2 – Preference for educational computer games with characteristics that appeal to players by gender

7.3.10 The influence of game characteristics that appeal to players on their view of educational computer games

The result of the analysis of the data collected from this location indicated that including game characteristics that appeal to players would influence the views of both girls and boys. Also, 23% of girls are undecided on the possible influence as compared to 28% of boys. In addition, 27% of girls would not be influenced as compared to 16% of participating boys. Figure 7.16 illustrates the result of the analysis.

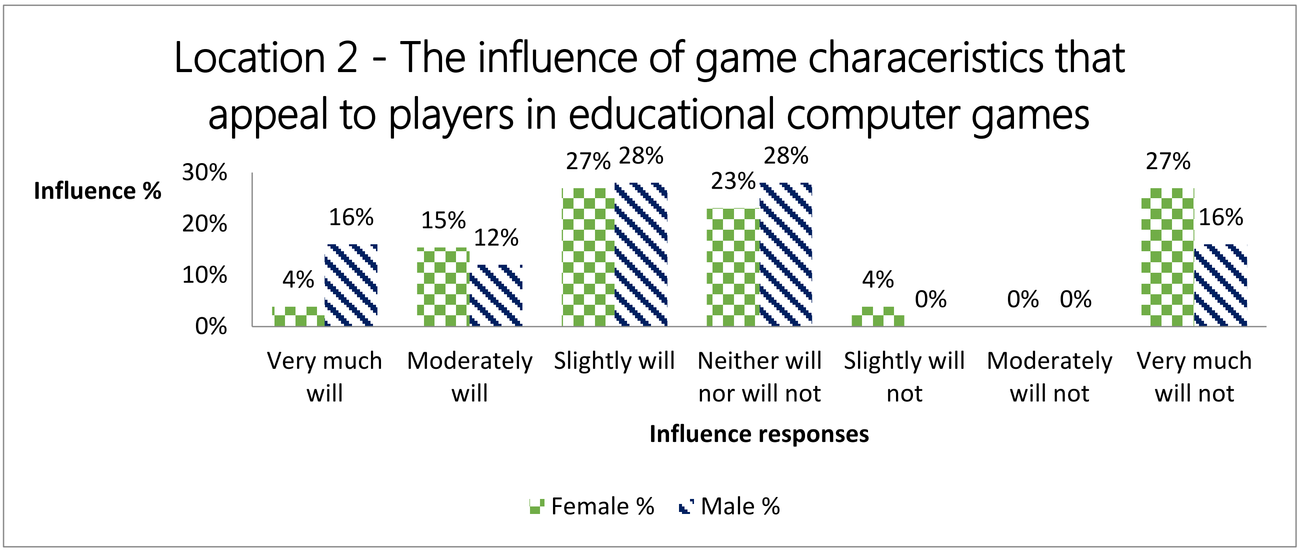


Figure 7.16. Location 2 – The influence of game characteristics that appeal to players in educational games

7.3.11 Conclusion of the results of Location 2

The result for the regularity of play of computer games for both girls and boys from this location was similar to location 1 i.e. boys play more regularly on a daily basis and girls more regularly on a weekly, fortnightly and monthly basis. Also more boys found computer games appealing as compared to girls. However, more girls found computer games appealing as compared to the proportion of girls that do not find computer games appealing.

The ranking of the top game characteristic for the girls indicated that storyline and a number of other game characteristics were ranked second. These included violence, ability to choose character, audio background sound etc. (see table 7.2). Also for the boys, the top characteristics were multiplayer games and action. Both genders would play computer games more regularly if they included characteristics that appeal to them. In addition, game characteristics that appeal girls and boys would influence their views of computer games. With reference to the research question, including game characteristics that appeal to girls and boys from the location would influence their perception of digital educational games.

7.4 Location 3 – Qualitative analysis of pre-study data

7.4.1 Age distribution

Location 3 was a single gender (girls) secondary school. In total, 50 students participated in the survey.

7.4.2 The regularity of computer gameplay

This location comprising only girl participants is a selective school which appeared to have more confident computer game players than locations 1 and 2 which were mixed gender schools. For this location, 46% of the girls play computer games daily and only 2% never play computer games. Another 2% play every other day. Consequently, the girls in this location play computer games more daily than weekly or fortnightly. Figure 7.17 illustrates the results.

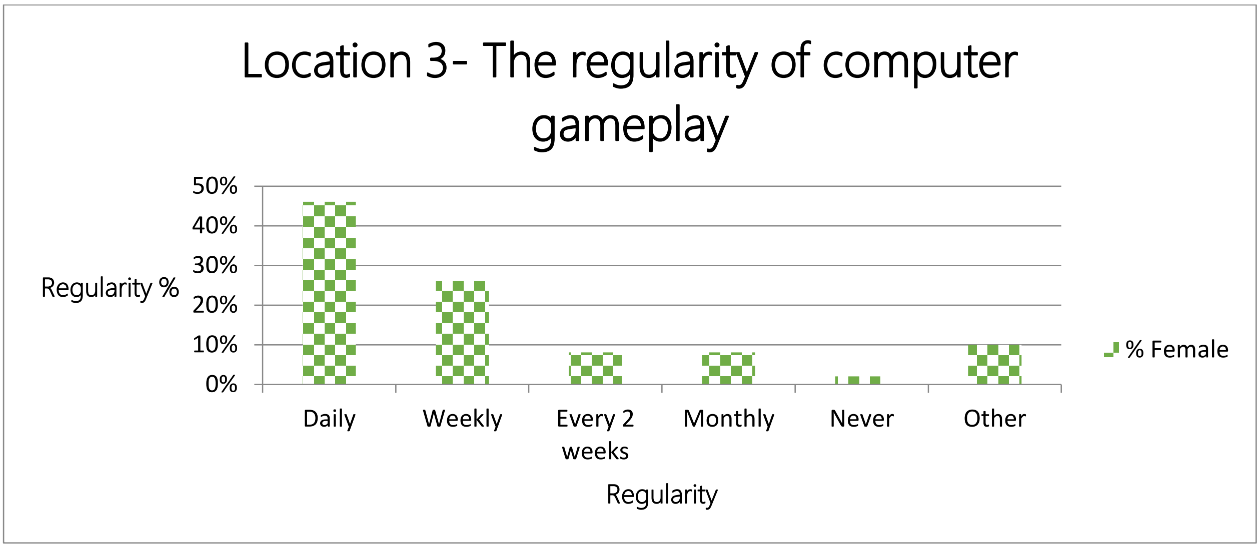


Figure 7.17. Location 3 – The regularity of computer game play by girls

7.4.3 The appeal of computer games

For this location, 80% of the girls indicated that computer games are appealing. In addition, 30% of the participants indicated that they find computer games very much appealing. Furthermore, there were no responses to the unappealing nature of computer games from this location. The illustration of the analysis for this location is shown in figure 7.18.

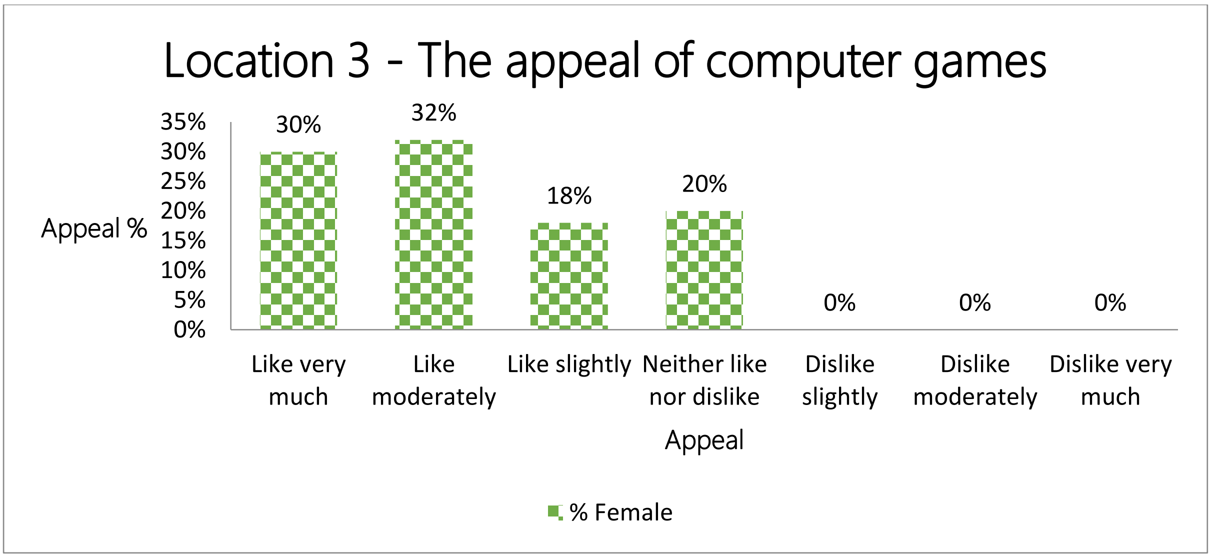


Figure 7.18. Location 3 – The appeal of computer games

7.4.4 Ranking the top 10 game characteristics

The analysis of the ranking of game characteristics that are significant to participants is illustrated in table 7.3. The analysis indicated that gameplay levels, progression, challenge, rewards and audio were the top characteristics.

Game characteristic ranking	Game characteristics
1	- Gameplay levels
2	- Progression - Challenge
4	- Game reward - Audio back ground sound - Audio sound effects
7	- Obvious purpose of game
8	- Good use of available space - Ability to choose characters
10	- Adventure - The use of easy to read text - Competition

Table 7.3. Location 3 - Ranking of top 10 game characteristics

7.4.5 The regularity of play of computer games with characteristics that appeal to players

Figure 7.19 illustrates the regularity of gameplay of computer games with characteristics that appeal to participants. The result indicated that 86% of the young females would play computer games frequently if they included characteristic that appeal to them. It was further indicated that 36% would play very frequently, 34% quite frequently and 16% moderately frequently. Only 12% of the participating population appear to play digital games neither frequently or infrequently.

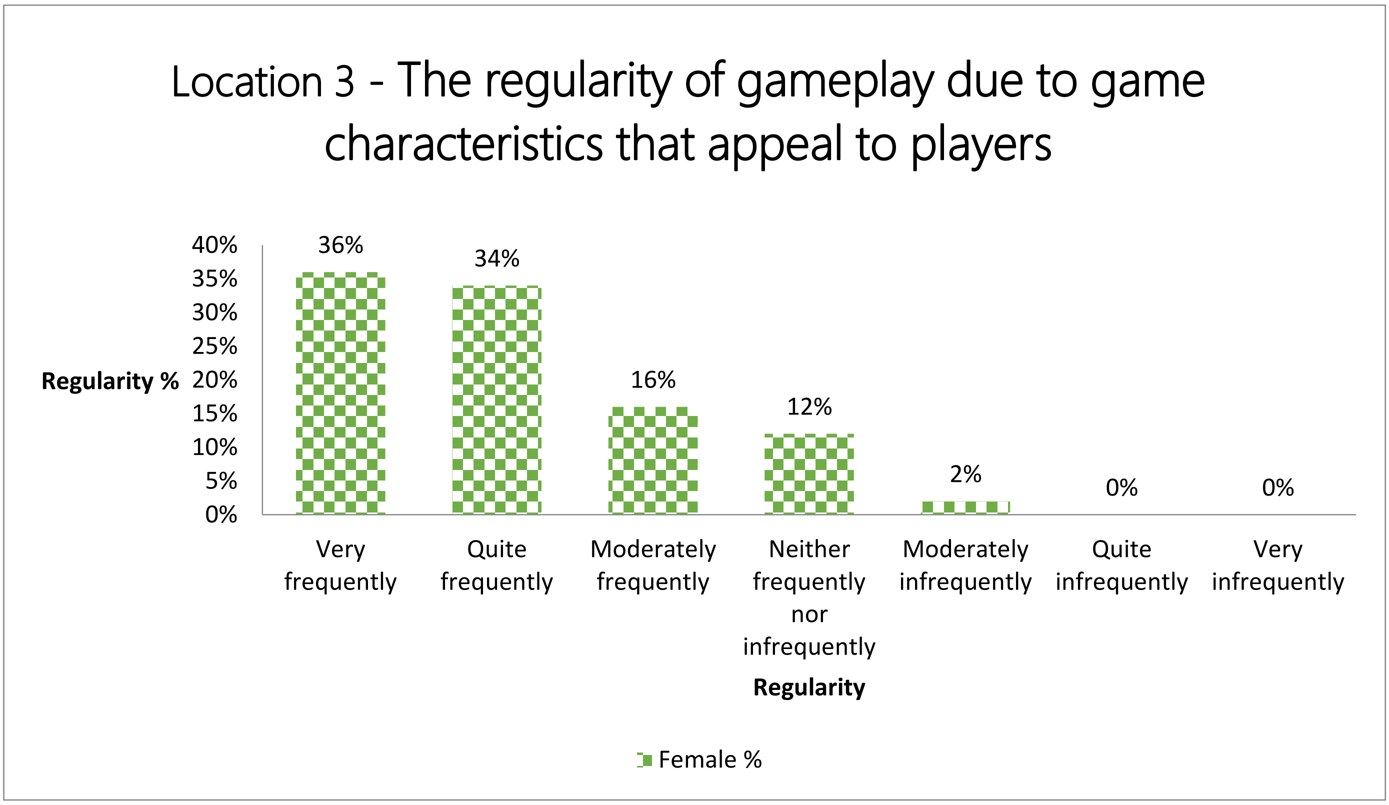


Figure 7.19. Location 3 – The regularity of game play due to game characteristics that appeal to player

7.4.6. The influence of game characteristics that appeal to players on their view of computer games

The data analysis of the influence on participants' view of computer games due to game characteristics that appeal to them indicated that cumulatively, 98% of the participants are influenced from this location. This result is illustrated in figure 7.20. Most participants (44%) indicated that their view would be influenced to some extent and 38% indicating that it would be influenced a lot.

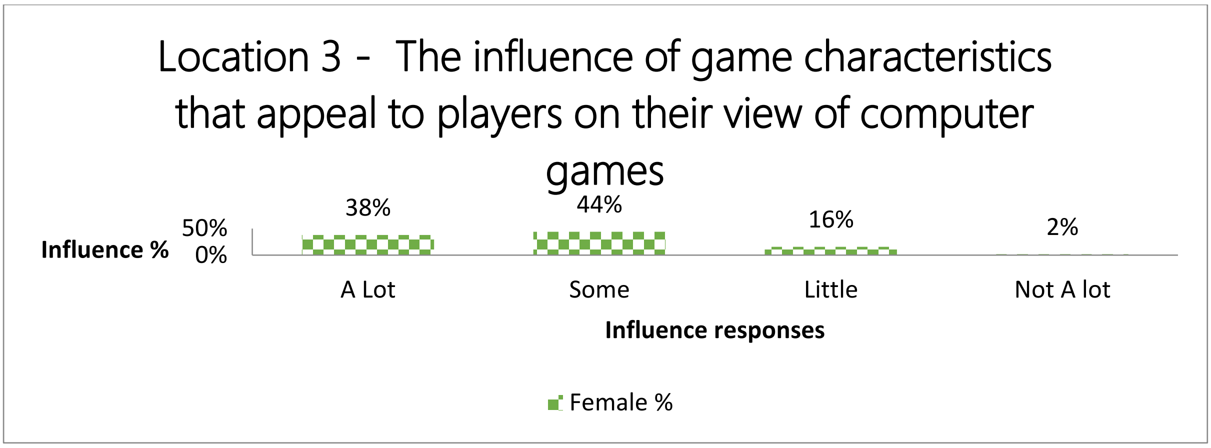


Figure 7.20. Location 3 – The influence of game characteristics that appeal to players on their view of computer games

7.4.7 The regularity of educational computer gameplay

From the analysis of the data for this location, as shown in figure 7.21, most participants will never play an educational computer game. In addition, fewer participants play daily, weekly and every two weeks. A further review of the other responses for regularity indicated that most participants would play if it is required by the teacher or essential for examination i.e. extrinsic motivational reasons.

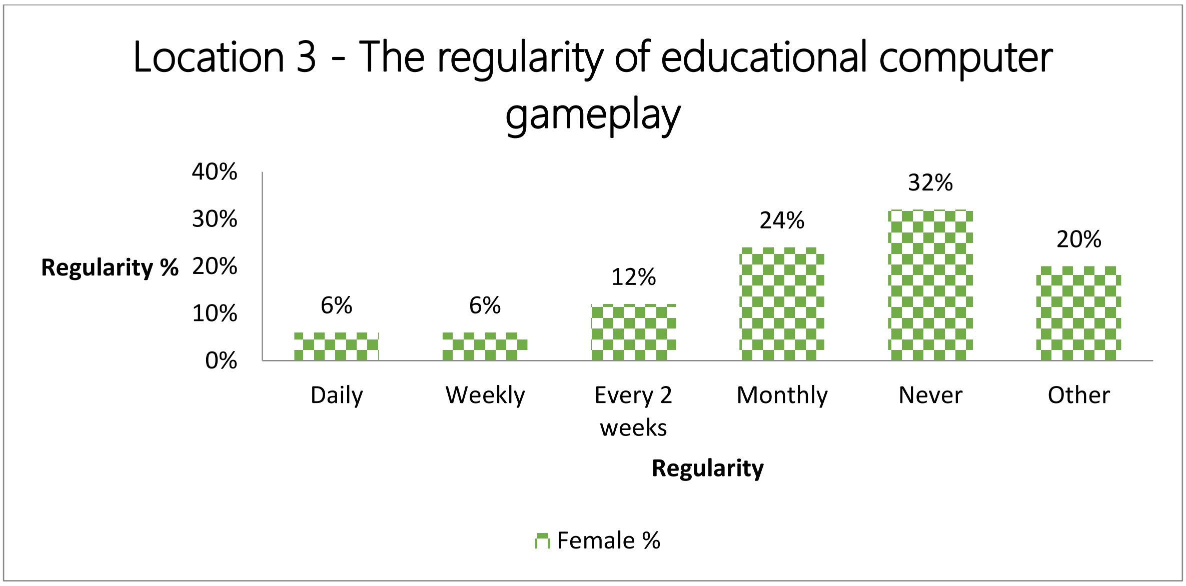


Figure 7.21. Location 3 – The regularity of educational computer gameplay

7.4.8 The appeal of educational computer games

The data analysis indicated that most participants (48%) do not find educational computer games appealing. Also, 32% of the participating population find educational computer games appealing with 20% not sure if they find educational computer games appealing or unappealing. The analysis is illustrated in figure 7.22.

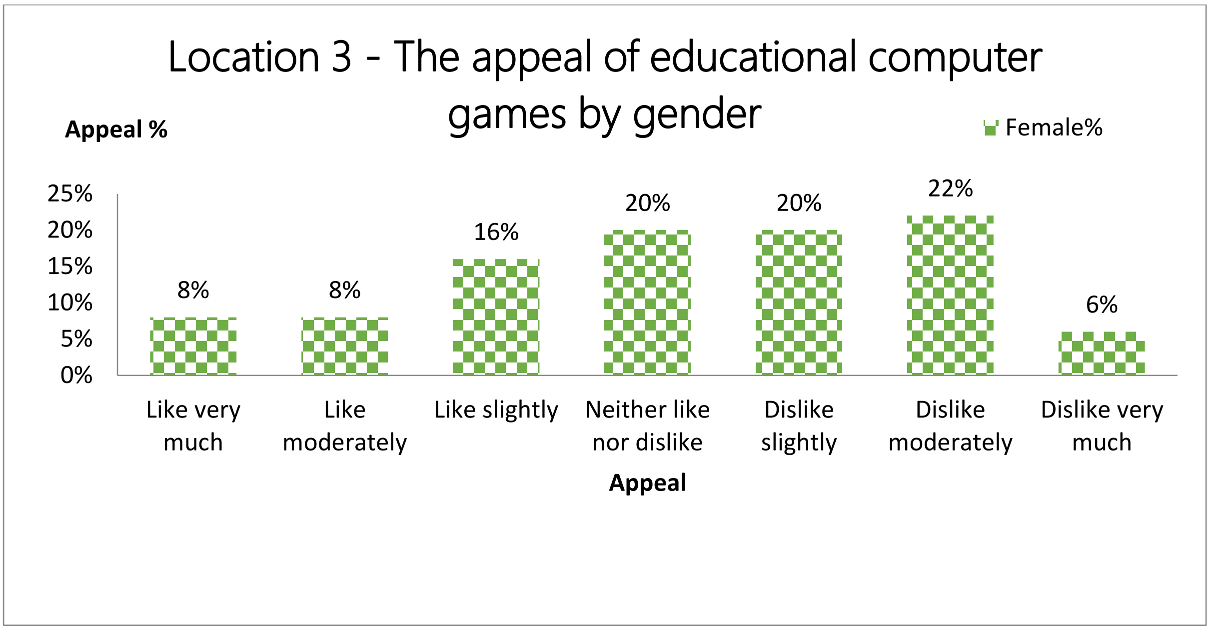


Figure 7.22. Location 3 – The appeal of educational computer games

7.4.9 The influence of game characteristics that appeal to players on their view of educational computer games

The influence of the game characteristic that appeals to young females in the location on their view of educational computer games is illustrated in figure 7.24. It indicated that 68% would be influenced very much, moderately or slightly. Furthermore, 0% indicated that there will be no influence at all. This suggests that game characteristics that appeal to participants might be significant in influencing the perception of participants from this location.

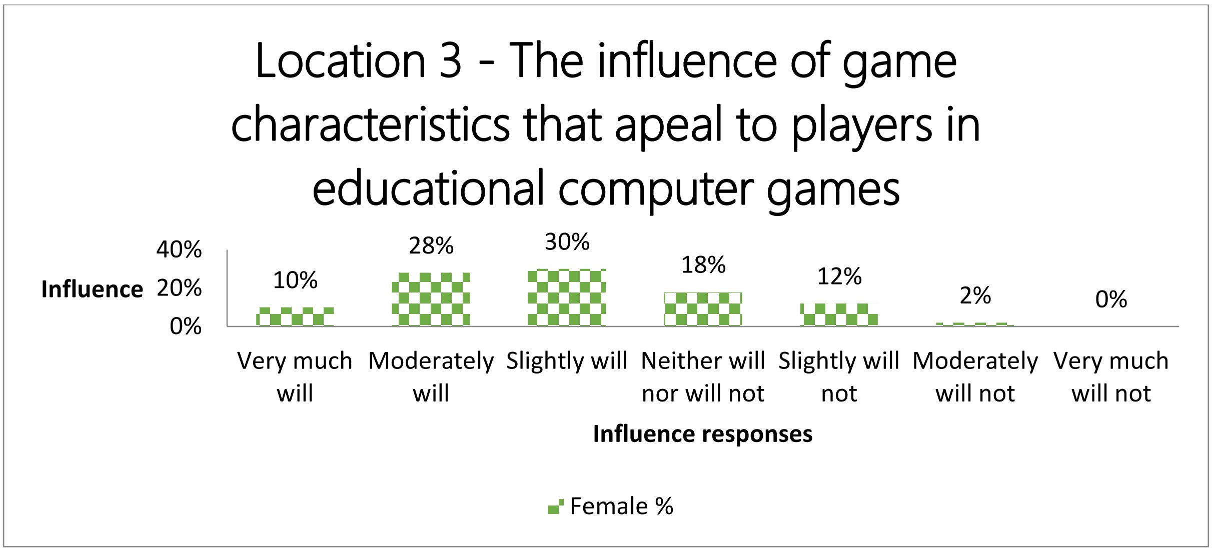


Figure 7.23. Location 3 –The influence of game characteristics that appeal to players in educational games

7.4.10 Conclusion of the results of Location 3

The result of this all girl location indicated that more girls play computer games daily as compared to those that play weekly, fortnightly and monthly. More girls also find computer games appealing as compared to those that find it unappealing. The top game characteristics included game levels, progression and game challenge.

Furthermore, most of the girls would play computer games regularly if they included game characteristics that appeal to them. Most girls from this location also indicated that their view of computer games would be influenced if they included characteristics that appeal to them.

The trend for the regularity of play of educational computer games for girls in this location indicated that they play more on a monthly and fortnightly basis. It was also indicated from this location that most of the girls disliked educational computer games. However, most of the girls reported that they would prefer to play educational computer games that included game characteristics that appeal to them. Also, including game characteristics that appeal to them in educational computer games would influence their views of these games. In relation to the research question, the location result also indicated that including game characteristics that appeal to participants would improve the regularity of play and influence their perception of digital educational games.

7.4.11 The preference for educational computer games with characteristics that appeal to players

An analysis of the data on the preference for educational computer games with characteristics that appeal to participants is illustrated in figure 7.23. From the analysis, 54% of participants indicated that this would improve their preference for educational computer games. In addition, 32% indicated no preference. This might be associated with the current poor experience, which that target age group have with computer educational games. Furthermore, 14% of participants indicated strongly that their preference will not change irrespective of the inclusion of game characteristics that appeal to them.

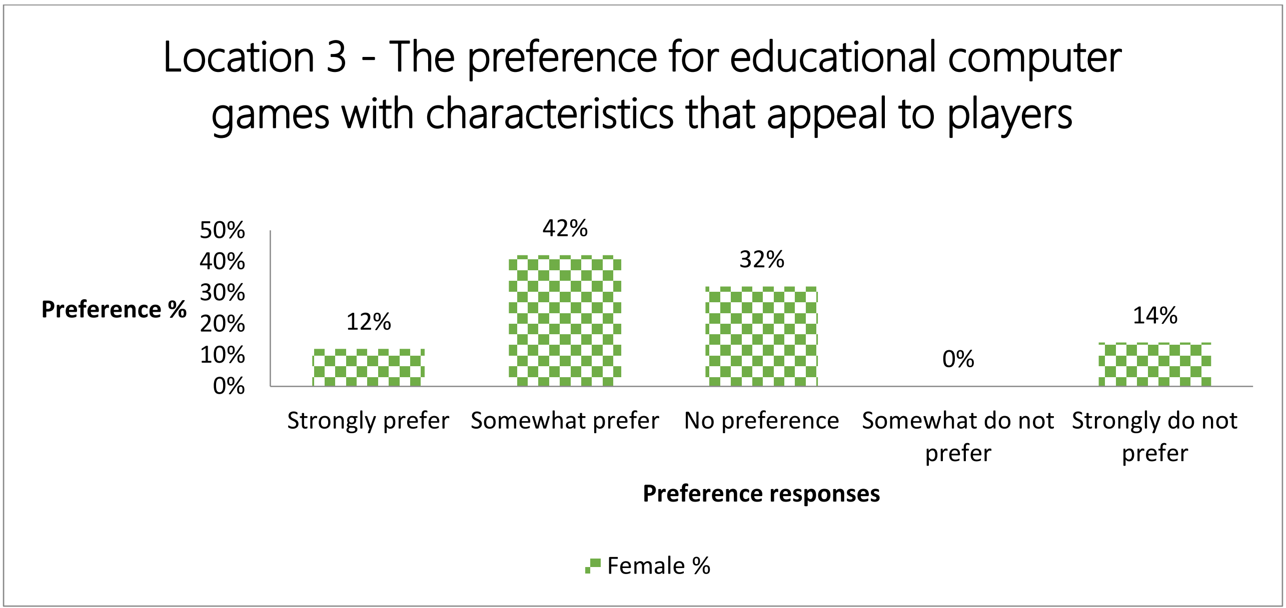


Figure 7.24. Location 3 – The preference for educational computer games with characteristics that appeal to players

7.5 Location 4 – Qualitative analysis of pre-study data

7.5.1 Age distribution

This location is a boy only secondary school. The total number of participants was 27.

7.5.2 The regularity of computer gameplay

For this location, 56% of the participating boys play on a daily basis and 7% never play computer games. Furthermore, 15% of the population responded to the other option. From this category, 4% indicated that they play twice a week; another 4% on weekends only and 4% responded that they rarely play computer games. The illustration of the analysis is presented in figure 7.25.

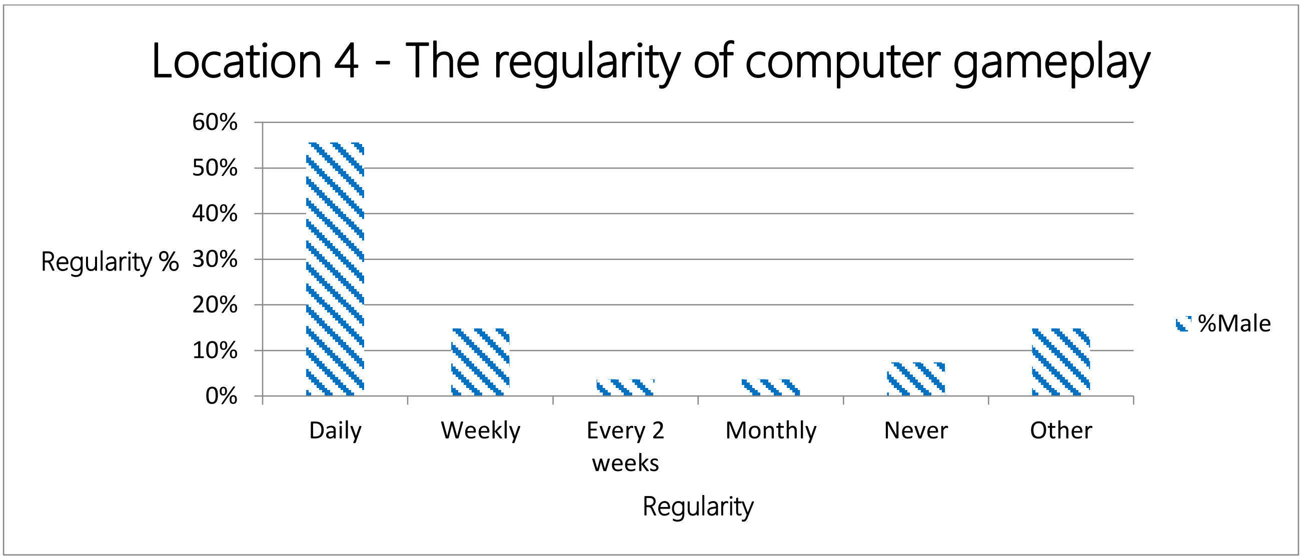


Figure 7.25. Location 4-The regularity of computer gameplay

7.5.3 The appeal of computer games

About 64% of boys from location 4 indicated that they find computer games appealing. The cumulative percentage of the appeal of computer games was 92% of the participants. Furthermore, 8% of the population did not find computer games appealing. The analysis of the data is illustrated in figure 7.26.

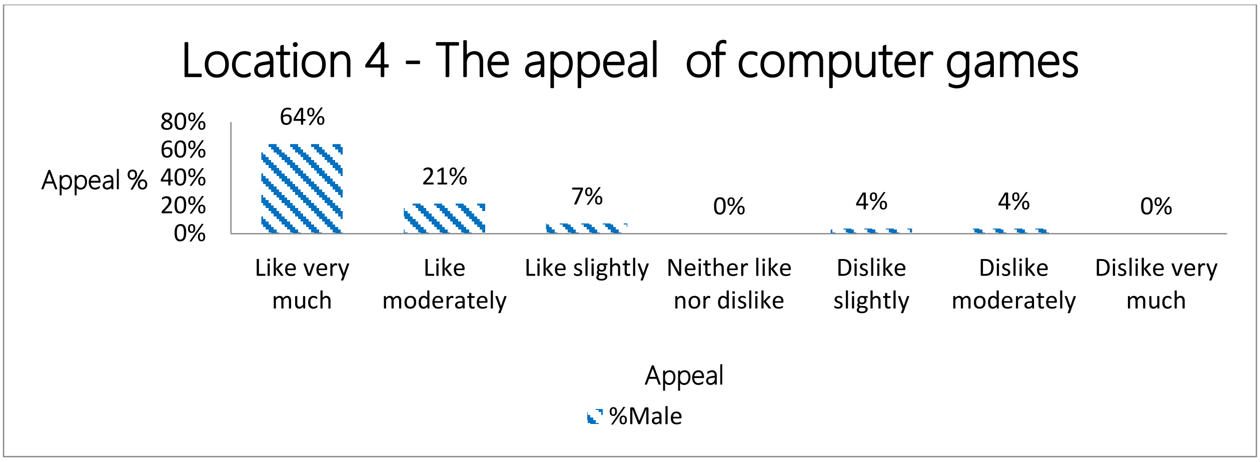


Figure 7.26. Location 4 –The appeal of computer games

7.5.4 Ranking the top 10 game characteristics

The ranking of game characteristics for this location in order of importance indicated that game audio, interactivity, progress within the game and multiplayer games were the top 3 characteristics. Other important game characteristics to participants are presented in table 7.4.

Game characteristic ranking	Game characteristics
1	- Audio sound effects
2	- Audio background sound
3	- Interactivity - Progress within the game - Multiplayer game
6	- Competitive game - Complex game mission - Adventure scenes
9	- Ability to choose characters - Action scenes - Good use of available space

Table 7.4. Location 4- Ranking of top 10 game characteristics

7.5.5 The regularity of play of computer games with characteristics that appeal to players

The illustration of the analysis for this location is provided in figure 7.27. It appeared that the boys play computer games frequently with 44% very frequently, 41% quite frequently and 7% moderately frequently. In total 92% of participants play computer games frequently. In addition, 4% play moderately infrequently with 0% quite infrequently and very infrequently. The analysis indicated that participating boys from this location would play computer games regularly if they included game characteristics that they find appealing.

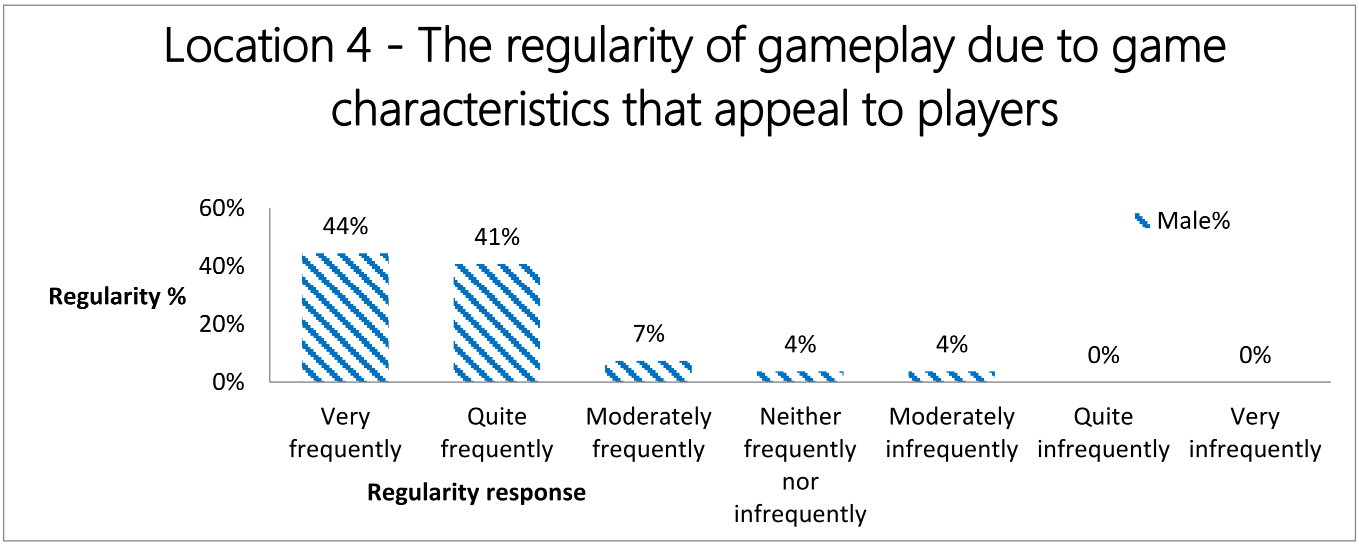


Figure 7.27. Location 4-The regularity of play of computer games with characteristics that appeal

7.5.6 The influence of game characteristics that appeal to players on their view of computer games

From the analysis of the data from this location, the players' views of computer games are influenced if games included characteristics that appeal to them. From the illustration of the analysis of this location in figure 7.28, 44% responded that their views would be influenced a lot, 41% some influence and 11% little influence. In total, 96% would be influenced to a reasonable extent.

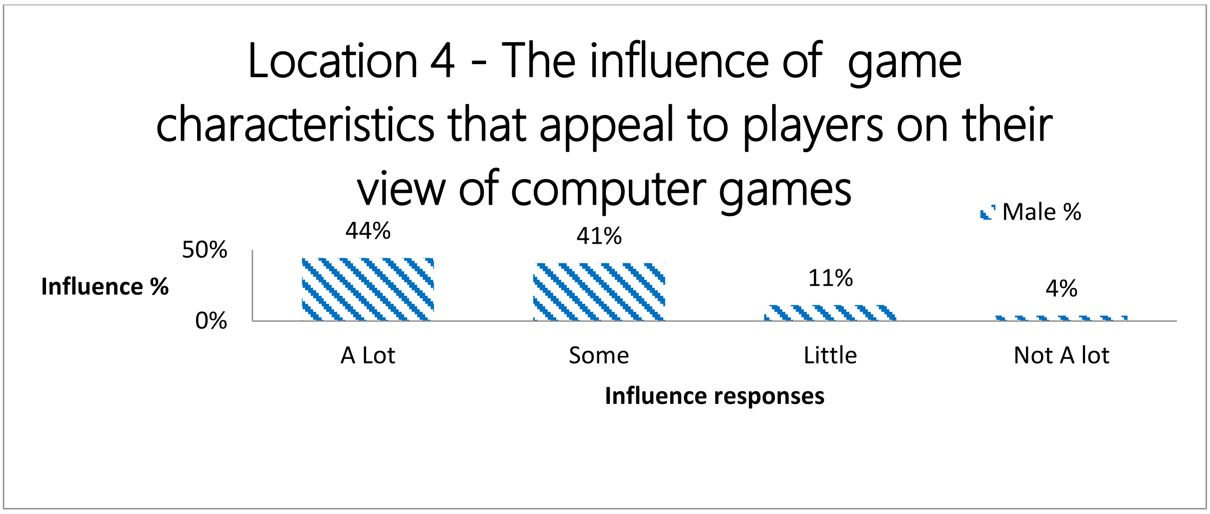


Figure 7.28. Location 4-The influence of game characteristics that appeal to players on their view of computer games

7.5.7 The regularity of educational computer gameplay

The result of the data analysis from this location indicated that participating boys do not play educational games as regularly as entertainment games. Most participants play weekly (15%) and every two weeks (15%). Only 7% of the sampled population play daily. However, more participants (37%) never play educational computer games. The analysis of the data is presented in figure 7.29.

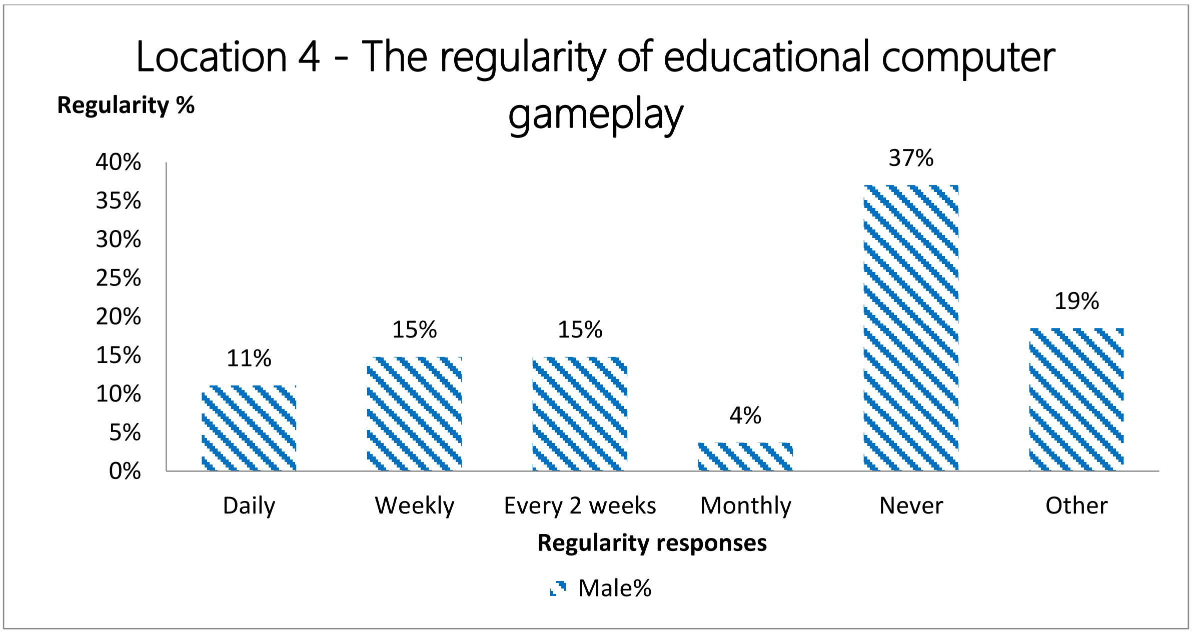


Figure 7.29. Location 4 – The regularity of educational computer gameplay

7.5.8 The appeal of educational computer games

From figure 7.30, cumulatively, most participants do not find computer educational games appealing in comparison to how much they find them unappealing. The most probable reason is the fun associated with games by boys and not as a learning tool. Also, 7% of the participating population find educational computer games very much appealing as compared to 22% that finds then very much unappealing.

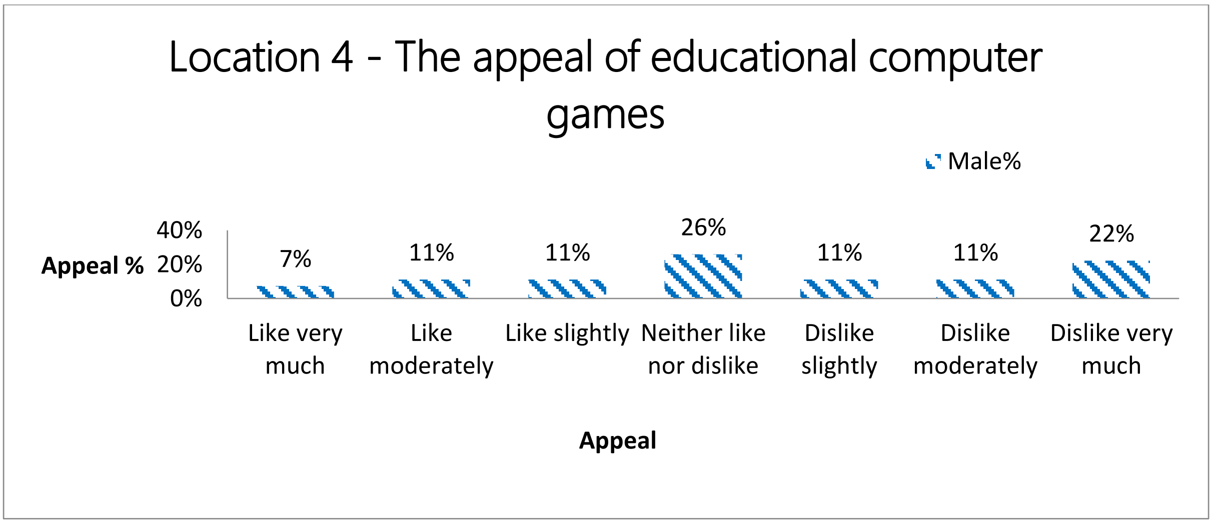


Figure 7.30. Location 4 -The appeal of educational computer games

7.5.9 Preference for educational computer games with characteristics that appeal to players

The result of the analysis of the data collected for this question indicated that participating boys prefer to play educational games with game characteristics that appeal to them. It appeared that 56% would prefer to play games that have the characteristics that appeal to them as compared to 15% that do not prefer games with characteristics that appeal to them. Furthermore, 30% indicated that there are no preferences at all. The illustration of the analysis is shown in figure 7.31.

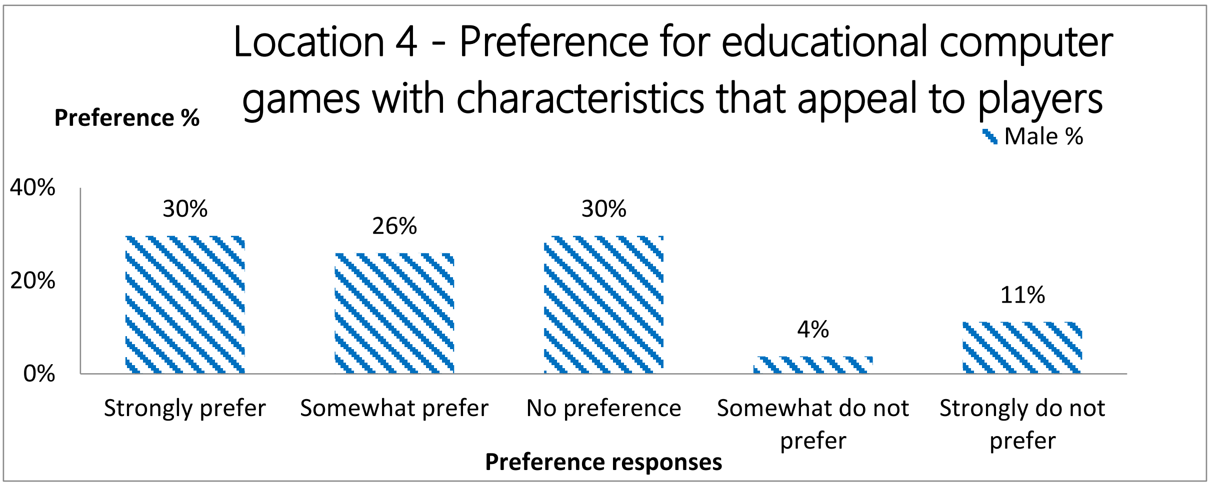


Figure 7.31. Preference for educational computer games with characteristics that appeal to players

7.5.10 The influence of game characteristics that appeal to players on their view of educational computer games

From this location, participants would be influenced rather than not being influenced by game characteristics that appeal to them in educational computer games. It was indicated that 67% would be influenced by the game characteristics that appeal to them in educational games as compared to 15% that would not be influenced. A reasonable group of participants are not certain of the influence of game characteristics that appeal to them in educational computer games. The illustration of the analysis is shown in figure 7.32.

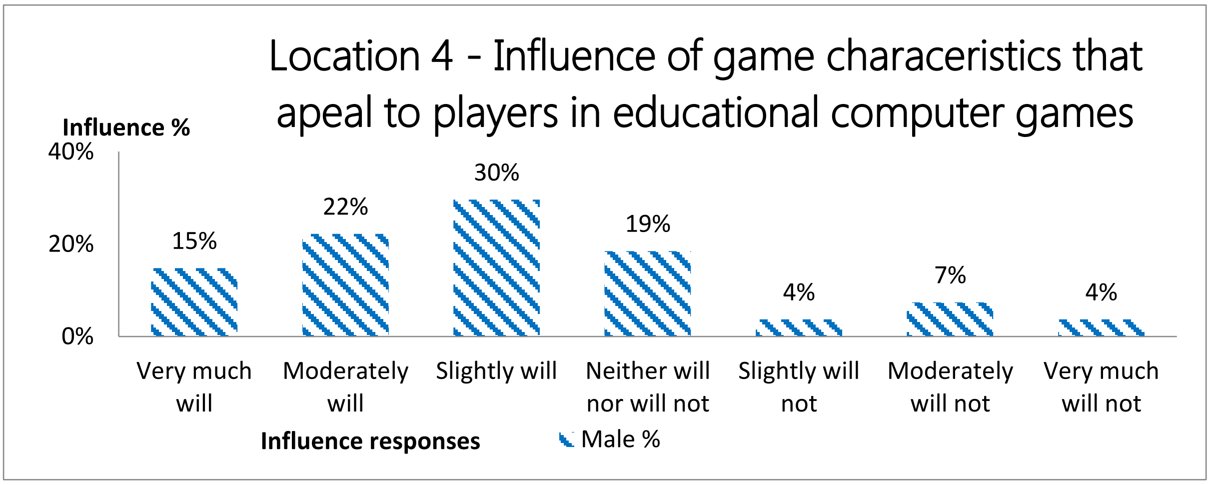


Figure 7.32. Location 4 - The influence of game characteristics that appeal to players in educational games

7.5.11 Conclusion of the results of Location 4

The result of this all boys location suggested that more boys play computer games daily as compared to those that play weekly, fortnightly and monthly. Most of the boys found computer games appealing and game audio i.e. sound effects and background sound were among the top game characteristics for this group. The boys in this location also indicated that they would play computer games more regularly if they included characteristics that appeal to them. Also, their view of computer games would be influenced if the games included characteristics that appeal to them.

In addition, most of the boys play educational computer games more on a weekly and fortnightly basis than monthly and daily basis. Most of the boys dislike educational computer games and would play more regularly if they included game characteristics that appeal to them. It was also indicated from this location that including game characteristics that appeal to the boys in educational computer games would influence their views of these games.

In relation to the research question, the result from this location also indicated that the boys prefer computer games to educational computer games and including game characteristics that appeal to them would influence their views of educational computer games. Hence, they would play educational computer games more regularly.

7.6 Location 5- Qualitative analysis of pre-study data

7.6.1 Age distribution

This location is also a boys only selective secondary school. The total number of participants was 28.

7.6.2 The regularity of computer gameplay

For this location, 46% of the participants play computer games daily and 36% weekly. Cumulatively, 96% of the participants play daily, weekly every 2 weeks or monthly. Only 4% of the participating population never play computer games. The data analysis is illustrated in figure 7.33.

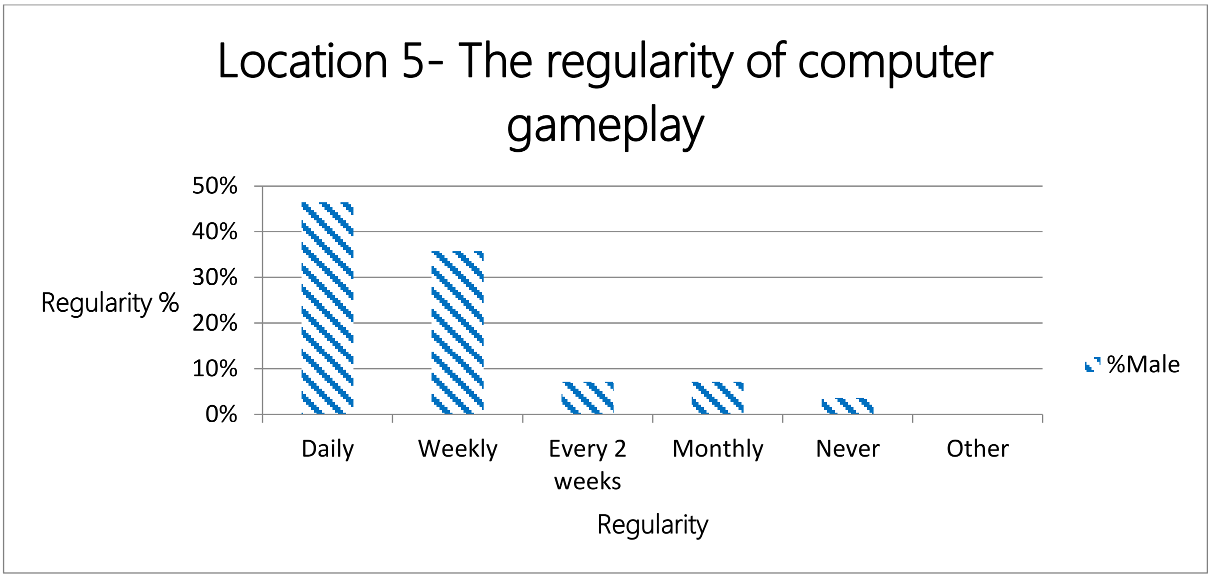


Figure 7.33. Location 5-The regularity of computer gameplay

7.6.3 The appeal of computer games

For this location, 97% of the participating boys indicated that computer games are appealing. There were no indications that they find computer games unappealing (0%). It was also indicated by 4% of the population that they were not sure if they found computer games appealing or unappealing. The analysis is illustrated in figure 7.34.

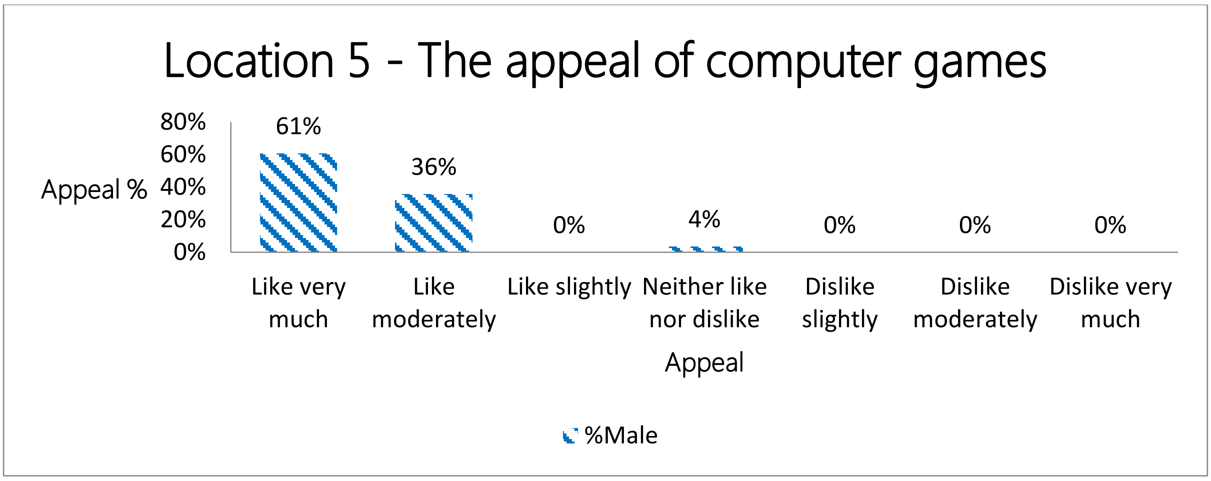


Figure 7.34. Location 5 – The appeal of computer games

7.6.4 Ranking the top 10 game characteristics

Table 7.5 illustrates the data analysis of the top 10 ranking game characteristics from location 5. The top game characteristics were action, challenge, good use of available space, single player games and gameplay levels.

Game characteristic ranking	Game characteristics
1	- Action - Challenge - Good use of available space
4	- Single player game - Gameplay levels
6	- Ability to choose characters - Reward
8	- Multiplayer game
9	- Competition - Adventure

Table 7.5. Location 5 ranking of top 10 game characteristics

7.6.5 The regularity of play of computer games with characteristics that appeal to players

From location 5, 100% of participants would play computer games regularly if they included game characteristics that appeal to them. From the data analysis, 46% would play these games very frequently, 39% quite frequently and 14% moderately frequently if they included game characteristics that appeal to them. The analysed data is illustrated in figure 7.35.

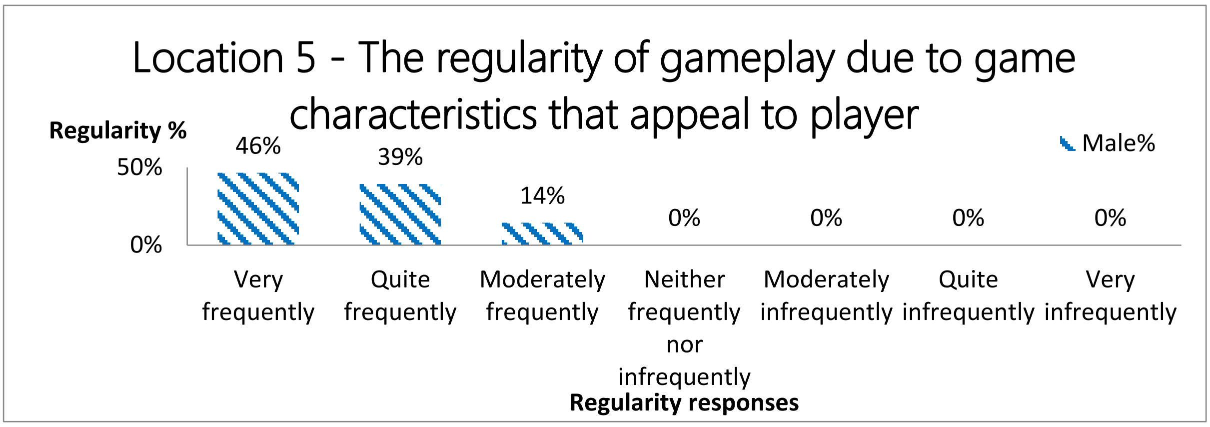


Figure 7.35. The regularity of gameplay due to game characteristics that appeal to player

7.6.6 The influence of game characteristics that appeal to players on their view of computer games

From the analysis of the data as shown in figure 7.36, including game characteristics that appeal to participants in this location would influence their views of computer games. The analysed data indicated that 46% would be influenced a lot, 39% to some extent and 11% a little. No participant indicated that they would not be influenced by game characteristics that appeal to them.

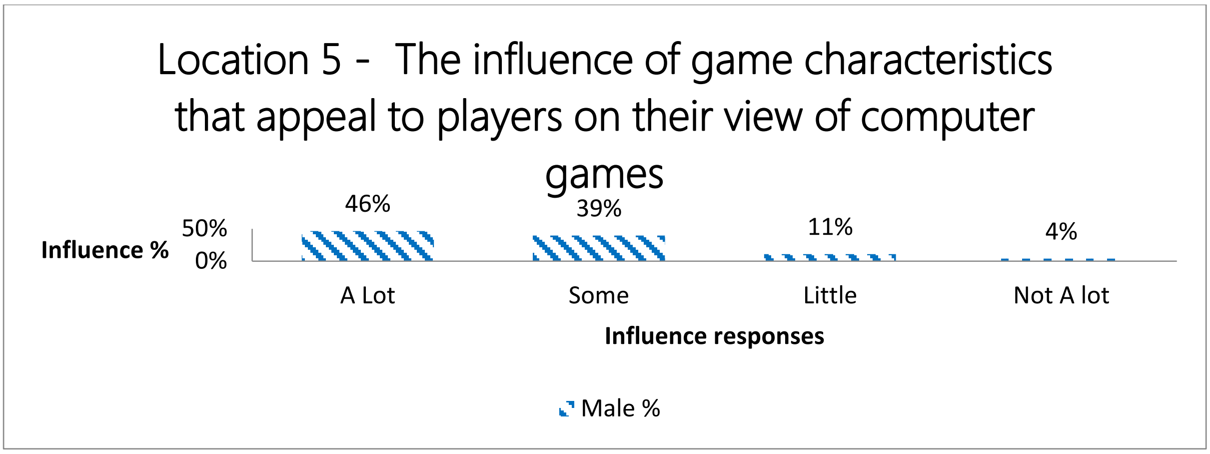


Figure 7.36. The influence of game characteristics that appeal to players on their view of computer games

7.6.7 The regularity of educational computer gameplay

Figure 7.37 illustrates the data analysis for the regularity of educational computer gameplay for this location. Most participants play educational computer games weekly, every two weeks and monthly with the least number of participants playing educational computer games daily. Also, 11% of participants never play educational computer games.

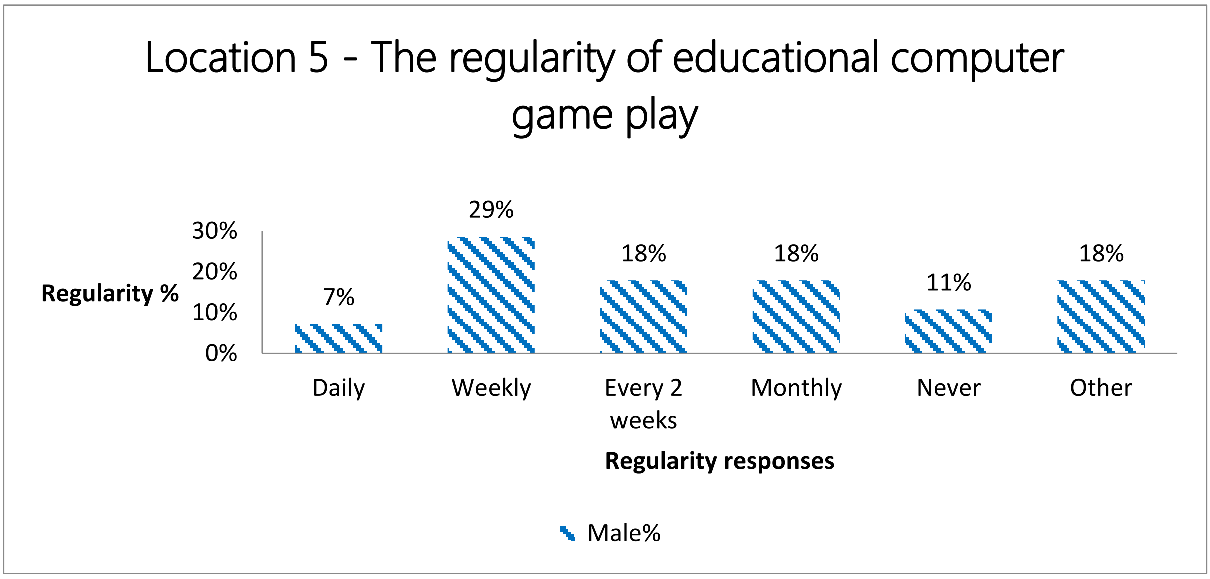


Figure 7.37. The regularity of educational computer gameplay

7.6.8 The appeal of educational computer games

For this location, 32% of participants were uncertain of the appeal of educational computer games. Only 7% indicated that they very much found educational computer games very much appealing. Cumulatively, 57% find educational computer games appealing to some extent. The analysis is illustrated in figure 7.38.

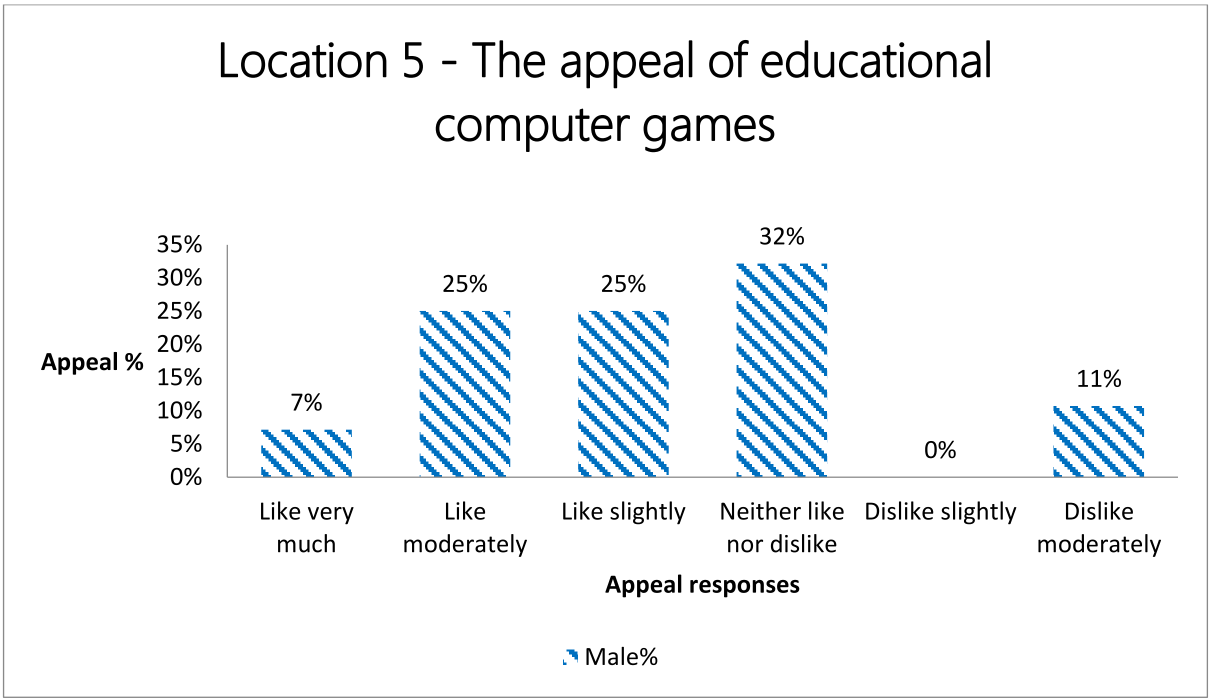


Figure 7.38. The appeal of educational computer games

7.6.9 The preference for educational computer games with characteristics that appeal to players

Similar to location 4, participants from this location would prefer educational computer games with characteristics that appeal to them. In total, 89% would prefer these games if they included characteristics that appeal to them as compared to 11% of participants that have no preference at all. This analysis is illustrated in figure 7.39.

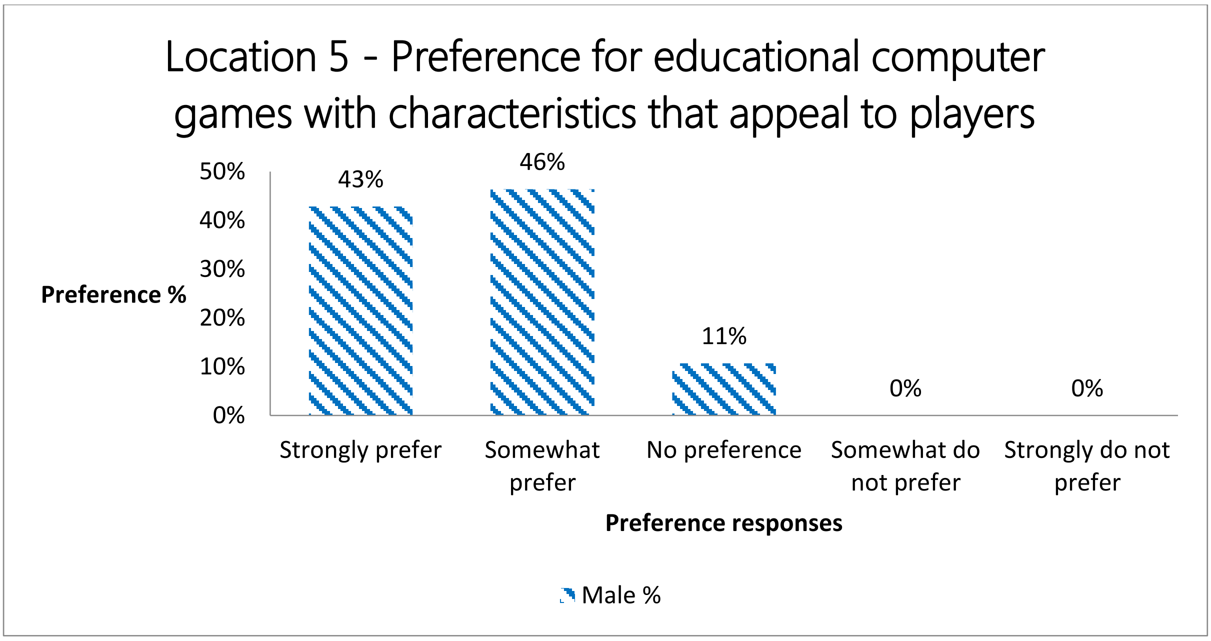


Figure 7.39. The preference for educational computer games with characteristics that appeal to players

7.6.10 The influence of game characteristics that appeal to players on their view of educational computer games

The analysis of data for this question indicated that the participants' views of educational computer games would be influenced if they included game characteristics that appeal to them. The data analysis is illustrated in figure 7.40.

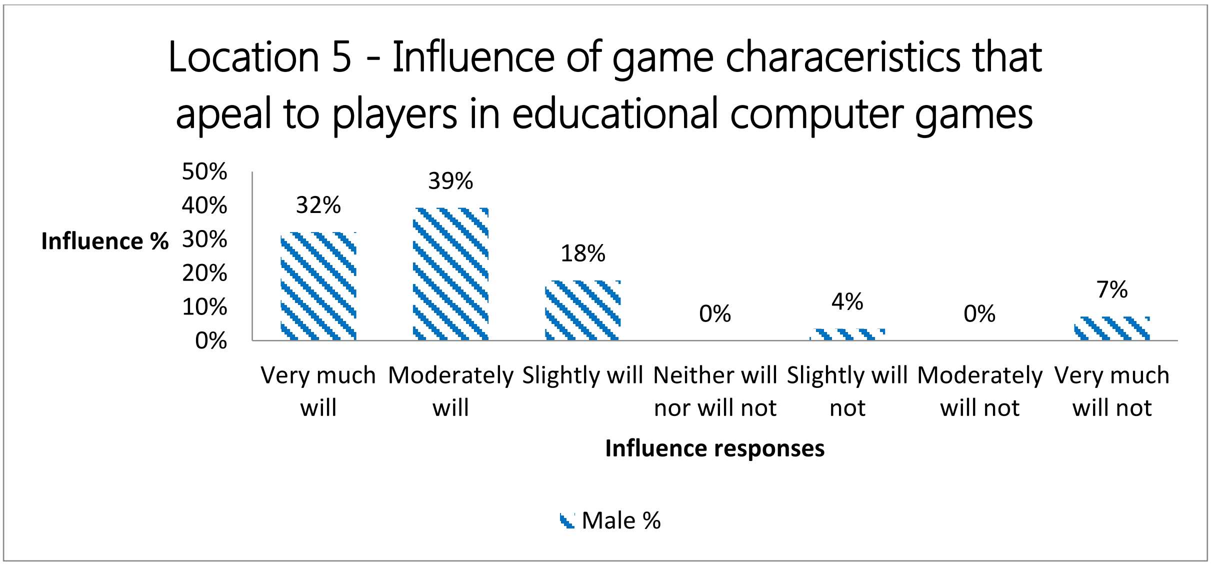


Figure 7.40. Location 5 -The Influence of game characteristics that appeal to players on their views of educational computer games

7.6.11 Conclusion of the results of Location 5

The result of this all boy location also suggested that more boys play computer games daily as compared to those that play on a weekly, fortnightly and monthly basis. Most of the boys also found computer games appealing and game action scenes, game challenge and good use of available space were among the top game characteristics for this location. The boys in this location also indicated that they would play computer games more regularly if they included characteristics that appeal to them.

Most of the boys play educational computer games more on a weekly basis than daily, fortnightly and monthly basis. More boys from this location like educational computer games than those that dislike them. Finally, in relation to the research question, the boys from this location would prefer educational computer games that include game characteristics that appeal to them.

7.7 Discussion and summary of pre-study questionnaire

The results from the 5 locations are reviewed collectively to understand the findings from this phase of the experiment and how it addresses the research question.

In the mixed gender schools, it is apparent that boys play computer games on a more regular basis i.e. daily as compared to the females that play more on a weekly, fortnightly and monthly basis. The picture from the single gender schools indicated that both genders play more daily in all three locations. Overall, the girls play computer games more on a weekly, fortnightly and monthly basis than the boys. In contrast, more boys play computer games on a daily basis as compared to the girls. This finding is supported by similar studies on the differences between girls' and boys' computer games play habits (Fromme, 2003; Lenhart et al., 2008; Desai et al., 2010).

On the appeal of computer games, the boys indicated that they find computer games very much appealing more than the girls. The appeal for computer games appears to be more with girls in the single gender school than the mixed schools. The finding of differences in the appeal of computer games between girls and boys is supported by related studies (Yee, 2009; Rideout et al., 2010; Homer et al., 2012; ESA, 2012).

The top ten ranking game characteristics presented some differences in the positions of the significant game characteristics to participating girls and boys. However, the composition of the significant game characteristics was similar for most of the locations. Game interactivity, reward, multiplayer, action, challenge and gameplay levels repeatedly occurred in the top three for most locations.

On the frequency of gameplay due to characteristics that appeal to players, both young female and male populations would play frequently if the computer games included characteristic that appeal to them. In the single gender schools, girls and boys would play very frequently if the games included characteristics that appeal to them.

Furthermore, girls and boys from the surveyed locations indicated that including game characteristics that appeal to them would significantly influence their views of computer games.

In relation to the play of educational computer games, fewer boys play daily as compared to entertainment games. However, there is evidence from the analysis that more boys play educational computer games daily, weekly and monthly than the girls. Furthermore, a comparative analysis of the data indicated that more girls will never play educational computer games as compared to boys. The appeal of educational computer games to both girls' and boys' population from the locations was significantly low. This evidence suggests that there is scope for improving on the appeal of educational computer games to both girls and boys of this age group. The analysis of the data collected from the locations also indicated that more girls would prefer educational computer games with characteristics that appeal to them as compared to the boys. Finally, the view of educational computer games would be influenced for both genders comparative to not being influenced.

From the pre-study analysis of data from all five locations, there are indications that the variants of the significant game characteristics contribute to the appeal of digital games. However, these game characteristics and their variants could be similar or different between girls and boys of age 11-14 year old.

The pre-study analysis confirms the findings of the exploratory study, which suggested that there are differences and similarities between the variants of game characteristics that are significant and appeal to the target audience. The result of the pre-study analysis further provided the evidence in response to the research question, such that, the variants of significant game characteristics can make some digital entertainment games more appealing to 11-14 year old girls. Furthermore, it also suggested that including these variants in digital educational games would also influence the regularity of gameplay and the perception of digital educational games of girls of age 11-14 years old.

On the completion of the pre-study data analysis, the post-study data analysis was completed to identify the impact of the educational computer games created based on the findings of the exploratory study.

7.8 Comparative analysis of post-study data

The initial post-study analysis reviewed the responses of participants by location after engaging with both games. The comparative data analysis, which followed thereafter, provided an insight into the impact of the customised games on participating girls and boys from each location.

The empirical evidence from the data analysis should indicate the influence of each experimental game i.e. *The Lost Astronaut* and *The Lost Hippo* on girls of age 11-14 years old.

As mentioned in sections 7.0 and 7.1, the analysis of the post-study data would include both qualitative and quantitative analysis. The qualitative analysis would be used to identify the trends, which are represented graphically. In addition, the quantitative analysis would include the use of statistical test to confirm the statistical significance of the qualitative trends. A test for the distribution of data i.e. parametric (evenly distributed) and non-parametric distribution (unevenly distributed) was initially conducted. This test would determine the type of statistical tests that would be applied for the quantitative analysis of data. An indication that the data is evenly distributed would suggest that parametric tests i.e. the T-test and one-way analysis of variance (ANOVA) test should be applied.

Alternatively, a non-parametric measure indicates that the distribution is not normally distributed and the Wilcoxon, Friedman, Mann-Whitney U, Kruskal-Wallis and Spearman tests are applied.

A normality of distribution test conducted indicated the data was found to be non-parametric. Consequently, a number of non-parametric test were conducted at different stages to confirm the significance of the qualitative findings.

- Friedman test–This test is used to measure the effect of independent variables on dependent variables. This statistical test similar to the analysis of variance (ANOVA) for parametric measures is used to rank the variance of repeated measure for three or more related samples (Cohen et al., 2007). The application of this test should rank the independent variables such that the game characteristics are in order of statistical significance;
- The Kruskal-Wallis test–This test is similar to the Friedman test but used with measures for three or more independent samples (Cohen et al., 2007). The application of this test should indicate a comparative statistical significance of the game characteristics in experimental games 1 & 2 between both genders.
- Mann-Whitney U test–This test measures differences between two independent samples (Cohen et al., 2007). The application of this test should indicate the statistical significance of the difference in the learning effectiveness of the experimental games 1 & 2 between both genders.
- Spearman's rho–This is a correlation coefficient measure for two ordinal variables (Cohen et al., 2007). This statistical test would correlate the statistical significance of results obtained from participating girls and boys populations of the study.

The result from both qualitative and quantitative analysis provided empirical information towards the impact of education computer games that include variants of significant game characteristics to the target audience. The methods of the statistical quantitative analysis were reviewed and confirmed by a statistician for validity.

7.8.1 Comparative analysis of *The Lost Astronaut* and *The Lost Hippo* games

7.8.1.1 The appeal of the "The Lost Astronaut" and "The Lost Hippo"

The appeal of "*The Lost Astronaut"* game to the girls from all 3 locations is illustrated in figure 7.41a. A good percentage of the girls appear to like the game. Cumulatively, most girls like the game *very much*, *moderately* and *slightly*. An analysis by location based on mixed and single gender schools suggested that more girls from the single gender school cumulatively *like very much* and *moderately* in comparison to the girls from the mixed gender schools. This could be associated with the level of confidence the girls demonstrated during the study as the data indicated that they play digital games more on a daily basis than the girls from the mixed gender schools.

A comparative analysis with the boys indicated that most boys dislike this game very much or moderately (see figure 7.41b). Cumulatively, the boys from the mixed gender schools appear to dislike the game more than the boys from the single gender school. 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.

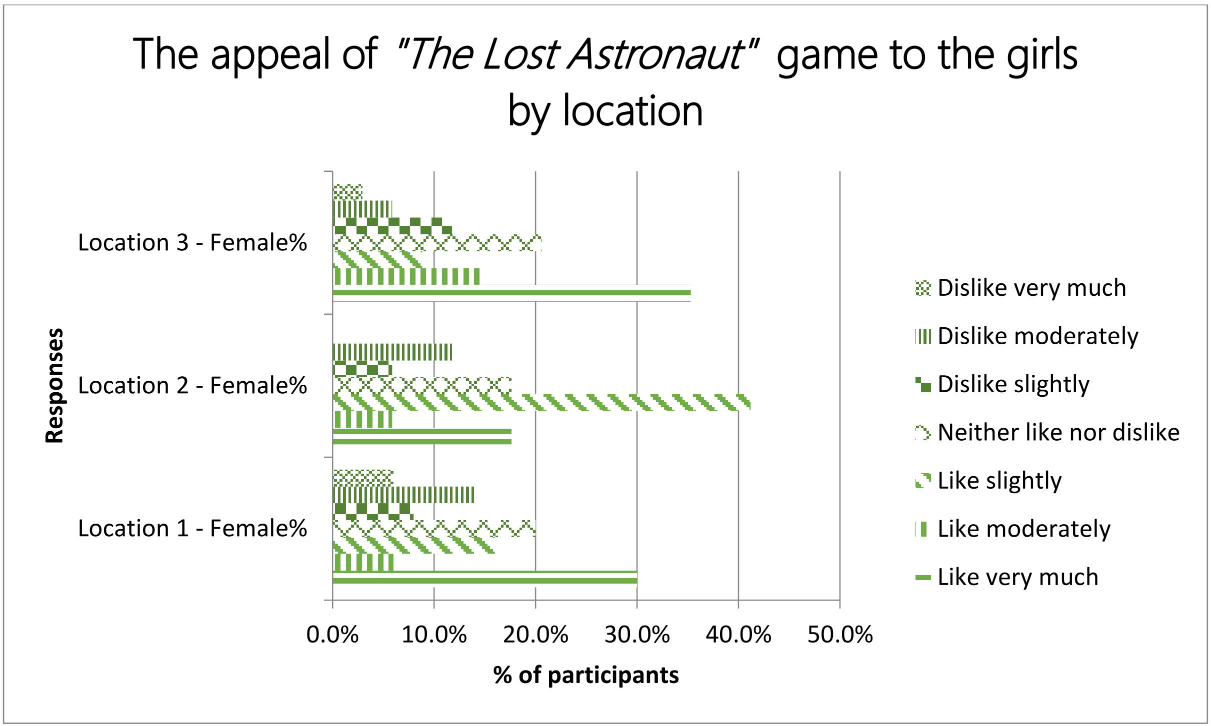


Figure 7.41a. The appeal of The Lost Astronaut game to the girls by location

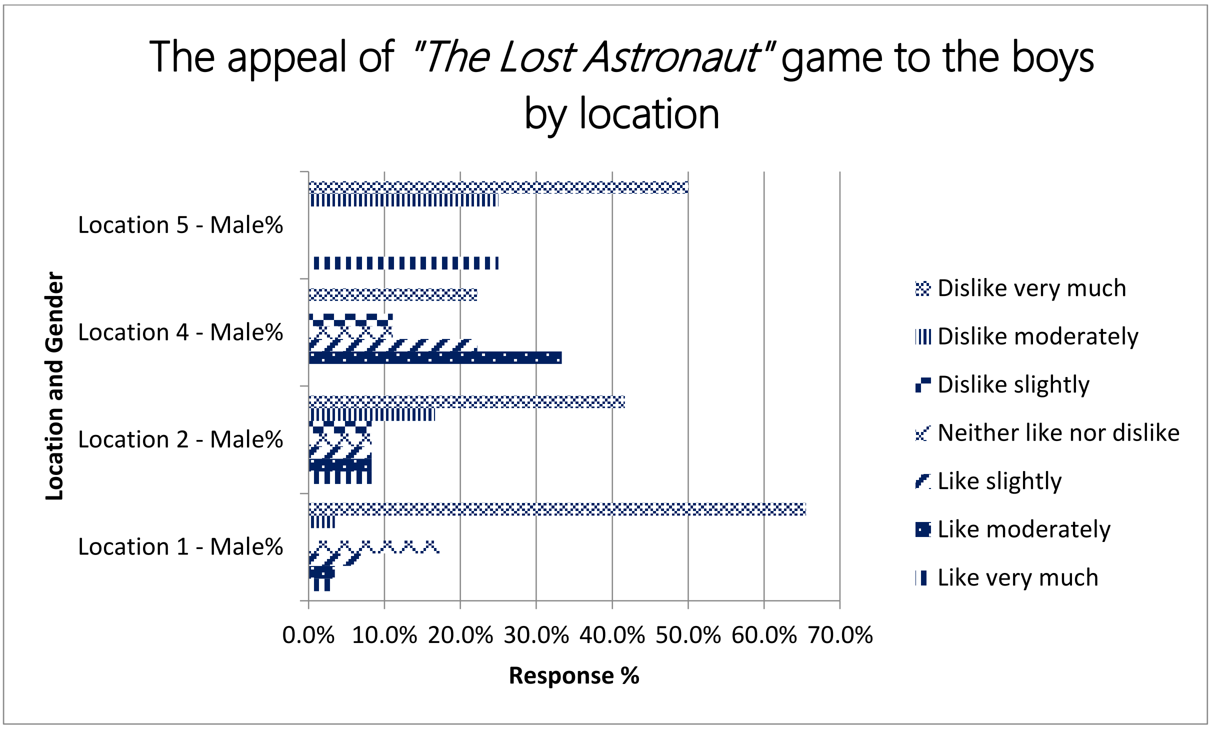


Figure 7.41b. The appeal of The Lost Astronaut game to the boys by location

A similar analysis for *"The Lost Hippo"* game was also conducted by gender for all locations of the study. Figure 7.42a 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 because the cumulative dislike suggested that very few girls found this game appealing. The girls in the single gender school appeared to dislike this game more than the girls from the mixed gender schools.

However, a similar analysis by location for the boys as illustrated in figure 7.42b suggested that cumulatively, *"The Lost Hippo"* game appealed more to the boys than it was disliked. The boys from the single gender schools appeared to like this game more than the boys from the mixed gender schools. 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.

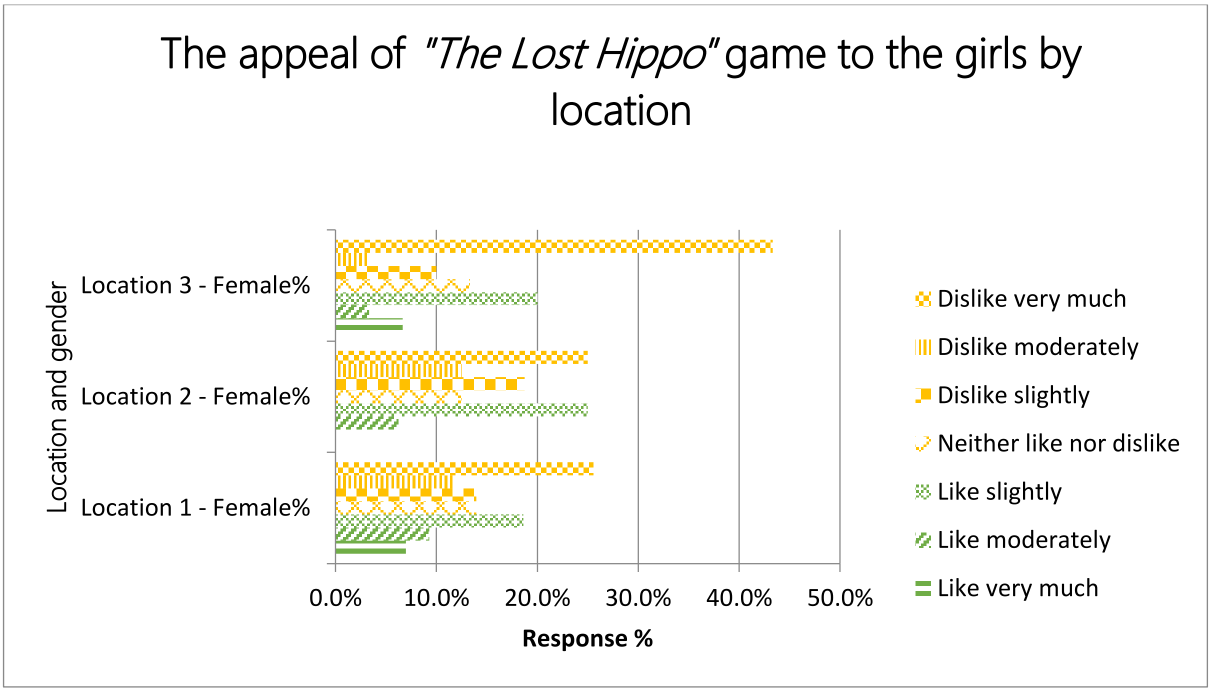


Figure 7.42a. The appeal of The Lost Hippo game to the girls by location

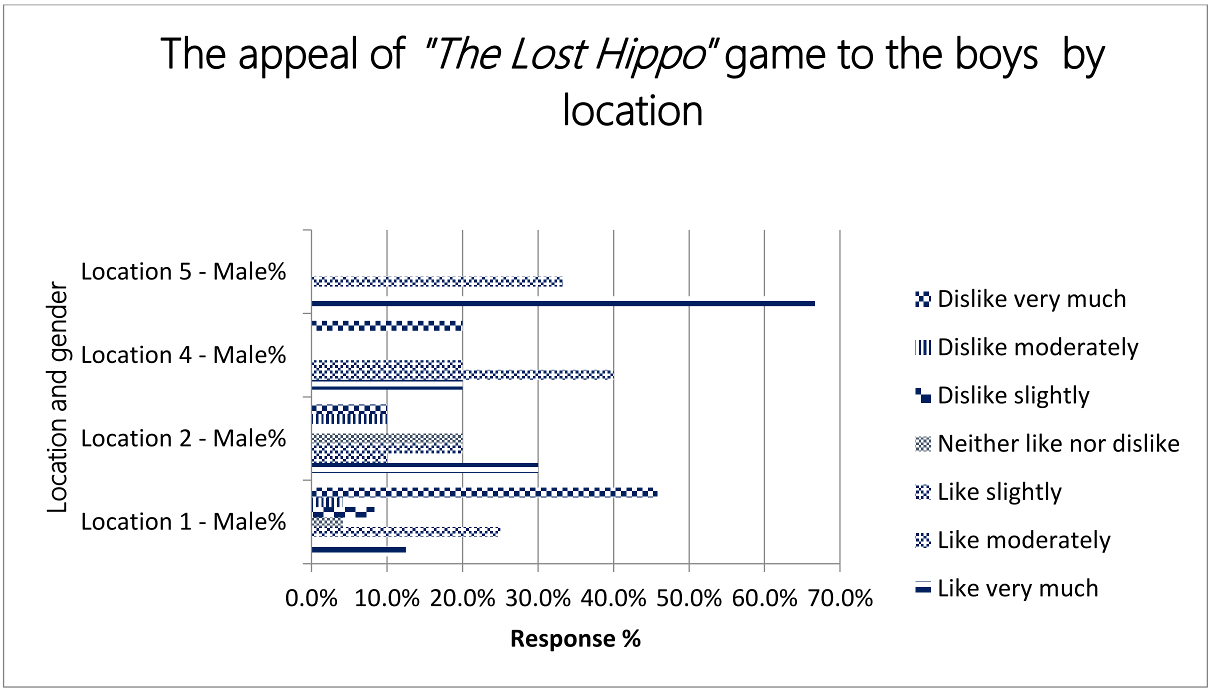


Figure 7.42b. The appeal of The Lost Hippo game to the boys by location

7.8.1.2 Ranking of the appeal of game characteristics used in The Lost Astronaut and The Lost Hippo

The ranking of the appeal of game characteristics was also explored in both games. Table 7.6 illustrates the qualitative ranking of the game characteristics based on the appeal by location and gender. The '*like very much'* point scale was used to review the most appealing game characteristics by participants from all locations.

Across all locations, the most appealing game characteristic for the "*The Lost Astronaut"* was the gameplay levels, which represents individual progression and comparative assessment with peers. The next most appealing game characteristic was the interaction with other players. From our exploratory study, it was indicated that both genders found the inclusion of social interactive characteristics in the gaming environment significantly appealing. However, while the girls prefer to collaborate and share ideas, the boys would rather compete and use the game characteristic for comparative assessment of progression and competence. The colour used for the game character is another game characteristic that was significantly to participating girls and boys. Although the preferred shade of colour has been shown from the body of evidence and the exploratory study to be different, the colours are of significance to participating girls and boys.

The top 3 game characteristics for the girls from this analysis included the game levels, interaction with other players and colours used for characters. For the boys, the top 3 game characteristics also included gameplay levels, colours used for characters, audio effects/background and including violence in the game.

	Location 1		Location 2		Location 3	Location 4	Location 5
Ranking order by appeal (Game characteristic)	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Boys**
1	Gameplay levels	Gameplay levels	Image used	Interaction with other players e.g. chat room, forum	Gameplay levels	Age appropriateness Gameplay levels	Gameplay levels
2	Interaction with other players e.g. chat room, forum	Fun to play Feedback on how to improve	Gameplay levels Colour used for characters Interaction with other players e.g. chat room, forum	Including violent scenes	Audio-effect/background	Colour used for character	Colour used for character Including violent scenes
3	Colour used for character	Audio-effect/background Definite storyline Colour used for character Age appropriateness		Definite storyline	Interaction with other players e.g. chat room, forum Colour used for character	Images used	

Table 7.6. Ranking of game characteristics by appeal in The Lost Astronaut game

The qualitative ranking of the game characteristics (present and not present) based on the appeal of *The Lost Hippo* is illustrated in table 7.7. In location 1, for the girls, interaction with other players using chat rooms etc. was indicated as the most preferred game characteristic. In location 2, the top ranking game characteristics were the age suitability of the game, colours used in the gaming environment, feedback on how to improve and the appeal of the characters. In location 3, the game audio (effect/background) was the top ranking game characteristics. Other top ranking characteristics for the girls across the locations were the images used, game levels and the fun associated with the game.

The participating boys in location 1 indicated that the game levels and images used were appealing game characteristics. In location 2, including violence and first person shooter type of gaming environment was indicated as a top ranking characteristic. Other top ranking characteristics for this location included images used and feedback on how to improve. In location 4 and 5, the game levels were identified as the top ranking game characteristics. The other variants of the game characteristics that were appealing were audio effect, colours for characters, violence and fun. From all 5 locations, the game level, images used and including violent scenes were identified as the top ranking game characteristics for the boys.

	Location 1		Location 2		Location 3	Location 4	Location 5
Game characteristic ranking order	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Boys**
1	Interaction with other players e.g. chat room, forum	Gameplay levels	Age appropriateness Colours used for character Feedback on how to improve Appeal of major character	Including violent scenes	Audio- effect/ background	Gameplay levels	Gameplay levels
2	Age appropriateness Gameplay levels Audio- effect/background Fun to play	Images used	Audio- effect/background	Use of images Feedback on how to improve	Gameplay levels Images used	Audio- effect/ background	Including violent scenes
3	Definite storyline Appeal of major character Choose colour of character	Fun to play Age appropriateness Colour used for character Appeal of major character	Gameplay levels Fun to play		Fun to play Appeal of major character Age appropriateness	Colour used for character	Fun to play

Table 7.7. Ranking of game characteristics by appeal in The Lost Hippo game

A review of the variants of the game characteristics as used in both games from each location by gender indicated that there are differences and similarities in their appeal as shown in table 7.6 and 7.7. A statistical analysis was conducted to rank the game characteristics from both games by gender. The data collected on the appeal of the game characteristics were based on a 7-point Likert-scale; hence a non-parametric analysis of data which would statistically rank the independent variables for each game was conducted using the Friedman Test. This test is suitable for this analysis as the independent variables were ordinal data.

The illustration of the Friedman mean rank for both games by gender from five different locations is shown in table 7.8. The statistical ranking indicated the most significant and least significant game characteristics as used e.g. gameplay level or not used e.g. violence in the game.

From the ranking of the game characteristics for *The Lost Astronaut,* game level, game interactivity, the colour used for the character and images used were the top four characteristics for the participating girl's population. The least on the ranking for the female sample population were violence (absent), age appropriateness, storyline and feedback on how to improve. For the boys, gameplay level, fun, the colour used for character and age appropriateness were the top four game characteristics. Comparatively for the boys sample population, the least ranked game characteristics were violence (absent), audio, storyline and feedback on how to improve.

Female Ranks for game characteristics as used in "*The Lost Astronaut*"

Game characteristics	Mean Rank	Statistical ranking
Interactivity	8.42	2
Fun	6.74	6
Violence	4.33	12
Audio	6.09	9
Storyline	5.79	11
Use_of_images	7.12	4
Appeal_of_major_Character	6.52	7
Feedback	6.21	8
Choose_character_colour	7.06	5
Gameplay_level	8.99	1
Character_colour	7.79	3
Age_approriateness	5.94	10

Female Test Statistics for "*The Lost Astronaut*"

N	101
Chi-Square	167.963
df	11
Asymp. Sig.	.000

Male Ranks for game characteristics as used in "*The Lost Astronaut*"

	Mean Rank	Statistical ranking
Interactivity	6.31	7
Fun	7.39	2
Violence	5.44	12
Audio	5.55	11
Storyline	5.73	10
Use_of_images	6.76	5
Appeal_of_major_character	6.15	8
Feedback	5.99	9
Choose_character_colour	6.46	6
Gameplay_level	7.76	1
Character_colour	7.31	3
Age_appropraiteness	7.15	4

Male Test Statistics for "*The Lost Astronaut*"

N	55
Chi-Square	47.715
df	11
Asymp. Sig.	.000

Table 7.8. Game characteristics mean ranks and test statistics by gender for The Lost Astronaut

The game characteristic ranking by gender for *The Lost Hippo* is shown in table 7.9. The top ranking game characteristics for the girls were the gameplay level, audio, age appropriateness and ability to choose character colour.

The least ranked characteristics were the storyline (absent), violence, interactivity (absent) and images used. For the boys, the top ranking game characteristics were the gameplay level, character colour, use of images and the appeal of the major character. The least ranked characteristics were the storyline (absent) violence (mild), interactivity (absent) and use of images.

Female Ranks for game characteristics as used in "*The Lost Hippo*"

	Mean Rank	Statistical ranking
Interactivity	5.82	10
Fun	6.34	6
Violence	5.78	11
Audio	7.20	2
Storyline	5.56	12
Use_of_images	5.99	9
Appeal_of_major_Character	6.11	8
Feedback	6.77	5
Choose_character_colour	6.99	4
Gameplay_level	8.19	1
Character_colour	6.14	7
Age_appropriateness	7.10	3

Female Test Statistics for *"The Lost Hippo"*

N	88
Chi-Square	68.875
df	11
Asymp. Sig.	.000

Male Ranks for game characteristics as used in
"The Lost Hippo"

	Mean Rank	Statistical ranking
Interactivity	6.10	10
Fun	6.55	5
Violence	5.40	11
Audio	6.17	8
Storyline	5.26	12
Use_of_images	6.82	3
Appeal_of_major_Character	6.56	4
Feedback	6.31	7
Choose_character_colour	6.48	6
Gameplay_level	8.36	1
Character_colour	7.83	2
Age_appropriateness	6.17	8

Male Test Statistics for
"The Lost Hippo"

N	42
Chi-Square	56.737
df	11
Asymp. Sig.	.000

Table 7.9. Game characteristics mean ranks and test statistics by gender for The Lost Hippo.

A review of this analysis in relation to the first investigative statement: ***Are there digital game characteristics that are significant to girls of age 11-14 in educational games?***

The qualitative and quantitative analyses indicated that there game characteristics that are significant to girls and boys from both games. Although some of the characteristics were present or absent in the games, it was clear from the data analysis that they are significant to the participants. From the analysis, the game characteristics: gameplay level, colours used for the character, images used, interactivity and violence were significant to the target audience.

A statistical significance test of the ranking of the game characteristics was conducted. The null hypothesis *(H_0)* was that there are no significant game characteristics to this target audience if $p >= 0.05$. For both games characteristics ranking by gender, $p = 0.000$, hence the alternative hypothesis *(H_1)* was accepted. The finding from the post- study evaluation is consistent the findings from the pilot study (Osunde et al., 2015).

The second investigative statement was also reviewed: ***Are there differences and similarities in game characteristics that are significant to girls and boys of age 11-14 in educational games?***

The analysis of variance for independent groups from five locations, which comprised of female and male sample populations, was conducted on both games. The statistical analysis was implemented using the Kruskal Wallis test which is most suited for non-parametric data for independent groups as illustrated in table 7.10.

The result indicated that there are differences in game characteristics that are significant to participating girls and boys population as H_0 was rejected for some game characteristics such as interactivity, fun, storyline, the appeal of the major character, character colour etc. in *The Lost Astronaut* game. The null hypothesis (H_0) was accepted for game characteristics such as game audio, game level and suitability. The analysis of the result indicated that there are differences in the variants of game characteristics such as game interactivity, fun, storyline, the appeal of the major character and character colour. However, there are similarities in the variants of gameplay level and age appropriateness of the game. A similar result was noted for *The Lost Hippo.*

Test Statistics[a,b] for combined female and male game characteristics for "*The Lost Astronaut*"

	Interactivity	Fun	Violence	Audio	Storyline	Use_of_images	Appeal_of_major_character	Feedback	Choose_character_colour	Gameplay_level	Character_colour	Age_appropriateness
Chi-Square	29.638	9.752	1.306	4.033	26.154	16.655	26.259	32.007	34.016	.111	8.278	.051
df	1	1	1	1	1	1	1	1	1	1	1	1
Asymp. Sig.	.000	.002	.253	.045	.000	.000	.000	.000	.000	.739	.004	.821

Test Statistics[a,b] for combined female and male game characteristics for *"The Lost Hippo"*

	Interactivity	Fun	Violence	Audio	Storyline	Use_of_images	Appeal_of_major_character	Feedback	Choose_character_colour	Gameplay_level	Character_colour	Age_appropriateness
Chi-Square	.611	22.991	5.913	4.752	2.020	23.675	6.434	2.026	5.208	.113	11.991	1.673
df	1	1	1	1	1	1	1	1	1	1	1	1
Asymp. Sig.	.435	.000	.015	.029	.155	.000	.011	.155	.022	.737	.001	.196

Table 7.10. Comparative game characteristics by gender and game

The third investigative statement was also comparatively reviewed using the empirical evidence: ***Are there variants of the game characteristics that can make digital educational games appealing to girl of age 11-14?***

From the statistical analysis in table 7.8 and 7.9, the ranking of the game characteristics as used in the games are presented. Where the variant of a game characteristic is used, the mean rank indicated its appeal to the participating population. For both games, the mean ranks indicated that there are differences in the appeal of the variants of the game characteristics. The statistical significance showed that $p=0.000$ hence H_1 was accepted for both girls and boys sample populations. This indicated that there are variants of the game characteristics that can make digital educational games appealing to girls and boys of age 11-14.

7.8.1.3 Additional game characteristics used/ not used in The Lost Astronaut and The Lost Hippo games

For *The Lost Astronaut* game, the boys indicated that the characteristics which contributed to the appeal of the game were the suitability of the game challenge, the use of a maze for the game and the use of a visual gaming environment. Game characteristics that could be included to improve the appeal of the games were violence, a multiplayer environment, other forms of game reward, faster movements, more gameplay levels, more challenge.

The girls indicated the visual programming environment, use of a game maze model, ability to choose characters and colours, the level of challenge and the appropriateness of the graphics used contributed to the appeal of the game. Game characteristics that could be included to improve the appeal were some element of violence and rewards other than progression in the game.

For *The Lost Hippo* game, there were also a range of suggestions on how to improve the game. Some of the suggested improvements from the girls were the colours used were too dark, the choice of character was not suitable, more game levels, including some interactivity such as chat rooms etc., including a storyline to provide a clear purpose of the game, having a range of characters , role play and improved help instructions.

From the review of the boys' feedback, the following were the suggestions for improvement – improved graphics, keyboard movements should be included, multiplayer game, including a social interactive facility and more violence.

7.8.1.4 Consideration of playing the experimental game or similar game

An analysis of repeat play of the games or similar games indicated different responses based on location and gender. For the locations of mixed gender participants, more girls appear to very much consider playing *The Lost Astronaut* game in comparison to the boys. More girls from the single gender location 3 indicated that they would play *The Lost Astronaut* game again or similar games. For the moderate and slightly consider responses, more girls than boys also indicated these options from the mixed gender locations.

Although for the moderate and slight consideration responses from the single gender location 3, 4 and 5, more males from this locations compared to locations 1 and 2 would play *The Lost Astronaut* game or similar game again. It is important to note that the low number of participating boys in the survey from these locations is a factor for consideration. Cumulatively, 18% of the girls would consider playing the game or similar games as compared to 12% of the boys. The illustration of the responses is presented in figure 7.43.

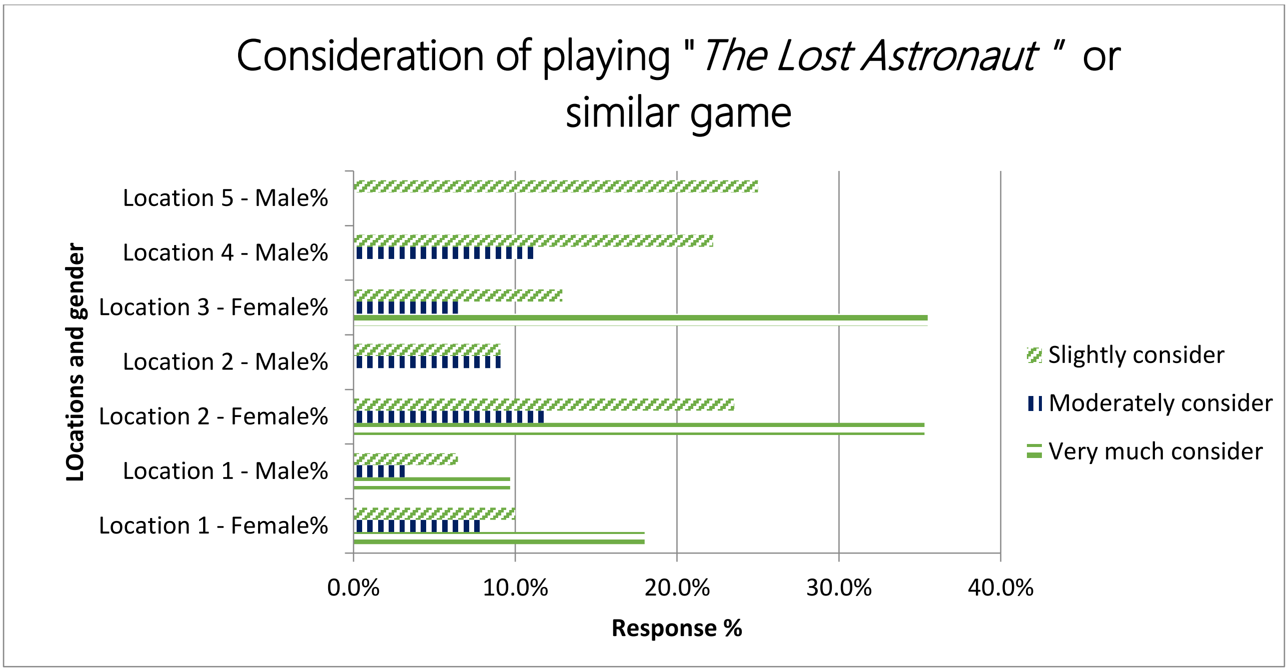


Figure 7.43. Consideration of playing The Lost Astronaut game or similar game.

A similar analysis of the responses to *The Lost Hippo* game is illustrated in figure 7.44. Cumulatively, 8% of girls would consider playing *The Lost Hippo* or similar games as compared to 19.2% of the boys. From the analysis, the boys would consider to playing The *Lost Hippo* game or similar game again as compared to the participating girls.

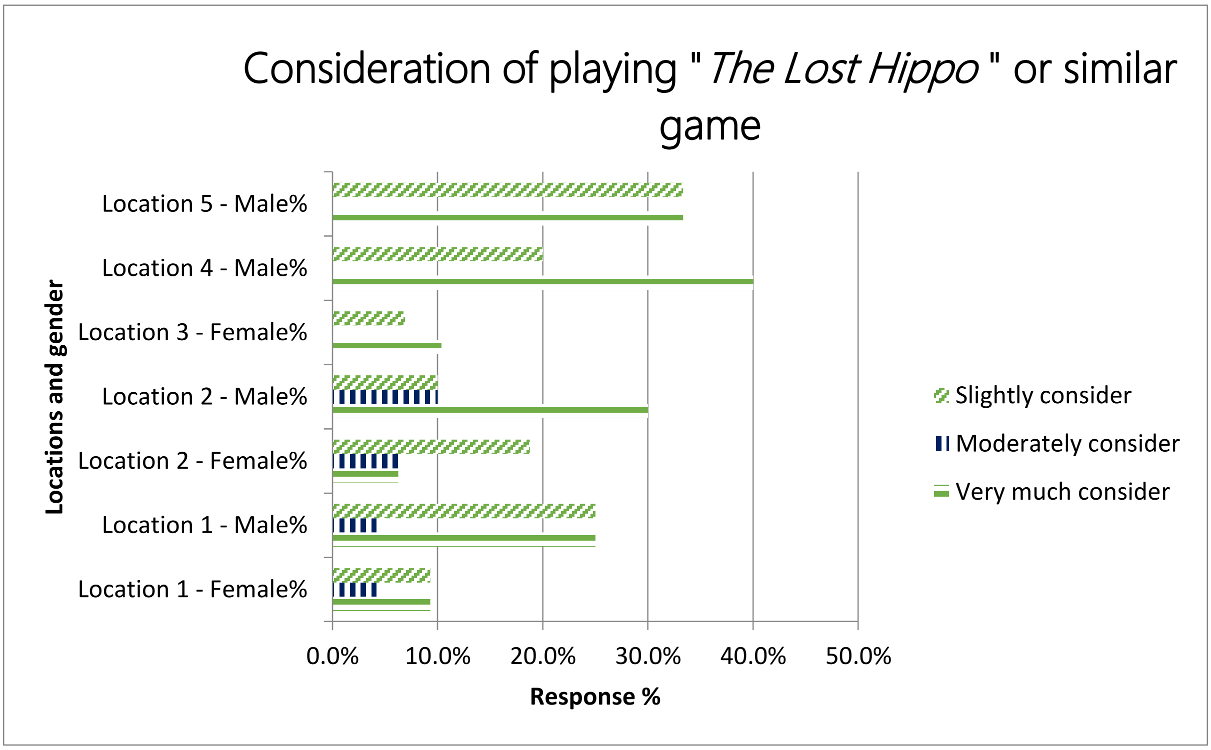


Figure 7.44. Consideration of playing The Lost Hippo game or similar game

7.8.1.5 The perception of the influence on learning from The Lost Astronaut and The Lost Hippo games

The perceived effectiveness of the games as learning tools was evaluated with this question. From the data collected and analysed in figure 7.45, the evidence indicated that *The Lost Astronaut* game was effective as a learning tool. From all locations, both groups of girls and boys gained a lot of insight about basic algorithms from engaging with this game. The participating girls in location 1 and 3 appeared to have learned a lot more than location 2. Location 3 a single gender female school indicated that 58.1% gained a lot, 9.3% some insight of concept and 16.3% a little insight of the concept. Furthermore, the boys in location 5 a single gender selective school appeared to have made gains of about 50% learning a lot and 25% making some gains using the game as a learning tool. Overall, *The Lost Astronaut* game did engage both girls and boys from all locations effectively as a learning tool.

The girls relatively appear to have engaged more using this game. The use of educational computer games for learning has been identified by a number of studies to be effective with all age groups (Kalwe, 1999; Rosas et al., 2003; Ke & Grabowski, 2007; Papastergiou, 2009).

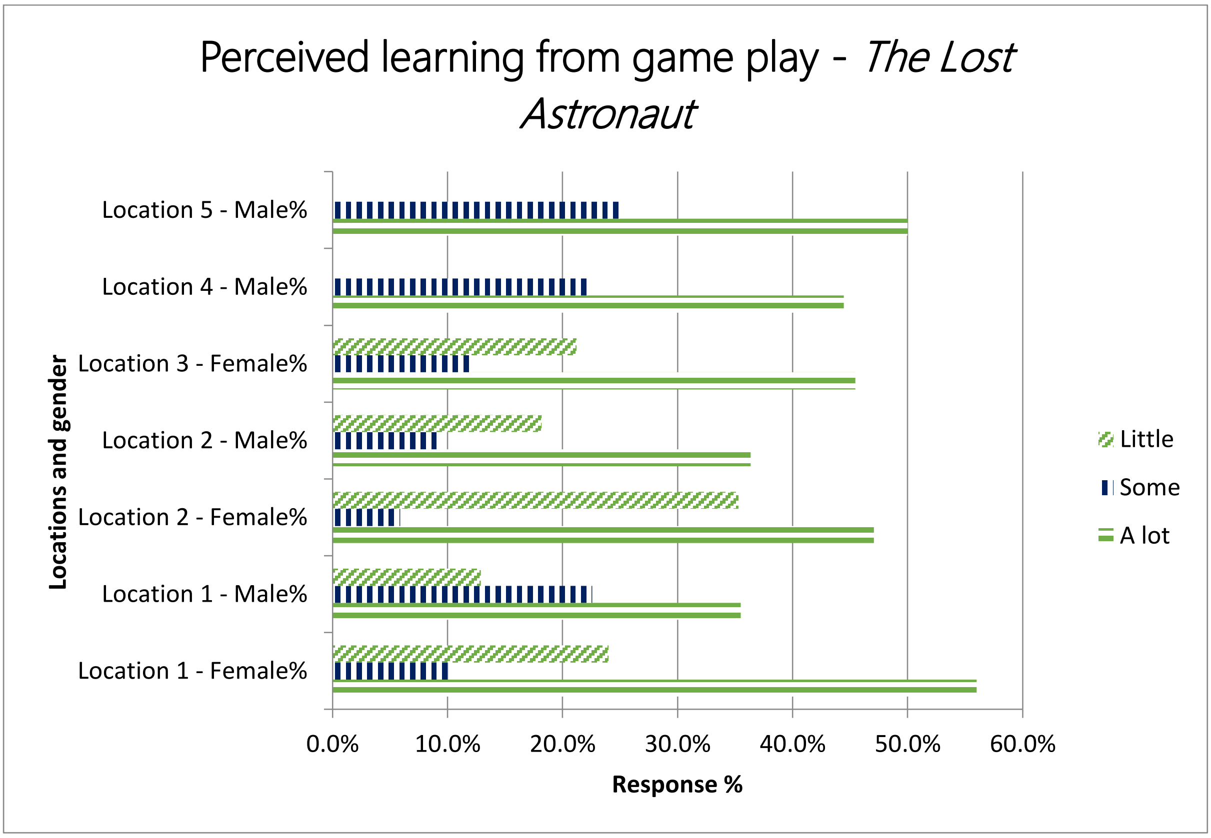


Figure 7.45. Perceived learning from the gameplay of The Lost Astronaut

The perceived learning associated with the gameplay of *The Lost Hippo* is illustrated in figure 7.46. From the responses, it is indicated that the boys appear to learn more from this game than the participating girls.

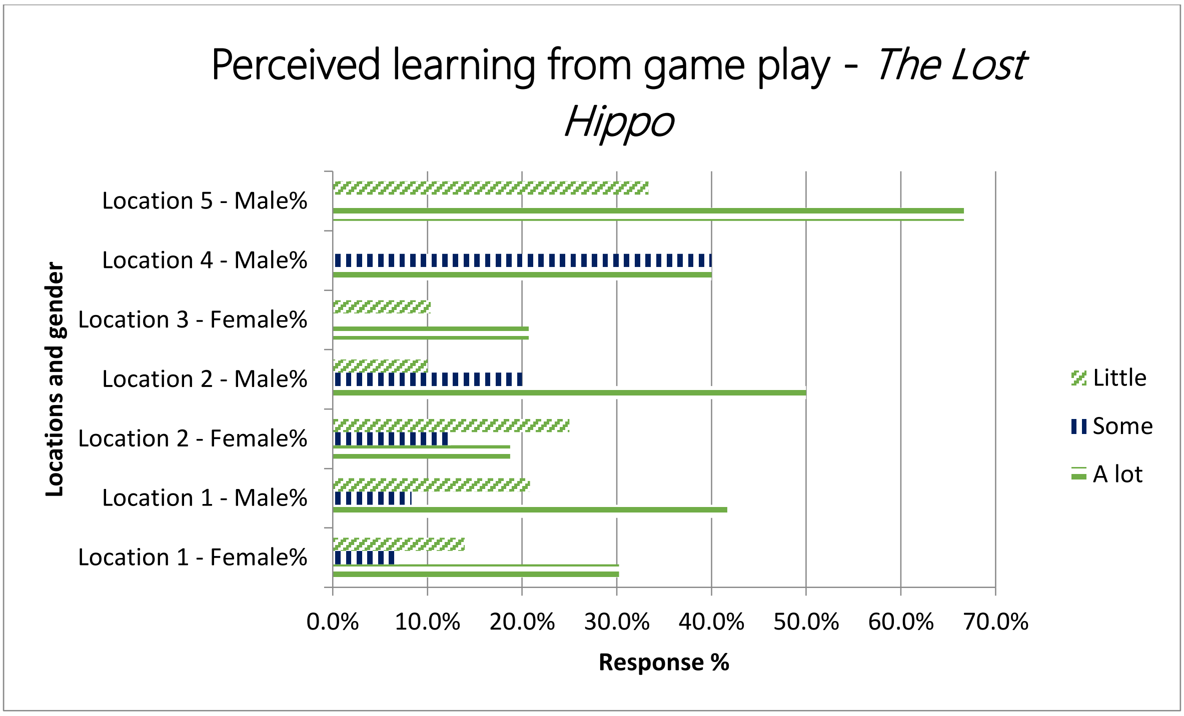


Figure 7.46. Perceived learning from gameplay of The Lost Hippo

Further statistical analysis of the data collected was used to validate the investigative statement: ***Is it helpful to learn computer science concepts using games that appeal to learners?***

The result of the ranking of responses using the Mann–Whitney test is shown in table 7.11. This test can be used to measure the difference between two independent samples. In this case, the independent samples were the two games – *The Lost Astronaut and The Lost Hippo.* The mean rank for both games indicates a significant difference – *The Lost Astronaut* (62.26) and *The Lost Hippo* (114.74). Furthermore $z = -7.118$ and $p = 0 .000$. Since $p<0.005$, H_0 is rejected and H_1 accepted i.e. there is significant support to learn computer science concepts using games that appeal girls of age 11-14.

Female Ranks

	Games	N	Mean Rank	Sum of Ranks
Perceived learning	The Lost Astronaut	88	62.26	5479.00
	The Lost Hippo	88	114.74	10097.00
	Total	176		

Test Statistics[a]

	Learning
Mann-Whitney U	1563.000
Wilcoxon W	5479.000
Z	-7.118
Asymp. Sig. (2-tailed)	.000

Table 7.11. Statistical analysis of the perceived learning associated with the use of learning games that appeal to girls of age 11-14

A similar test was completed for the sample boys target group. The result is illustrated in table 7.12. The mean rank is polarized towards *The Lost Hippo* with a significant difference between both games. The value of $Z=-5.196$ and $p= 0.000$. From these results, H_1 is also accepted.

Male Ranks

	Games	N	Mean Rank	Sum of Ranks
Perceived learning	The Lost Astronaut	42	55.81	2344.00
	The Lost Hippo	42	29.19	1226.00
	Total	84		

Test Statistics[a]

	Learning
Mann-Whitney U	323.000
Wilcoxon W	1226.000
Z	-5.196
Asymp. Sig. (2-tailed)	.000

Table 7.12. Statistical analysis of the perceived learning associated with the use of learning games that appeal to boys of age 11-14

7.8.1.6 The appeal of The Lost Astronaut and The Lost Hippo games in comparison to other educational games

The comparative appeal of each game with other educational games was also conducted. It was indicated that the appeal of *The Lost Astronaut* appealed more to the girls than the boys. In addition, the percentages of female participants that liked the game a lot were more than those that liked it to some extent, a little or not at all for all locations. For the boys in locations 1 and 5, *The Lost Astronaut* appealed to more boys than those that did not find it appealing. In locations 2 and 4, more participants did not like this game as compared to those that liked it a lot.

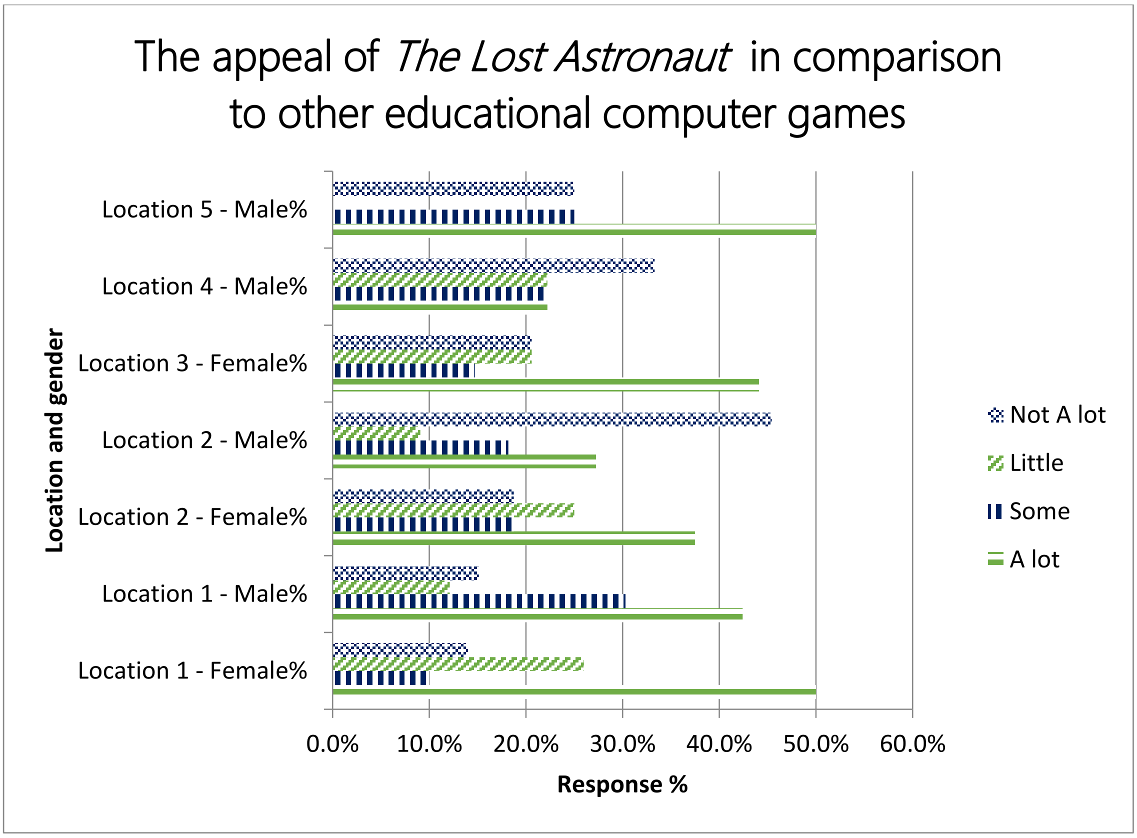


Figure 7.47.The appeal of The Lost Astronaut in comparison to other educational games by gender and location

The comparison of *The Lost Hippo* game with other educational computer games was also completed. The result is illustrated in figure 7.48, which indicated that the boys found this game more appealing than other educational games. In addition, more boys had this preference in comparison to the female target group. Furthermore, the girls would rarely consider this game in comparison to other educational games.

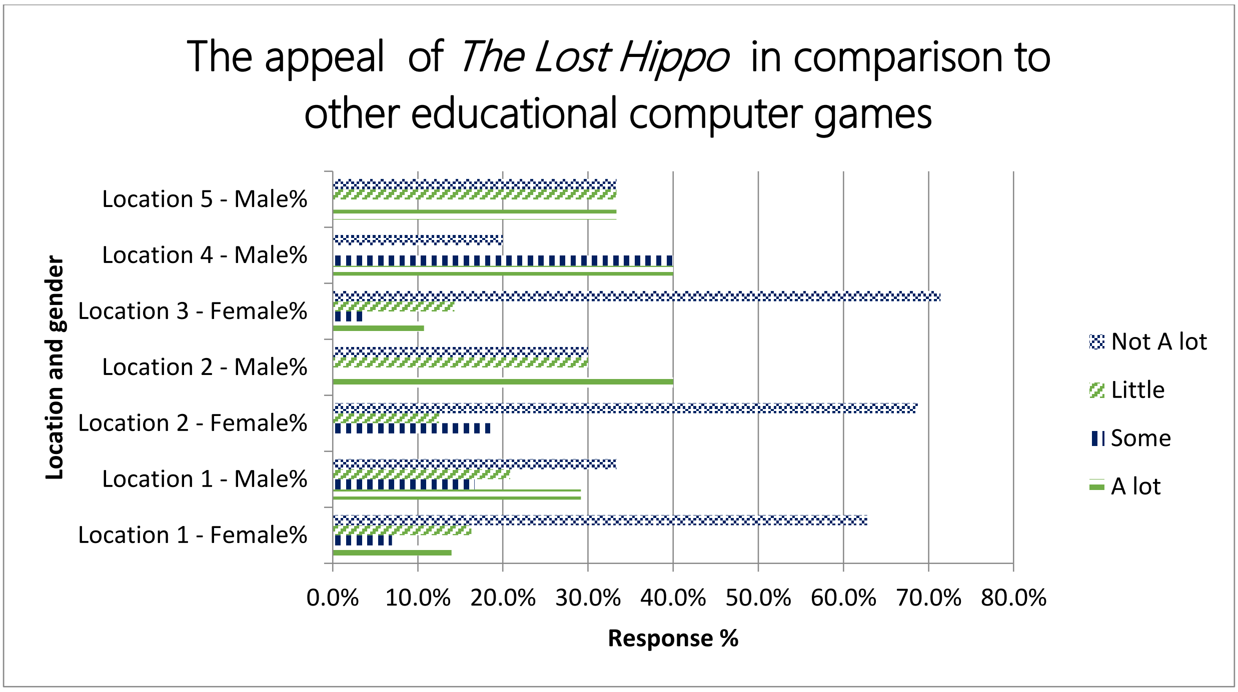


Figure 7.48. The appeal of The Lost Hippo in comparison to other educational games by gender and location

7.8.1.7 Suggested improvements to The Lost Astronaut and The Lost Hippo games

A number of suggested improvements to *The Lost Astronaut* were made by participants at the end of the gameplay. In location 1, the participating girls suggested that interactivity of the game needed improvements to include multiplayer type environment. Also, the age suitability of the game to ensure that it was accessible to all age groups that engaged with it. Furthermore, suggestions were made to improve the quality of the game graphics and the use of a wider range of colours. The boys in this location suggested that some violence should have been included in the game, improved graphics and the game should be less challenging.

In location 2, the females suggested an improvement of the instructions on how to play the game. The age-appropriateness of the game was also an area of suggested improvement. Lastly, a wider range of colours can be explored for future development. The suggestions from the participating males from this location also included the improvement of the colours of the game, including violence and the cartoon graphics used should be changed to real images.

From location 3, the suggestions for improvement included more characters in the game environment, more levels, more challenging, extended interactivity to include multiplayer environment and the use of a wider range of colours.

In location 4, there were suggestions to improve the graphics of the game, including action scenes and the game being too complex at higher levels. Finally in location 5, there were also suggestions to include violence and quick movements in the gaming environment.

The suggested improvement for *The Lost Hippo* was collected at the close of the survey session. From location 1, the girls suggested including multiplayer gaming environment and more characters. Other improvements included the amount of violence could be more and improving the quality of the graphics. The boys in this location suggested more levels, improved graphics, keyboard movement and more rewards.

From location 2, it was suggested by the girls that there should have been some form of social interaction. There should also be more movement types and a storyline to the game. The boys suggested that the images and graphics could be improved, more violence and competition.

The participating girls in location 3 suggested including a storyline to the game. It was also suggested that the game should be more realistic, age suitable for older age groups (14 years old), use of bright colours and a change of the main character. The suggestions for improvements from location 4 were the use of better graphics and in location 5 including a variety of sound tracks for different levels, a storyline and more violence.

7.8.1.9 Summary of analysis of The Lost Astronaut and The Lost Hippo by location and gender

The initial post-study data collected was to investigate the impact of *The Lost Astronaut* and *The Lost Hippo* on the sample girls and boys population. A review of the appeal of the games by gender indicated a majority of the girls found *The Lost Astronaut* more appealing of the two prototypes. The reverse was the case for the participating boys. The ranking of game characteristic as used in *The Lost Astronaut* by gender indicated that there are differences in the characteristics that are significant to both genders.

The participating girls identified game levels, interactivity and colour used as top ranking game characteristics. For the boys, the game levels, appropriateness for age group, including violence and colours used were top ranking game characteristics identified.

A review of repeat gamers of this game or similar games indicated that the participating girls and boys would engage with the game again. A larger number of girls will very much consider this game as compared to the boys.

Furthermore, based on participants' responses, *The Lost Astronaut* was identified as an effective learning tool by both genders and its appeal in comparison with similar educational games to be a lot more. The suitability of the game appeared to be more for the girls from the analysed data. However, it was also an effective game for the participating boys with a clear suggestion for improvement on the amount of action, violence and movements in the game. The game graphics and colours were also areas for improvement as suggested by the boys. These game characteristics were not included in this game.

The suggestions for improvement by the participating girls included improving some of the game characteristics such as the interactivity to include a multiplayer environment, suitability of the game for all ages and the exploring a wider range of colours.

The Lost Hippo game was designed to explore the variant of the game characteristics that were not identified in the exploratory study as appealing to the target group of 11-14 year old girls. The game characteristics explored included dark colours, use of animal characters that were not age appropriate, no social interaction platform and some violence in the form of explosions included. It appeared that the boys preferred this game to the girls in the mixed gender locations 1 and 2. Also, this game was appealing to the boys in the single gender location 4.

The participating girls indicated that including some form of interaction with other players was desired. Also, a storyline should be included to provide some purpose for the player. The colour scheme used in the game and the type of character used can also be improved. The girls found the game levels, its suitability for the age group, the audio and the option to choose the colour of the character appealing.

The boys from the various locations found the images, the game levels, game audio and the inclusion of some violence appealing in *The Lost Hippo* game. Other appealing characteristics included the colours used for the character and the feedback on how to improve. The boys suggested that improving the movement options in the game can make it more appealing in addition to more violence included. The development of the game as a multiplayer game could also improve the appeal of the game.

Furthermore, the boys would very much consider playing *The Lost Hippo* game or similar games again as compared to the girls. Although it appeared that both genders did learn from playing the game, the result of the analysis suggested that the boys engaged a lot more than the girls with this game.

In relation to the research question, the analysis of data collected based on the target group engaging with the experimental games by location evidenced that the variants of the significant game characteristics appealed differently to girls of age 11-14 years old. This implies that including the variants of the significant game characteristics as identified from the exploratory study can impact on the appeal of digital educational games to girls of age 11-14.

The next section explores a comparative evaluation of both games by gender to identify the most preferred game based on the variants of the game characteristics investigated in both experimental games.

7.9 Comparative evaluation of games by gender

At the end of the investigative study, participants completed a comparative evaluative questionnaire of both games. The gender distribution of the completed survey is shown in figure 7.49.

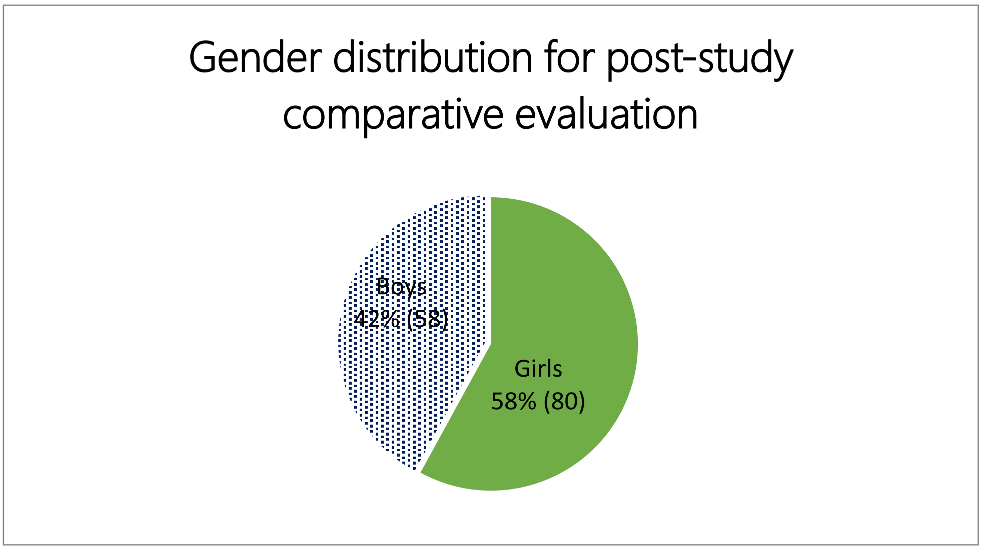


Figure 7.49. Gender distribution of the post-study comparative evaluation

The data collected here were analysed qualitatively and quantitatively to identify the statistical significance of the qualitative findings. The results were also tested against the relevant investigative statements identified earlier in section 6.5.1.

7.9.1 The comparative appeal of games to participating girls and boys

The data collected from this question was used to identify if there were any significant differences in the appeal of the games, considering that they included variants of the selected significant game characteristics obtained from the exploratory study. The result is illustrated in figure 7.50. The illustration indicated that the girls found *The Lost Astronaut* more appealing in comparison to *The Lost Hippo* game. In contrast, the boys found *The Lost Hippo* more appealing than *The Lost Astronaut.*

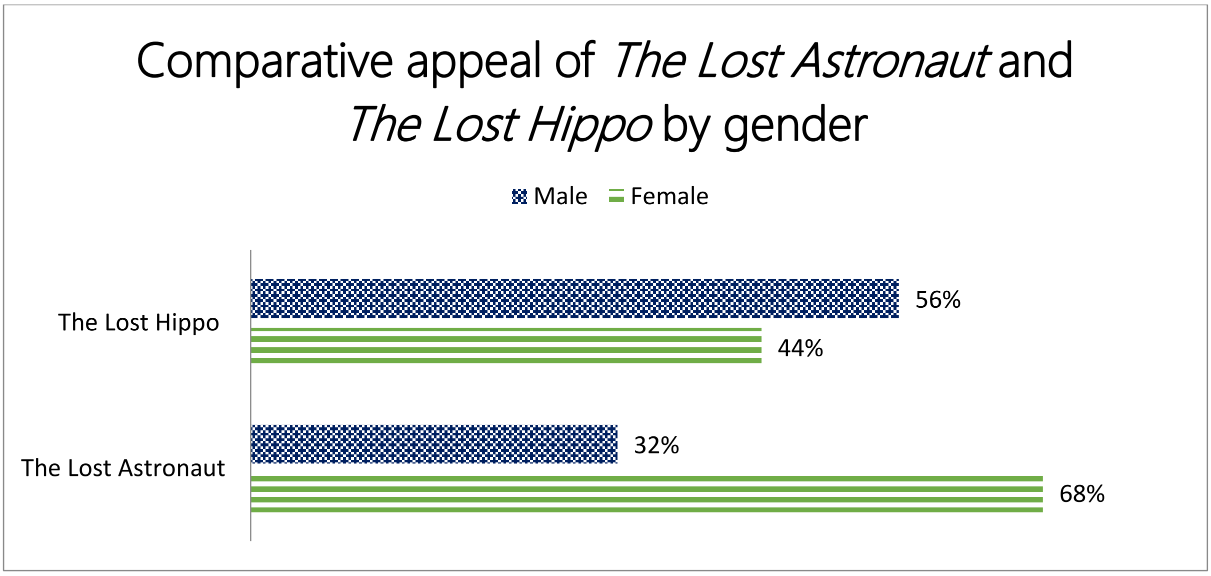


Figure 7.50. Comparative appeal of The Lost Astronaut and The Lost Hippo to young female and male participants

To examine this result quantitatively in the context of the sampled population, a statistical analysis was conducted. A procedure to determine the normality of the distribution of the data is required for the generalisation of the result. A normality test was completed to confirm the distribution of the data within the sampled population.

From the test, there was an indication that the data is not consistently approximately normally distributed using the Kurtotic check (Doane & Seward, 2011), Box plot and the Shapiro – Wilk test (Razali & Wah 2011). This test was repeated for all test data and they were identified to be not normally distributed.
We cannot, therefore, assume that the data captured for analysis is normally distributed hence parametric analytical tools was not used for the quantitative analysis.

A non-parametric test that 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 games to the target audience – girls and boys of ages 11-14. The results of the rank Mann-Whitney test is shown in table 7.13. The mean rank value for the game appeal for the girls was 64.10 and the boys 76.95, which are significant differences.

Ranks

	Gender	N	Mean Rank	Sum of Ranks
The Lost Astronaut	f	80	64.10	5128.00
	m	58	76.95	4463.00
	Total	138		

Table 7.13.Rank test results for game appeal by gender

Furthermore, the test statistics in table 7.14 suggested that there were statistically significant differences in the distribution of the appeal values between girls and boys (*z=-2.154, p=.031*). 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 the $p = 0.031$ i.e. there is a significant difference in the appeal indicated by participating girls and boys groups for the games.

Test Statistics[a]

	Game
Mann-Whitney U	1888.000
Wilcoxon W	5128.000
Z	-2.154
Asymp. Sig. (2-tailed)	.031

Table 7.14. Test statistics for the significance of the game appeal difference.

From this test, there is evidence that difference in the appeal of *The Lost Astronaut* to the girls and *The Lost Hippo* to the boys is statistically significant.

7.9.2 Reasons for the differences in appeal of the games

The comparative survey further collected data for the reasons responsible for the differences in the appeal of the games between the genders. The significant game characteristics identified by the participating girls were game fun, social interaction, colour used, background used, graphics, character used, ease of understanding, storyline and the appeal of the game. This result is illustrated in figure 7.51.

Note that storyline appears to be one of the least preferential characteristics from figure 7.51. A possibility of this low preference can be as a result of the simplistic nature of the narrative of the storyline which appear to be significant to girls (Howland & Good, 2015; Kafai & Burke, 2015). Consequently, an improved narrative of the storyline used for *"The Lost Astronaut"* game could have improved the preferential rating of this characteristic in the game.

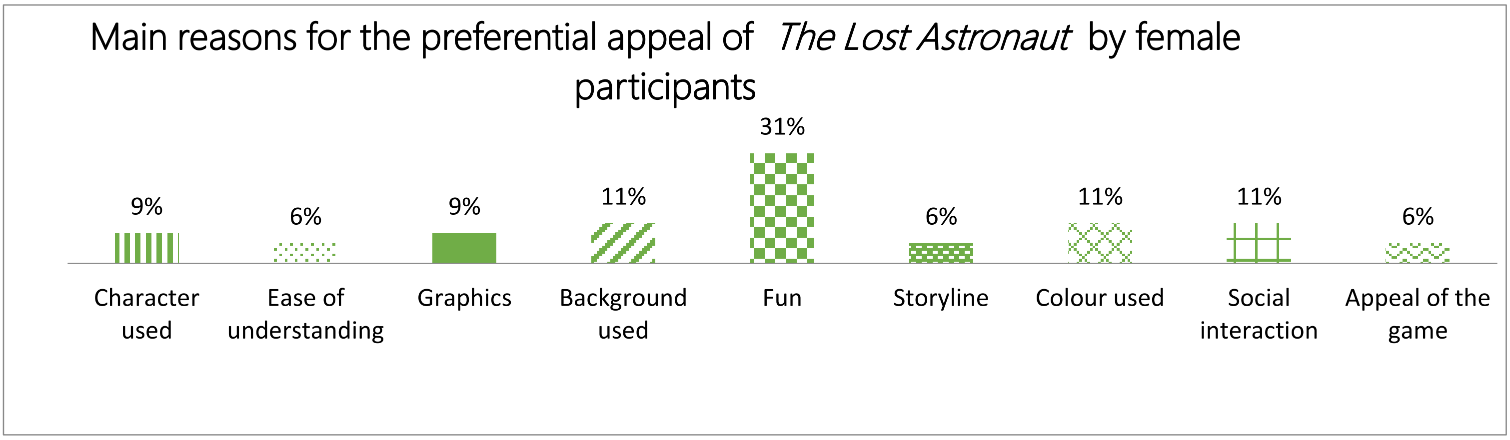


Figure 7.51. The reasons for the preferential appeal of The Lost Astronaut to participating girls

The main reasons for the preferential appeal of *The Lost Hippo* to the participating boys were also captured during the survey and illustrated in figure 7.52. The top six game characteristics were game fun, graphics, background used, character used, ease of understanding and colour used. A comparison of the game characteristics mentioned by both genders show a number of similarities. However, the difference was in the variation of the game characteristics, which would have been the reason for the difference in appeal of the games. For example, fun, graphics, character used, colour used and background used are similar game characteristics. The difference was variants of these game characteristics used in both games.

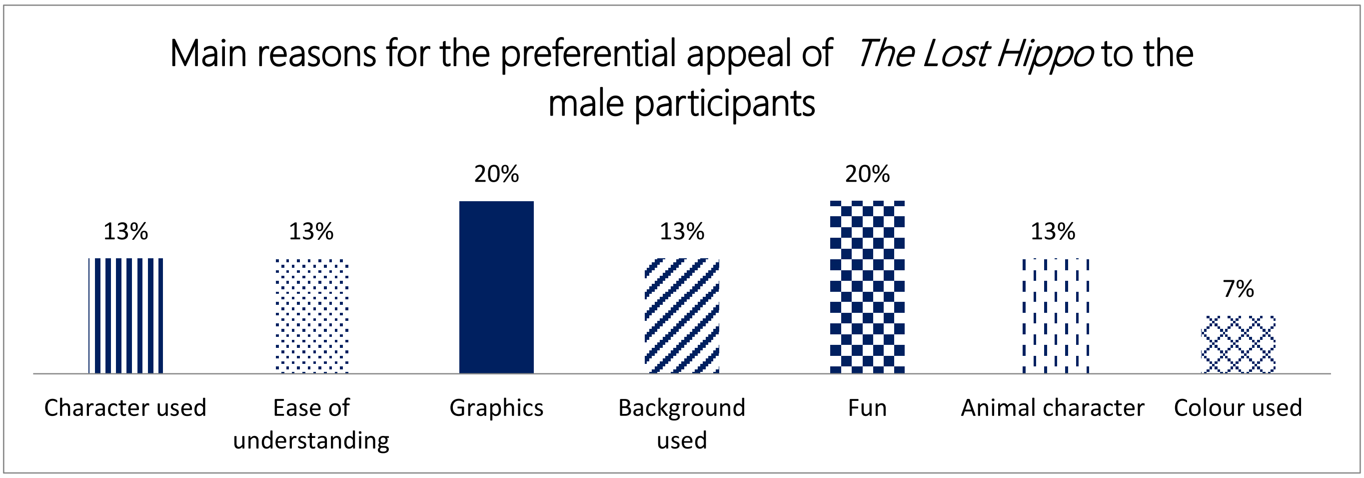


Figure 7.52. The reasons for the preferential appeal of The Lost Hippo to the boys

7.9.3 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. The result is presented in figure 7.53. From the results, 48% of girls indicated that the preferred game influenced their perception of educational games for learning computer science a lot. Cumulatively, *The Lost Astronaut* game influenced the perception of 75% of the girls as compared to 24% that 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) of the boys. Cumulatively, 78% of the boys were influenced to a reasonable extent as compared to 21% that indicated that the influence was not a lot.

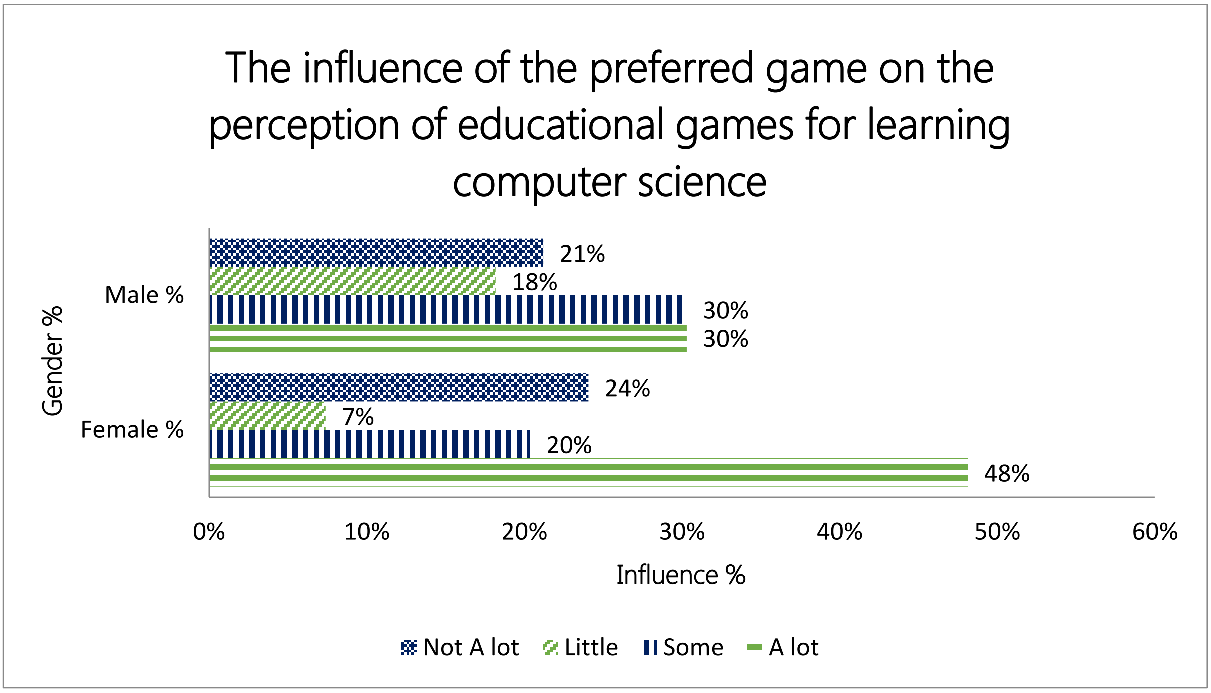


Figure 7.53. The influence of the preferred game on perception of educational games for learning computer science

Both games were analysed based on the responses indicating the preferred game and the level of impact on perception using the ranked test. Table 7.15 illustrates the result of the Mann–Whitney U test statistics for the sample girls' population. The mean rank indicated that there is a significant difference in the impact on perception between both games. The value of *Z=-2.897* and *p=0.004* is less than the hypothetical *p value* of *0.0500.* Consequently, there is evidence that educational computer games with game characteristics that appeal to participating girls can influence their perception significantly.

Female Ranks

	Games	N	Mean Rank	Sum of Ranks
Perception	*The Lost Astronaut*	53	35.32	1872.00
	The Lost Hippo	27	50.67	1368.00
	Total	80		

Test Statistics[a]

	Perception
Mann-Whitney U	441.000
Wilcoxon W	1872.000
Z	-2.897
Asymp. Sig. (2-tailed)	.004

Table 7.15.The statistical analysis of the influence of educational games with characteristics that appeal to girls of age 11-14

The result of the test conducted for the boys population is shown in table 7.16. The mean rank also indicated a significant difference for *The Lost Hippo* as the preferred game. The value of $Z=-3.164$ and $p=0.002$ also indicated that H_1 should be accepted. There is also evidence to suggest that including game characteristic that appeal to the participating boys significantly influence their perception of educational games for learning computer science.

Male Ranks

	Games	N	Mean Rank	Sum of Ranks
Perception	*The Lost Astronaut*	24	37.42	898.00
	The Lost Hippo	34	23.91	813.00
	Total	58		

Test Statistics[a]

	Perception
Mann-Whitney U	218.000
Wilcoxon W	813.000
Z	-3.164
Asymp. Sig. (2-tailed)	.002

Table 7.16. The statistical analysis of the influence of educational games with characteristics that appeal to boys of age 11-14

7.9.4 Discussion and summary of the comparative post-study analysis

From the comparative analysis of *The Lost Astronaut* and *The Lost Hippo*, it was evident that whilst the participating girls found *The Lost Astronaut* more appealing, the boys found *The Lost Hippo* relatively more appealing than *The Lost Astronaut*. Further analysis of the data indicated the reasons for the difference in the appeal of the experimental games between the girls and boys. These reasons were associated with the variants of the game characteristics of both games.

The analysis of the data also indicated that the difference in the appeal of the experimental games influenced the perception of the games by both genders. The most appealing game to both genders improved their perception of digital educational games. This provided the empirical evidence used in responding to the research question.

The analysis of data also indicated that the game characteristics that were identified in digital entertainment games from the exploratory study, which supported the motivational appeal of girls of age 11-14 were still appropriate in the educational game. This is because, *"The Lost Astronaut"* game which implemented the game characteristics that appealed to the girls from the exploratory study appeared to influence the motivational appeal positively when applied in the educational game for learning basic computer science concepts.

In order to ensure that the independent variables i.e. the variation of digital game characteristics and not confounding factors are responsible for these findings, the validity test of the main study was carried out. The findings of the validity test are reported in the next section.

7.10 Internal and external validity of the study

As mentioned in section 6.6, the internal and external validity threats to the study were considered during the design of the experiment and investigated for their statistical significance in this chapter. This section describes the analysis conducted for the internal and external validity factors that could impact on the results of the main study.

7.10.1 Internal validity of experiment

The internal validity of an experiment is threatened if the observed differences are not explained by the independent variables but possibly by a rival explanation (extraneous variables). In the seminal paper, Campbell & Stanley (1963) identified nine threats to internal validity: history, maturation, testing, instrumentation, statistical regression, order bias, differential selection of participants, mortality and interaction effects.

In this study, eight of the threats with the exception of the statistical regression threat are considered to affect this study significantly. Table 7.17 illustrates each of the threat to the internal validity of the experiment, their possible impact on the outcome of the study and how their impact can be minimised.
From the eight threats identified, three (history, maturity and mortality) could significantly impact on the outcome of the study irrespective of the design of the experiment. These threats were statistically investigated for the significance of their impact. The other five threats would not impact significantly on the outcome of the study due to the nature of the experimental design. Consequently, these threats were not statistically evaluated.

#	Internal validity threat	Impact on study	Relevant to study? (Yes/No)	Action plan
1	History	This threat refers to specific events during the experiment in addition to the experimental variables that might significantly influence the outcome of the study. These events are external to the participants e.g., how comfortable the classroom was during the experiment.	Yes	The experiment should be conducted in a familiar environment and in the normal class setting. The class teacher should ensure that the exercise is completed in conditions that are similar to the usual learning environment of the group.
2	Maturity	This threat refers to processes that occur within the participants as the experiment progresses e.g. growing hungrier and tired during the experiment.	Yes	The participants should be comfortable during the experiment and the duration of exercise monitored to ensure threat factors such as boredom and tiredness are minimised.
3	Mortality	This is the difference in the loss of participants from the comparison groups. For this study, this would be the comparative difference in the number of girls and boys that complete the study.	Yes	The comparative numbers of girls and boys at the start of the experiment should be almost similar such that any loss of participants from one group should not threaten the validity of the experiment significantly.
4	Statistical regression	Also referred to as regression to the mean. This threat occurs when the pre and post-study parameters are poorly correlated in a research where extreme scores are used (Campbell & Stanley, 1963; Slack & Draugalis, 2001). The post-survey result is expected to go up irrespective of the pre-study parameters. If the participant post-study parameter indicates regression after intervention, it is assumed that the intervention used actually made the participant worse relative to the population.	No	This threat does not apply to this study, as participants' performance is not tested and scores subsequently used.
5	Order bias	Order bias occurs when multiple interventions is compared in a study. If participants are exposed to and measured under each intervention condition, an order effect can provide a threat to internal validity such that the impact of the intervention is not distinguishable from the effect of the order.	Yes	The study involved each participant interacting with two games and completing questionnaires for each game. This threat was minimised by ensuring that not all participants engaged with the same game at the same time. While a group engaged with one game, others engaged with the other game such that the effect of the order was minimised. The selection of the game to play first was based on participants' preference.
6	Differential selection of participants	In some research studies, there is a differential in the selection of participants for the comparison groups. For this study, this would be different selection methods used for participating girls and boys.	Yes	There are no differential in the selection of girls and boys for the study.
7	Selection interaction effects	The impact of other confounding factors that might be mistaken for the effect of experimental variables e.g. a significant comparative differential of mortality between the girls and boys can affect the results, which might appear as the impact of the intervention.	Yes	The findings of the experiment should be tested for the significance of other confounding factors being responsible for the outcomes.

8	Testing	In the experimental design of some studies, pre and post-study tests with scores are incorporated to ascertain the impact of intervention. The testing threat occurs when a test score improves because the participants repeated the test rather than the effect of an intervention. In other instances, this might be the effect of the completion of more than one feedback form with or without similar questions.	Yes	This study has not incorporated pre and post-study tests scores to assess the impact of the intervention. However, participants completed four different questionnaires, which can have significant impact on the quality of completion. Due to participants not completing these questionnaires in a similar order, the effect of this threat is significantly minimised.
9	Instrumentation	The instrumentation threat to internal validity of a study occurs when there are changes to the way measures are taken between experiments or changes in observers of the session.	Yes	The duration of the sessions was such that the same observer completed each session with participants. In addition, the questionnaires and procedure used to evaluate the different games were exactly similar for all locations.

Table 7.17. Internal validity threats, their impact and actions to minimise or eliminate bias

7.10.1.1 History threat

This type of threat occurs when the outcome of the study was affected by specific events during the experiment in addition to the experimental variables that might significantly influence the outcome of the study. This type of threat is common with longitudinal studies (observational research that involves the repeated collection of data from the same subjects over an extended period). For this study, the history threats included how comfortable in the classroom the participants were during the study or any other physical events that could impact their responses significantly.

In the course of the study, participants were initially required to indicate how often they play educational computer games and the consideration to play the preferred game or similar games again. The analysis of the regularity of play data by gender is shown in figure 7.54. Although the boys play regularly more than the girls, (boys – daily = 12%, weekly = 15%, every 2 weeks = 9%; girls – daily =7%, weekly= 12%, every 2 weeks = 8%) more girls play digital educational games on monthly basis (girls = 18%, boys = 14%) than boys. In addition, more females (42%) never play digital educational games as compared to the male participants (34%). The result does not indicate extreme negativity from the participating females or males with regards to engagement with digital educational games. About half never play digital educational games from both gender and about half play digital educational games from both genders.

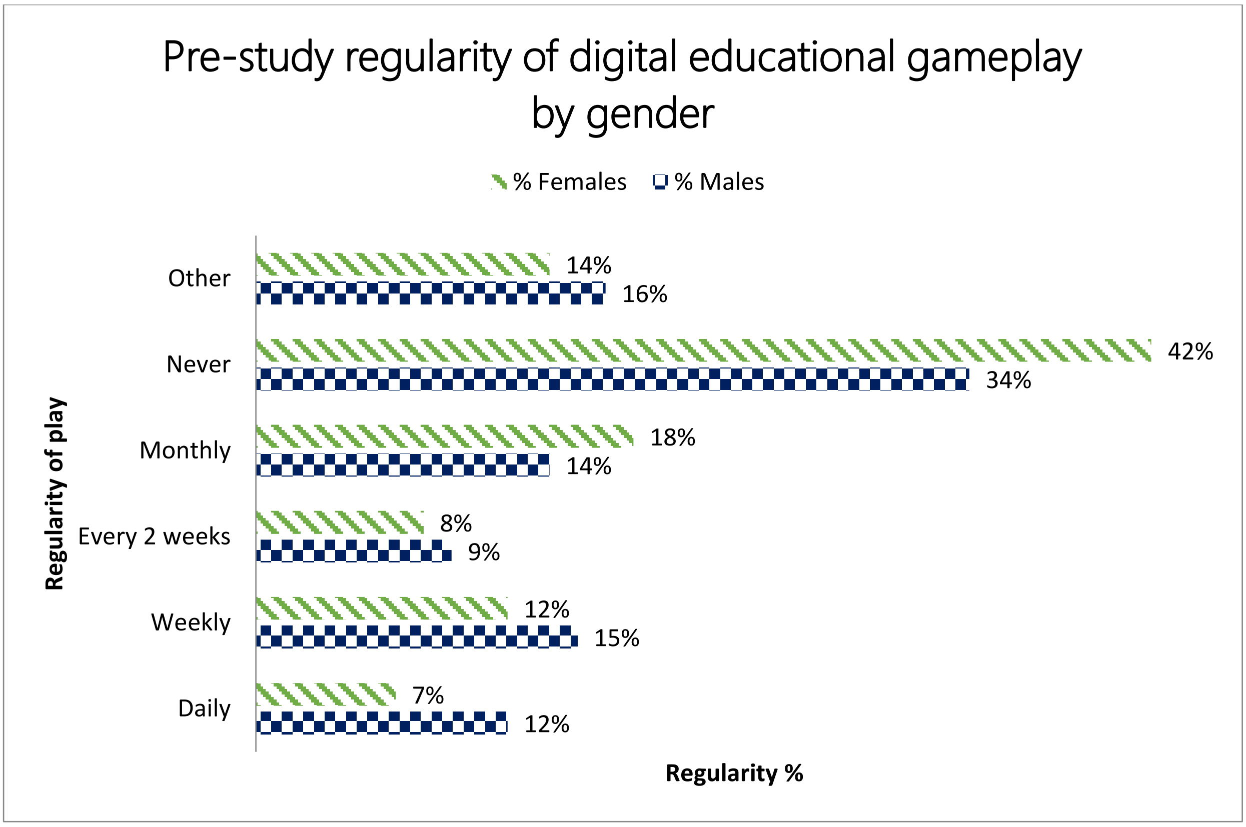


Figure 7.54. Pre-study regularity of digital educational gameplay by gender

During the post-study data collection, participants identified their preferred game and the possibility of being return gamers. If the pre-study experiences have influenced their responses, there should be no increase or improvement of the play pattern of the participants. In addition, the adverse impact of study conditions would not support the trend observed during the study. Figure 7.55 illustrates the comparative post-study evaluation of the preferred game by gender.

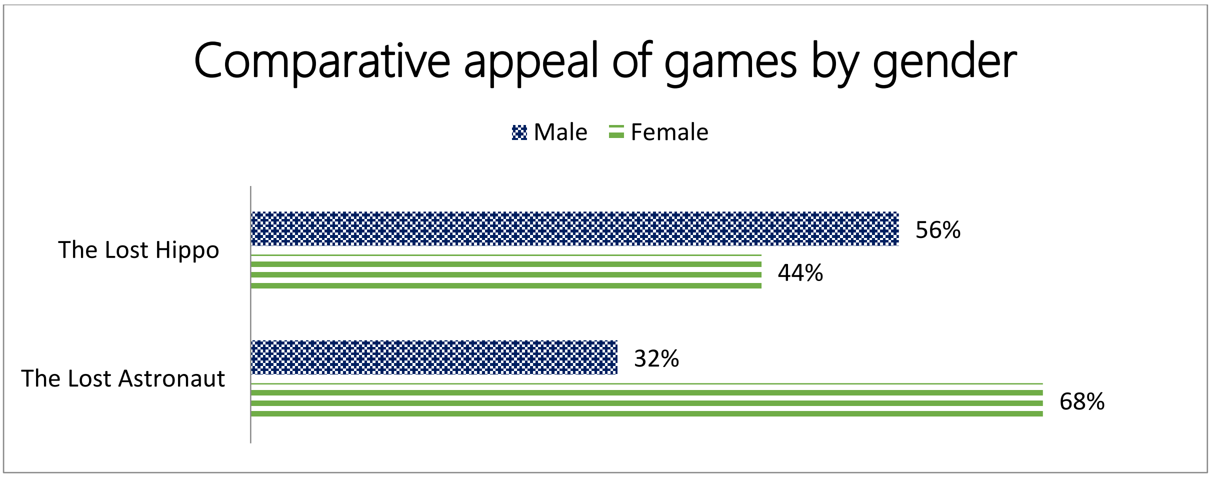


Figure 7.55 Comparative appeal of experimental games by gender

The preferred game by gender is illustrated in figure 7.55 and it is indicated that the girls prefer *The Lost Astronaut* and the boys *The Lost Hippo*. This information was then compared with the consideration to play the preferred game or similar games in the future. The result of the analysis is shown in figure 7.56.

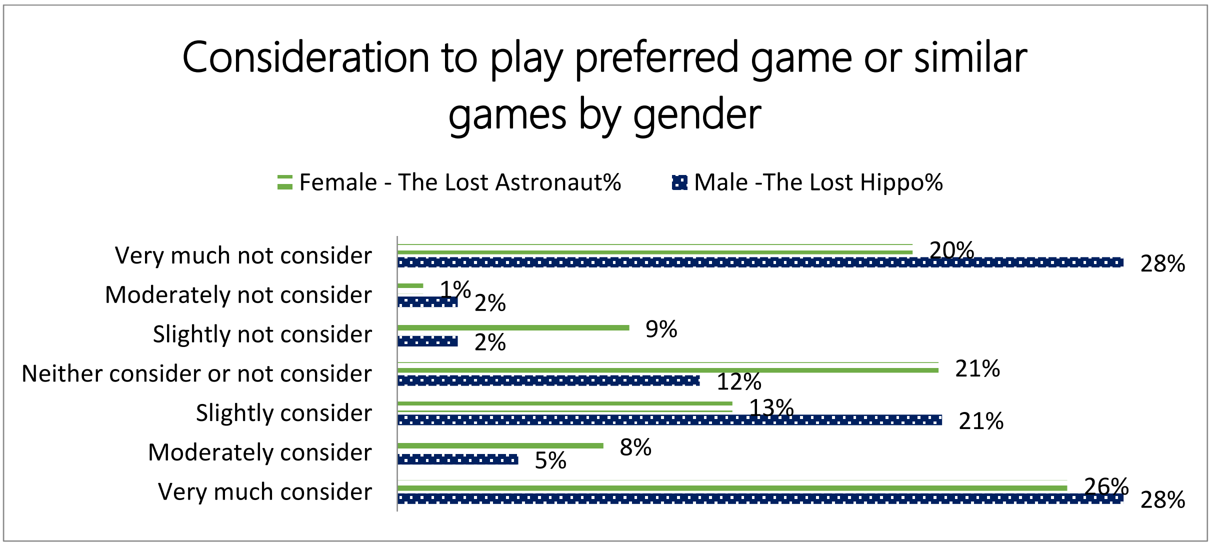


Figure 7.56. Consideration to play preferred game or similar games at a later date by gender

From the analysis of the results, cumulatively, 47% of participating girls would consider returning to the preferred game or similar games and 30% not considering a return. However, 21% are not sure if they would consider returning. Similarly, 54% of the boys would consider returning, 12% not sure of returning and 32% not returning.

A qualitative comparison of the results from all three analysis indicated that the historical threat did not significantly impact on the study. If this were the case, there would be a significant change in the responses in comparison to the pre-study analysis. A statistical significance test that can correlate the ordinal data from the pre-study and the post-study analysis was identified. The Spearman's test was selected and applied for this analysis. This test can correlate two ordinal data from non-parametric measures for the statistical significance of differences between measures. The evidence of the statistical significance for the girls is illustrated in table 7.18. The pre-study regularity of play was compared with the return gamers based on their preferred game or similar games for learning computer science concepts.

The result suggested that there is no significant impact of the historical threat on the responses as the mean difference = *0.4* and Standard deviation difference=*0.011*. In addition, $P>0.005$, hence H_0 was accepted - There is no significant evidence of historical threat influences on the responses collected from participating females pre and post-study.

Descriptive Statistics for female sample group

	N	Mean	Std. Deviation	Minimum	Maximum
Pre study Regularity	36	2.4722	1.96376	1.00	7.00
Post study Return_gamers	36	2.8889	1.95343	1.00	7.00

Pre-study (Regularity of digital educational games play) and Post-study (Return gamers)Correlations

			Regularity	Return_gamers
Spearman's rho	Pre-study Regularity	Correlation Coefficient	1.000	-.194
		Sig. (2-tailed)	.	.257
		N	36	36
	Post-study Return_gamers	Correlation Coefficient	-.194	1.000
		Sig. (2-tailed)	.257	.
		N	36	36

Table 7.18.Statistical analysis and significance of the historical threat for the girls sample population

A similar test was conducted for the boys to determine the impact of the historical threat. Table 7.19 illustrates the result of the Spearman's test. The mean difference=*1.3*, Standard deviation *=0.125* and *p=0.622*. Consequently, there is evidence that there is no significant historic threat to the study conducted on the participating boys.

Descriptive Statistics for male population

	N	Mean	Std. Deviation	Minimum	Maximum
Pre-study Regularity	42	3.9048	1.96071	1.00	7.00
Post-study Return_gamers	42	2.5476	2.08599	1.00	7.00

Pre study (Regularity of digital educational games play) and Post study (Return gamers)Correlations

			Regularity	Return_gamers
Spearman's rho	Pre-study Regularity	Correlation Coefficient	1.000	.078
		Sig. (2-tailed)	.	.622
		N	42	42
	Post-study Return_gamers	Correlation Coefficient	.078	1.000
		Sig. (2-tailed)	.622	.
		N	42	42

Table 7.19 Statistical analysis and significance of the historical threat for the boys sample population

7.10.1.2 Maturity threat

The concept of maturity threats occur within the participants as the experiment progresses. For this study, maturity threats considered included participants growing hungrier or tired during the experiment. This may differ between participants and might impact on how the target group engage with the session.

During the study, information on how often participants engage with digital educational games was conducted at the pre-study stage with a comparison to how much digital educational games appeal to them. The result is shown in figure 7.57. The analysis by gender indicated that the participating boys play digital educational games more on a regular basis than girls.

Relatively, the boys also find educational games more appealing to them in comparison to girls. This was in agreement with studies on the differences in the engagement levels between girls and boys with digital educational games.

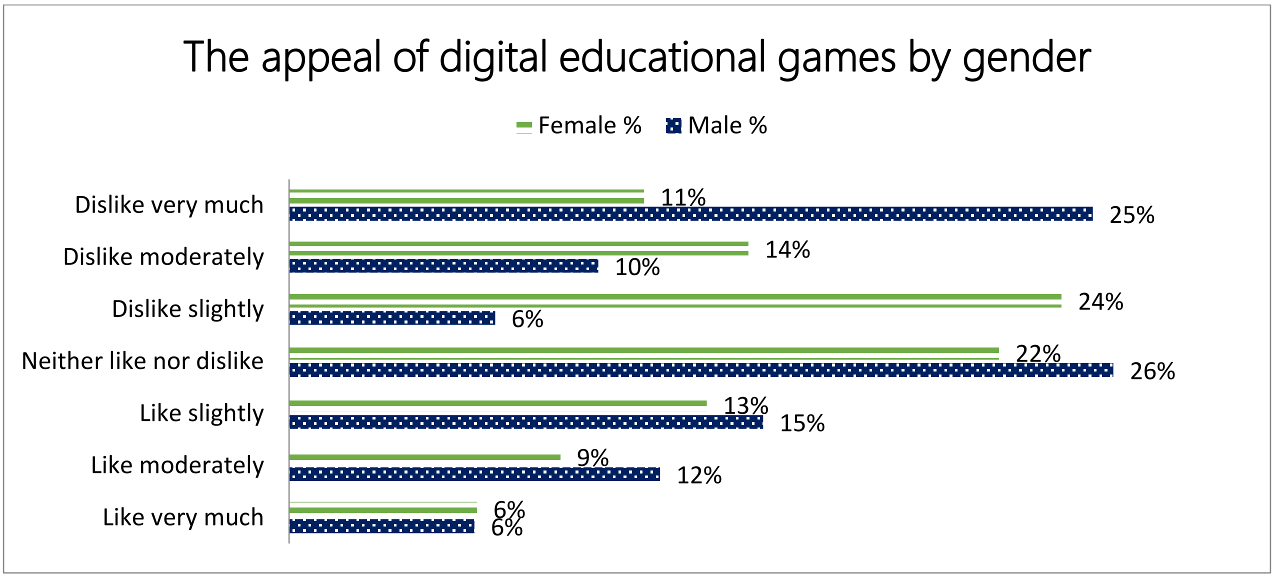


Figure 7.57. The pre-study appeal of educational computer games by gender

A further investigation of the statistical significance of the finding using the Spearman's test was conducted between the pre-study and post-study appeal of preferred games. The result is shown in table 7.20. The correlation coefficient value of *0.048* is moderate and *p= 0.634*. From this result, the impact of the pre-study data on the post-study outcome is not statistically significant. Hence, H_0 was accepted for the maturity threat for the female population.

Female sample population correlation coefficient pre and post-study data

			Pre-Study_Appeal	Post-Study_Appeal
Spearman's rho	Pre-Study_Appeal	Correlation Coefficient	1.000	.048
		Sig. (2-tailed)	.	.634
		N	101	101
	Post-Study_Appeal	Correlation Coefficient	.048	1.000
		Sig. (2-tailed)	.634	.
		N	101	101

Table 7.20. The pre-study and post-study maturity threat test for the girls sample population

The statistical significance of the threat was also conducted for the male population. The result is illustrated in table 7.20. The Spearman's correlation coefficient was *-0.217*. This is a weak or small correlation where *p=0.233*. Hence, it can be concluded that there is no significant maturity threat to the study conducted with the boys.

Male sample population correlation coefficient pre and post-study data

			Pre-Study_Appeal	Post-Study_Appeal
Spearman's rho	Pre-Study_Appeal	Correlation Coefficient	1.000	-.217
		Sig. (2-tailed)	.	.233
		N	32	32
	Post-Study_Appeal	Correlation Coefficient	-.217	1.000
		Sig. (2-tailed)	.233	.
		N	32	32

Table 7.21. The pre and post-study maturity threat test for the boys sample population.

7.10.1.3 Mortality threat

This threat refers to the drop-out rate of participants from the comparison groups of the study. This is often a considerable threat for studies that are conducted over an extensive period of time. Since most negative responses are usually provided by the drop-out participants, the responses obtained might appear more positive than usual.

Furthermore, when the drop-out rate is high or equal to the non-drop rate for a study, the result is controversial. This is a threat for any experimental design with more than one group (Roberts & Ilardi, 2008).

To evaluate the degree of mortality threat, the drop-out data is often compared to the non-dropout (participation) data from the comparison group (SRM, 2006). If there are no major differences between the groups, it is assumed that mortality was happening across the entire sample and is not biasing the outcome of the study. However, if the difference between the non-dropout and drop-out group is large, then the potential biasing effect of mortality needs to be carefully considered.

The drop-out and non-drop data was considered by gender for this study. Due to the brief duration of the study, the review considered the number of participants that initially completed the pre-study questionnaire, 3 post-study questionnaires, two post-study questionnaires and 1 post-study questionnaire. The participation rate comprised of the comparative between the groups of participants that completed the pre-study questionnaire and at all post-study questionnaire. Table 7.22 illustrates the data on the participation rate for the study. It indicated that the drop-out rate for the girls was 42% and 58% participation rate. Similarly, the drop-out rate for the boys was 65% and participation rate 35%. Both participation rates were considerably low especially the boys. The comparative drop-out rate for both gender was also high. The reason for the less numbers completing the post-study survey is unknown for this study. However, the data collected and analysed confirms some of the initial findings from the exploratory study and related studies. The mix of the completed post-study questionnaire provided responses from most participants including those that did not complete all four questionnaires. It can be concluded that for this study, the mortality threat did not impact significantly on the results of the study.

Gender	Pre-Study participation number	Post -study survey 1 (*The Lost Astronaut*) participation number	Post -study survey 2 (*The Lost Hippo*) participation number	Post -study survey 3 (Evaluation) participation number	Average post-study participation number	Dropout rate	Participation rate (3 post-study surveys)
Girls	154	100	88	80	89	42%	58%
Boys	150	55	42	58	52	65%	35%

Table 7.22. The dropout rate and participation rates obtained from the study

7.10.2 External validity of the study

The external validity of a study takes into account the extent to which the outcome of the study can be generalised to the target group from other locations. The investigation of this validity considered both the ecological and population factors.

The ecological validity of this study considered the impact of the test environment on the responses of the participants. The ecological validity can be strengthened by repeating a similar study in different location at different times with a similar target group. For this study, the investigation was conducted in 5 different locations with the same age group and both genders. This improved the ecological validity of the study.

The population validity of this study considered how the selected sample population of the study represented a real world population. Strong population validity is obtained when there is random selection of the sample and the variety of the distribution of the population is similar to the real world. In this study, there were no criteria in the selection of the sample population other than age and gender. These independent variables are obtainable in a natural population of young learners. Furthermore, other selection criteria such as pervious knowledge of the subject, interest in the subject and preferential selection was not used during the study. This also improved the population validity of this study.

The actions taken on both external validity factors during the study strengthened the validity of the study. Consequently, the result can be extended to the target group at different locations.

7.10.3 Summary of internal and external validity of the study

The evaluation of the internal and external validity of the study indicated the following:

a) *History threat* did not bias the outcomes of this study because, on a comparison of the pre-study data on the regularity of play of digital educational games and the return to preferred game or similar games. There was no overwhelming positive or negative differences. The margins of differences were reasonable. A statistical analysis of the data indicated that there were no significant differences.

b) *Maturity threat* did not endanger the outcome of this study as the qualitative analysis indicated that although pre-study data indicated that the male population engage more with digital educational games than females, the statistical correlation with the outcome of the study indicated that there was no significant threat to the validity of the study. This was because irrespective of how participants currently engage with digital educational games, if the variants of the significant game characteristics that appeal to them are included, they would engage in a different way with the game.

c) *Mortality threat* did not significantly impact the outcome of this study as the results from the different locations appear to be consistent with the sample population involved in the study. The comparative drop - out rate was high and the participation rates were low for both gender. However, the mix of the completion of the four questionnaires also ensured that the responses were balanced.

d) Both *population* and *ecological threats* did not significantly impact on the outcome of the study.

These results provide strong evidence that the internal and external threats listed above did not significantly bias the outcome of the investigation. In this case, the internal validity of the research supports the premise that the cause-effect relationship of the study is drawn from the variants of game characteristics that appeal to the participants rather than any other confounding factor. Consequently, the result of the study can be extrapolated to a larger population similar to the target group of the study.

7.11 Summary of results

The data captured using the pre and post-study questionnaires during the main study, were used to obtain the empirical evidence in responding to the research question.

The result of the pre-study analysis indicated that there are similarities and differences between the game characteristics that are significant and appeal to the target audience. The findings from the pre-study analysis further suggested that these variants of the significant game characteristics can influence the appeal of digital entertainment games.

The result of the post-study analysis data further suggested that the selected significant game characteristics that appeal to girls significantly improved the appeal of *The Lost Astronaut* in comparison to the alternative game *The Lost Hippo* with the girls. The results of the post-study analysis also indicated that both populations of participating girls and boys engaged more with their preferred game .The insight gained from the study also indicated that the participants' perception of their learning was influenced positively from engaging with their preferred game. Finally, the perception of digital educational games was also significantly influenced as a result of the customisation of the games to include variants of the significant game characteristics.

In conclusion, the result of the main study analysis indicated that the knowledge obtained from the investigation of digital entertainment games i.e. the variants of significant game characteristics can be used to create computer science educational games that appeal to 11-14 year old girls. It can also be concluded from the analysis of the results that digital educational games that appeal to the target group, can influence positively their perception of digital educational games for learning computer science concepts. The research comprising of the exploratory and main study met the objectives set at the start of the study as it provided empirical evidence to answer both research questions – *(1)"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?"* and *(2) "Can we use this knowledge to create computer science learning games that appeal to this audience?"*

CHAPTER 8

CONCLUSION AND FUTURE WORK

8.0 Introduction

This chapter outlines the main contributions of this study and identifies the limitations of the study with suggestions for future studies. Section 8.1 is a summary of the study. Section 8.2 reviews how the objectives of the study were accomplished. Section 8.3 reports the main contributions of the study. Section 8.4 identifies and describes the limitations of the study. The future work considering the limitations of the study is discussed in section 8.5. Section 8.6 is a reflection of the study with a concluding statement.

8.1 Summary of the study

The motivation for this study is the under-representation of females in computer science education and careers. This problem commonly referred to as the "*shrinking pipeline"* indicates that the representation of females in computer science education and careers declines progressively from the early stages of education through the tertiary stage into the workplace. A number of initiatives including the use of digital educational games have been implemented to attempt to tackle this problem but with limited success.

Digital entertainment games have been used over the years to engage girls and boys with technology (Greenberg et al., 2010; Granic et al., 2014). Current statistics indicate that this has been very successful with both genders (ESA, 2012) especially with females, because currently, more females (52%) engage with digital entertainment games than males (48%). The motivation demonstrated towards digital entertainment games by young people provided the opportunity for their use as a learning tool. A review of digital educational games with this target audience indicated that it is not successful with girls as it is with the boys (Hartmann & Klimmt, 2006; Boyle et al., 2011; Heemskerk et al., 2011; Nietfeld et al., 2014; Sullivan & Bers, 2016).

This finding led to further investigation of the role of digital educational games in the under-representation of females in computer science education as educational software designed for children and students is the same as that designed for boys. (Heemskerk et al., 2011; Stoilescu & McDougall, 2011; Misa, 2011; Scott & White, 2013; Sanders et al., 2013).

A number of related studies have also indicated the current design of digital educational games does not support the motivational appeal of girls (Hartmann & Klimmt, 2006; Ihamäki, 2011). This is shown to impact on career choices due to the poor perception of the subject and career (Adya & Kaiser, 2005; McEwan & McConnell, 2013; Wang & Degol, 2013).

The empirical evidence of the influence of digital educational games with motivational appeal on the age group (11-14 year old), where the pipeline significantly starts to shrink is missing from the current literature (Osunde et al., 2015; Sullivan & Bers, 2016; Atwood-Blaine & Huffman, 2017). An understanding of the key criteria responsible for the success of some digital entertainment games with this target group was important in addressing the research problem. Hence, the research questions for the study were:

(1)"Can we understand what makes some digital entertainment games appealing to 11-14 year old girls?" and (2) "Can we use this knowledge to create computer science learning games that appeal to this audience?"

This study was aimed at providing the missing evidence that digital educational games can:

1. Be created to appeal to girls of age 11-14 year old;
2. Positively influence their perception of digital educational games with a focus on games for learning basic computer science concepts if they are motivationally appealing.

8.2 How the research aims and objectives were met in the study

The aim of the research was to investigate how digital educational games can be designed to motivationally appeal more to the target group.

The research then further investigated the implications of the appeal on the perception of digital educational games for learning basic computer science concepts with the target group of the study.

These aims were initially decomposed into a set of objectives, which were outlined in Chapter 1 section 3.

The first objective was to conduct an investigation to identify the reasons some digital entertainment games are successful with 11-14 year old girls. However, boys of the same age group were included in the study to provide comparative information for the study. The first objective was achieved through an exploratory study conducted using an adapted user-led methodology of repeated single-criterion sort and a closed sort into girls perceptions of a set of 10 successful digital entertainment games (Chapter 4).

From the investigation, similarities and differences in the appeal of digital games between girls and boys were identified. The focus of the study was 11-14 years old girls. The findings from the exploratory study indicated that there are significant games characteristics, which make digital games appealing to the target audience. These game characteristics are either similar or different between girls and boys of age 11-14 (Chapter 4 section 2). At the conclusion of the exploratory study, the variants of seven game characteristics that are significant to girls of age 11-14 were chosen for further investigation in the main study (Chapter 4 section 2).

The second objective was to create two digital experimental educational games based on the outcome of the exploratory study. The first game - *The Lost Astronaut* included the seven variants of game characteristics that appeal positively to the 11-14 year old girls. The second game - *The Lost Hippo* included antithetic variants of the same game characteristics. The experimental games were created from an existing Google Blockly maze game.

The framework proposed by Aleven et al. (2010) was chosen and used to confirm the educational effectiveness of the Google Blockly maze game and guide the customisation process. This was to ensure that the educational effectiveness of the created games were not compromised. This objective was achieved and reported in chapter 5.

The third objective was the main study, which involved the target audience engaging with the games and the collection of participant feedback using online pre and post-study questionnaires (Chapter 6). The data collected was analysed in chapter 7. On completion of the analysis, the main findings of the investigation were:

1. There are digital game characteristics that are significant to the target group which can improve the motivational appeal of digital educational games;

2. Game appeal can have a significantly positive influence on the perception of digital educational games with the target group;

3. The knowledge acquired from the design of digital entertainment games that appeal to the target group can be applied successfully in the design of digital educational games for learning basic computer science concepts, as demonstrated by the two experimental games.

To conclude the analysis of the data, a review of the internal and external validity factors to determine their impact on the study was conducted. The analysis indicated that there was no significant impact from the internal and external factors that refutes the findings of the investigation. Consequently, the findings of the study can be extended to a wider population of the target group (Chapter 7 section 10). All the objectives of the research were achieved and the findings provided the evidence in responding to the main research question.

8.3 Main Contributions of the research

The contributions of the research are:

1. Empirical contribution - Significant game characteristics and game appeal

The study provided empirical evidence that identified some game characteristics that appeal and are significant to 11-14 year old girls in digital entertainment games. These game characteristics can be included in digital educational games for the study of computer science concepts to make them more motivationally appealing to this target group. The study further identified game characteristics that appeal to 11-14 years old girls and antithetically what might appeal to boys of a similar age range.

2. Empirical contribution - The impact of motivationally appealing games on the perception of learning games

The study provided further empirical evidence that the design and creation of digital educational games that are motivationally appealing to the target audience, can have a significant positive influence on their perception of learning games. The wider implication of this contribution is that the design and creation of digital educational games, which are motivationally appealing, can be used to effectively influence the perception of subjects that are identified as not motivationally appealing to this target group.

3. Empirical contribution - The collection of a substantial amount of data from the sample population of 11-14 year old girls and boys

A substantial amount of data which included the perception data of digital entertainment games, digital educational games that may appeal or not appeal to girls and boys of age 11-14 years old were collected during the study from 304 participants. This involved the use of four different questionnaires (one pre-study and three post study) resulting in a substantial amount of datasets. This type of evidence based on the data collected for this age group of girls and boys is currently lacking from the body of knowledge.

4. Design contribution – The application of a game design model for digital educational games

The study also provided empirical evidence of the use of the design information gained from digital entertainment games, which can be successfully applied to digital educational games, with a focus on computer science learning games. The application of this game design information and a suitable framework, can be used to create digital educational games that are motivationally appealing to the target group. This game design model can be extended to the design and creation of educational games for other subjects in a similar position with the target group.

8.4 Limitations of the study

Although the research aims and objectives were accomplished, there are limitations of the study, which are outlined below:

1. The investigation was based on the gender difference of the sample population. Other sub-group empirical data such as socio-cultural, ethnic, and economic data were not collected to determine if there are differences or similarities in the findings as identified with gender differences. This data could provide more evidence on the role of these factors in the differences in the motivational appeal of game characteristics.

2. The scope of the research was restricted to 11-14 year old girls in southeast England. There may be differences in findings if the study were conducted in a different part of the United Kingdom or other parts of the world. Consequently, the findings of the research are based on the context of a part of southeast England that possesses its unique ethnic and cultural mix. Over the years, due to the settlement of different ethnic groups in the United Kingdom, the pervasive ethnic groups guide the cultural identity in different parts of the country which can influence perceptions.

3. Limitation of the number of significant game characteristics investigated in the main study. The study focused on seven significant game characteristics from a list of significant game characteristics identified from the exploratory study. There is scope to investigate other significant game characteristics such as rewards, multiplayer environments etc.

4. The study is an investigation of a snapshot in time of digital game characteristics that appeal to 11-14 year old girls. The findings of a similar study conducted at a different time might produce a different result due to the changing nature of the appeal of digital games with the target group.

5. The data collected from the main study was based on the participants' engagement with the experimental games for 20 minutes per game. Had the participants engaged with the experimental games for a longer time, the results might have been different.

8.5 Future work

A follow-up longitudinal study that investigates the impact of significant game characteristics that appeal to the target group should be conducted.

- This study could also provide evidence of the changes in the appeal of the investigated significant game characteristics over time, due to other factors such as socio-economic differences. In addition, there could be changes in the composition of significant game characteristics which appeal to the target group in a different location outside the United Kingdom, or a different continent.
- Furthermore, a similar study can be conducted in the future involving a larger sample size drawn from different parts of the United Kingdom. This would provide a result representative of different parts of the United Kingdom with their socio-cultural and economic differences.
- The appeal generated from the experimental games, and the long-term impact on both the perception of computer science and digital educational games, could be investigated in a longitudinal study. The correlation between improved perception and interest in computer science can also be reviewed in a future study.
- The impact of digital educational games that appeal to 11-14 year old girls on their learning. This study would provide the empirical evidence to confirm the findings of this study, which suggests that games that appeal to this target group should positively influence their learning.

8.6 Final reflections

The motivation for this study is the under-representation of females in computer science education and careers. The research explored a game-based learning approach to providing an additional strategy given the wealth of initiatives in this area. The empirical and game design contributions of the research concludes that, identifying and including game characteristics that are significant to girls of age 11-14 years old can improve the motivational appeal and perception of digital educational games.

This study has provided empirical evidence in response to the research question about what makes some digital entertainment games appealing to 11-14 year old girls and this knowledge was used to create a computer science learning game that appealed to this audience.

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APPENDIX 1

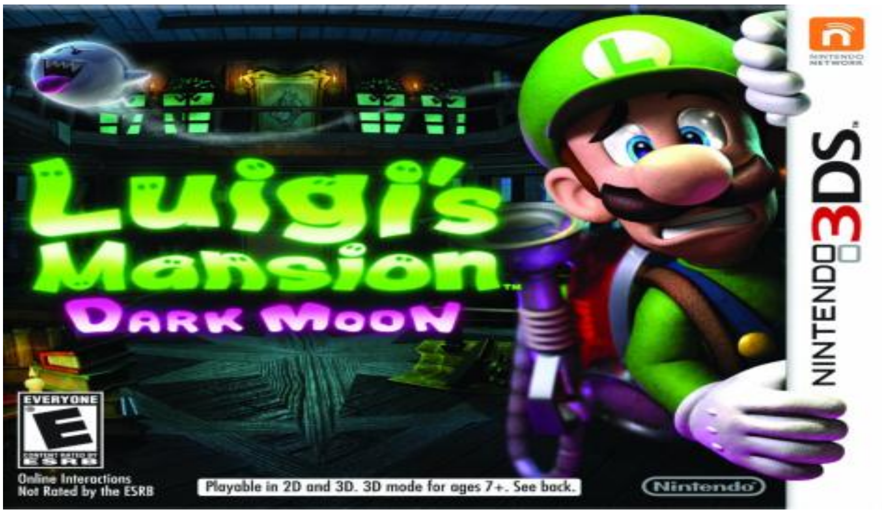
EXPLORATORY STUDY - CARD SORT PICTURE CARDS AND DATA COLLECTION SHEETS

#1

A single- player Wii game which takes place in Lego City. The player controls an undercover cop named Chase McCain. Chase goes on to hunt for criminals with various moves at his disposal. He can also pilot cars and helicopters. He has a device which is used as a communicator and as a scanner to locate criminals.

#2

In this game, Pac-Man and friends (Spiral and Cylindria) help protect Pac-World from the threat of Ghosts. The game can be played on Xbox 360, PlayStation 3 and Wii. It can be played by one or more players.

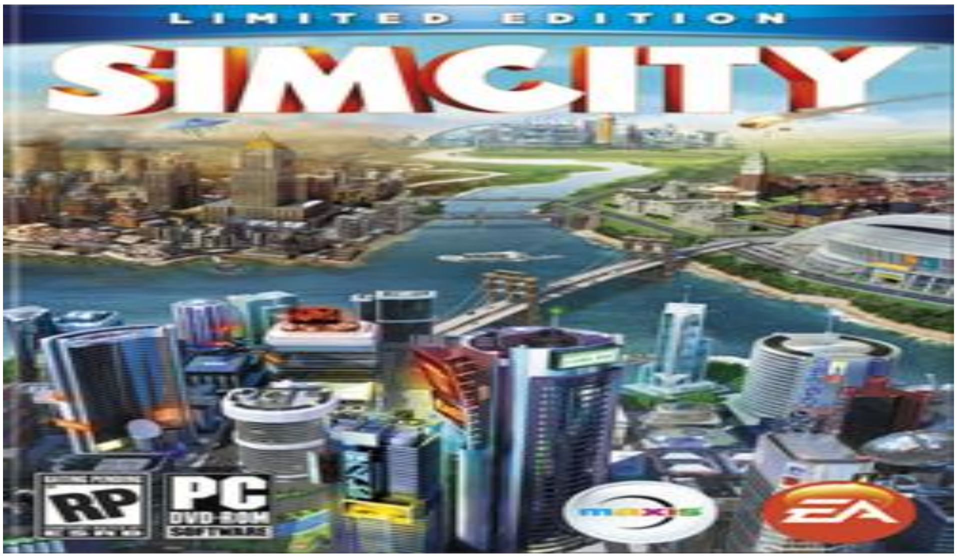


#3

This Nintendo 3DS game can be played by one or more gamers. The main character is Luigi, who is sent by Professor E. Gadd to explore abandoned haunted mansions and capture hostile ghosts using his specialised vacuum cleaner (Poltergust). At the end of each mission the player is scored based on treasures and ghosts collected.

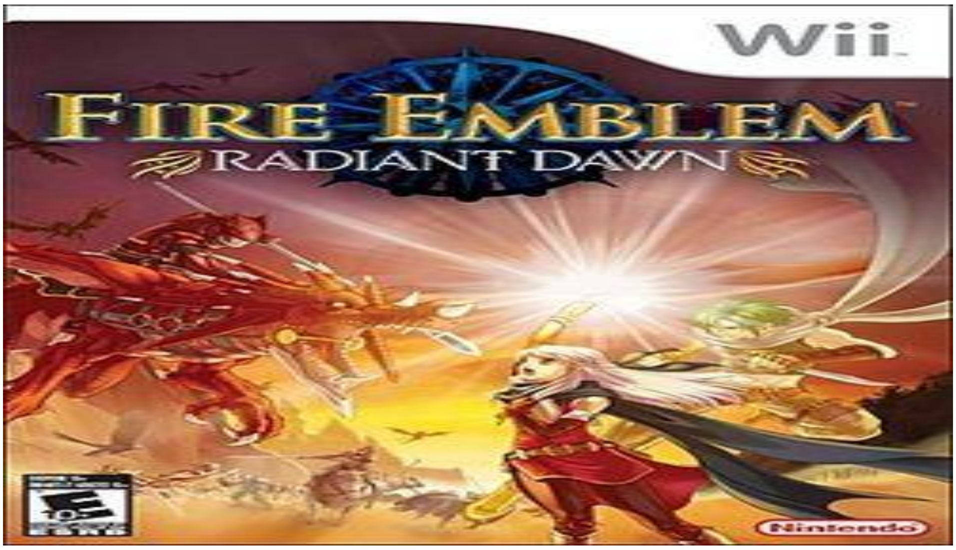
#4

This game is a Role Playing Game (RPG) which can be both single and multiplayer. It is centred on the Hunter as a stalker in the wild, living on the knowledge of survival and the skill of the bow or rifle. The Pet is also an important tool as a Trap for preys.



#5

SimCity is a Role Playing city-building computer and console video game. The player (acting as the mayor) must define the zones of the city, each having limits on the kind of development that can occur there. You are also given a budget with which to develop the city and you would have to keep to this budget. This game can be played in both single and multi-player mode to collaborate in developing the city.



#6

This is a tactical role playing game which is a single player mode. It is played on the Wii. The main character is Micaiah and her allies rebelling against the oppressive army of Begnion to restore the monarchy of Daein.

#7

This game can be played on the computer, Wii or Nintendo as a single or multiple player game. The Super Mario 3D world has four different playable characters: Mario, Luigi, Princess, Peach and Blue Toad. Each character possesses unique abilities. The player can select any of the four characters or play in collaboration in the multiplayer mode.

#8

This is a musical game which can be played on the Wii, Xbox 360 and PlayStation 3. Players are judges on their ability to mimic on-screen dancers performing a routine to a chosen song. This game can be single or multi-player mode.

#9

Toki Tori 2 is a single player mode game on the computer or Wii. Toki Tori manipulates the environment and the creatures within it using special skills like stomping and whistling.

#10

These rebel birds striking from a hidden base are fighting against evil imperial pigs. This game is available on PC, MAC, mobile and tablet devices. It is a single player mode game.

Card sort data collection sheet

Enter your assigned unique Ref. No, date and circle the appropriate information.

Ref No: Date: Age: 11,12,13,14 Gender: M/F

Do you play entertainment games? Yes No

Sort Number: _____

Criteria: _____________________________

Category or group name and corresponding card number(s):

Scale:
-
1______2______3_______4______5______6______7______8_____9_____
10

Sort Number: _____

Criteria: _____________________________

Category or group name and corresponding card number(s):

Scale:
-
1______2______3_______4______5______6______7______8_____9_____
10

APPENDIX 2

EXPLORATORY STUDY - PARTICIPANT INFORMATION GUIDE AND CONSENT DOCUMENTATION

University of Greenwich
School of Computing and Mathematical Sciences
Participants' Information sheet
(Research conducted by Osunde Joseph MPhil/PhD student University of Greenwich, London)

What is this study about?

The purpose of this study is to investigate the views of teenagers of age 11-14 years of a variety of video games (e.g. Just dance 4).

What do you want me to do?

We would like you to take part in an exercise that will take about 30 minutes to complete if you are comfortable with bright light as some of the game trailers might contain flashing lights. The structure of the exercise:

1. You will be allocated a unique number
2. There will be a short demonstration of the exercise (5-10 minutes) using cards. You can ask questions of the researcher if you are in doubt at any point
3. The exercise will require you to view a variety of game trailers (10)
4. You will be given a set of cards representing the games you have viewed
5. You will sort the cards representing the games into groups of your choice
6. You will go through the sorting process with the researcher
7. The researcher will note down the sorting procedure(s) you have carried out
8. The exercise should take 20-25 minutes to complete.

Please be assured that your anonymity is guaranteed. You have been allocated a unique number which cannot be traced back to you. You are not required to include your name in your feedback. You are only required to select your gender and age at the beginning of the exercise. Your answers will never be shared with your schools' staff, your parent or legal guardian and no attempt will be made to identify you. If at any time you wish to withdraw from the study, please inform your ICT teacher and you will be free to leave, no reasons need to be provided. Please be assured that your choice to participate or not in this exercise will have no effect on your studies.

What are you going to do with my answers?

The feedback you provide will be analysed and the data will be held securely by University of Greenwich in accordance with Data Protection laws until the expected date of completion of the research project- June 2016. We will keep the data for research purposes only and we intend to generate statistical information from this data. Some of the data we have gathered may be published as part of the project report; however individuals will not be identified and information will be kept confidential.

This project is supervised by:

Windall, G F
Principal Lecturer
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University of Greenwich
School of Computing and Mathematical Sciences

Participants' Parent/Legal guardian Information sheet

(Research conducted by Osunde Joseph MPhil/ PhD student University of Greenwich, London)

What is this study about?

The purpose of this study is to investigate the views of teenagers of age 11-14 years of a variety of video games (e.g. Just dance 4). All games used in this survey are certified by Entertainment Software Rating Board (ESRB) suitable for age 11-14.

What do we want you to do?

We would like you to read carefully the participant information sheet provided to your child or ward. The information sheet clearly informs you and your child/ward of the survey procedure. If you are pleased with this, we would like you to give your consent by signing this document.

Please be assured that the anonymity of your child/ ward is guaranteed. He/She will be allocated a unique number which cannot be traced back. He/She is not required to include names in the feedback. He/She is only required to provide details of gender and age at the beginning of the exercise. Answers will never be shared with the schools' staff and any other party. If at any time he/she wishes to withdraw from the study, the supervising staff should be informed and he/she will be free to leave. No reasons need to be provided. Please be assured that the choice to participate or not in this exercise will have no effect on studies. Some of the game trailers might contain flashing lights; hence the exercise will not be suitable for children with photo-epilepsy.

What are you going to do with the answers?

The feedback provided will be analysed and the data will be held securely by University of Greenwich in accordance with Data Protection laws until the expected date of completion of the research project- June 2016. We will keep the data for research purposes only and we intend to generate statistical information from this data. Some of the data we have gathered may be published as part of the project report; however individuals will not be identified and information will be kept confidential.

This project is supervised by:
Windall, G F
Principal Lecturer
University of Greenwich, London
Tel:02083318545
Fax: 02083318665
Email: G.F.Windall@gre.ac.uk

PARTICIPANT CONSENT FORM

To be completed by the participant. If the participant is under 18, to be completed by the parent / guardian / person acting *in loco parentis*.

- I have read the information sheet about this study
- I have had an opportunity to ask questions and discuss this study
- I have received satisfactory answers to all my questions
- I have received enough information about this study
- I understand that I am / the participant is free to withdraw from this study:
    - At any time
    - Without giving a reason for withdrawing
    - (If I am / the participant is, or intends to become, a student at the University of Greenwich) without affecting my / the participant's future with the University
- I understand that my research data may be used for a further project in anonymous form, but I am able to opt out of this if I so wish, by ticking here. ☐
- I agree to take part in this study ☐

Signed (participant)	Date
Name in block letters	
Signed (parent / guardian / other) (if under 18)	Date
Name in block letters	
Signature of researcher	Date

This project is supervised by:

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APPENDIX 3

EXPLORATORY STUDY- DATA ANALYSIS BY LOCATION

3.1 Location 1

Survey location 1 is a mixed gender secondary school with a sample size of eight participants comprising of four girls and four boys of ages 11-14 year old. The mean age for the girls and boys was 12.5 years. A total of 37 constructs were generated from both genders ($N_{Total\ Constructs} = 37$). The boys participants generated 19 constructs in total ($n_{boys\ constructs} = 19$; $Mean_{construct\ frequency} = 1.19$; $Median_{construct\ frequency} = 1.00$; $SD = 0.981$; 50 $percentile_{construct\ frequency} = 1.00$ and 75 $percentile_{construct\ frequency} = 2.00$).

The girls participants generated 18 constructs in total ($n_{girls\ constructs} = 18$; $Mean_{construct\ frequency} = 1.08$; $Median_{construct\ frequency} = 1.00$; SD 0.977; 50 $percentile_{construct\ frequency} = 1.00$ and 75 $percentile_{construct\ frequency} = 2.00$). A detailed representation of the descriptive statistics of location 1 data is illustrated on table 1.0.

		Superordinate Construct	Girls	Boys
N	Valid	26	26	26
	Missing	0	0	0
Mean			1.08	1.19
Median			1.00	1.00
Mode			1	1
Std. Deviation			.977	.981
Skewness			.953	.411
Std. Error of Skewness			.456	.456
Kurtosis			1.571	-.715
Std. Error of Kurtosis			.887	.887
Range			4	3
Percentiles	25		.00	.00
	50		1.00	1.00
	75		2.00	2.00

Table 3.0. Descriptive statistical analysis of location 1

Due to the small sample size of the exploratory study, the mean and standard deviation variances were not significant. Furthermore, the skewness (0.90) information indicate that the data is approximately normally distributed for the boys where the Standard Error (SE) =0.456. The data for the girls is also not approximately normally distributed for skewness (2.09) where the SE = 0.456. However, both girls and boys distributions were kurtotic where the z values are 1.77 and -0.806 respectively (Doane & Seward, 2011).

Table 1.2 presents an overview of the total constructs generated by girls and boys participants. The frequency of each construct is also presented in the table. The frequency value *zero (f=0)* indicates constructs that were identified from one gender but absent from the responses of the other gender.

Construct No	Superordinate Construct	Girls frequency	Boys frequency
1	Gameplay levels	1	0
2	Adventure	2	0
3	Popularity	2	2
4	Colour used	2	1
5	Storyline of game	2	0
6	Scenery	2	0
7	Mission	1	1
8	Action	0	3
9	Rewards	0	2
10	Graphics view	0	1
11	Graphics	2	3
12	Game duration	0	1
13	Age appropriateness	2	2
14	Number of Players	2	2
15	Gaming device	0	1
16	Creativity	0	1
17	Role Play	1	1
18	Movement	1	2
19	Control	1	1
20	Fonts	0	1
21	Audio	1	0
22	Fun	4	3
23	Violence	1	1
24	Use of animals and creatures	1	0
25	Game quality	0	1
26	Layout	1	0

Table 3.1. Construct frequency by gender for location 1

A number of verbatim agreements (i.e. similar words used for the same constructs) were identified from the superordinate constructs and six verbatim constructs were recorded for this location. Table 1.3 illustrates the verbatim constructs, frequency, average significance scale and gender information for location 1

Construct No	Superordinate Construct	Verbatim construct	Frequency	Average significance scale	Gender
1	Adventure	Adventure	2	7.50	Female, Female
2	Popularity	Popularity	2	6.50	Female, Male
3	Mission	Mission	2	8.50	Female, Male
4	Graphics	Graphics	2	7.00	Female, Male
5	Role Play	Role play	2	4.00	Female, Male
6	Violence	Violence	2	5.50	Female, Male

Table 3.2. Verbatim constructs for location 1

The frequency of the generated constructs was then analysed to identify the variability in the sample population from this location. The deviation from the central tendency (median) was minimal with a distinct upper quartile and outliers which were the most popular constructs for the location.

The illustration in figure 1.0 presents the boys constructs from location 1. The frequencies of the constructs are presented and the chart clearly indicates the lower, median, upper quartile and outliers for boys construct frequency.

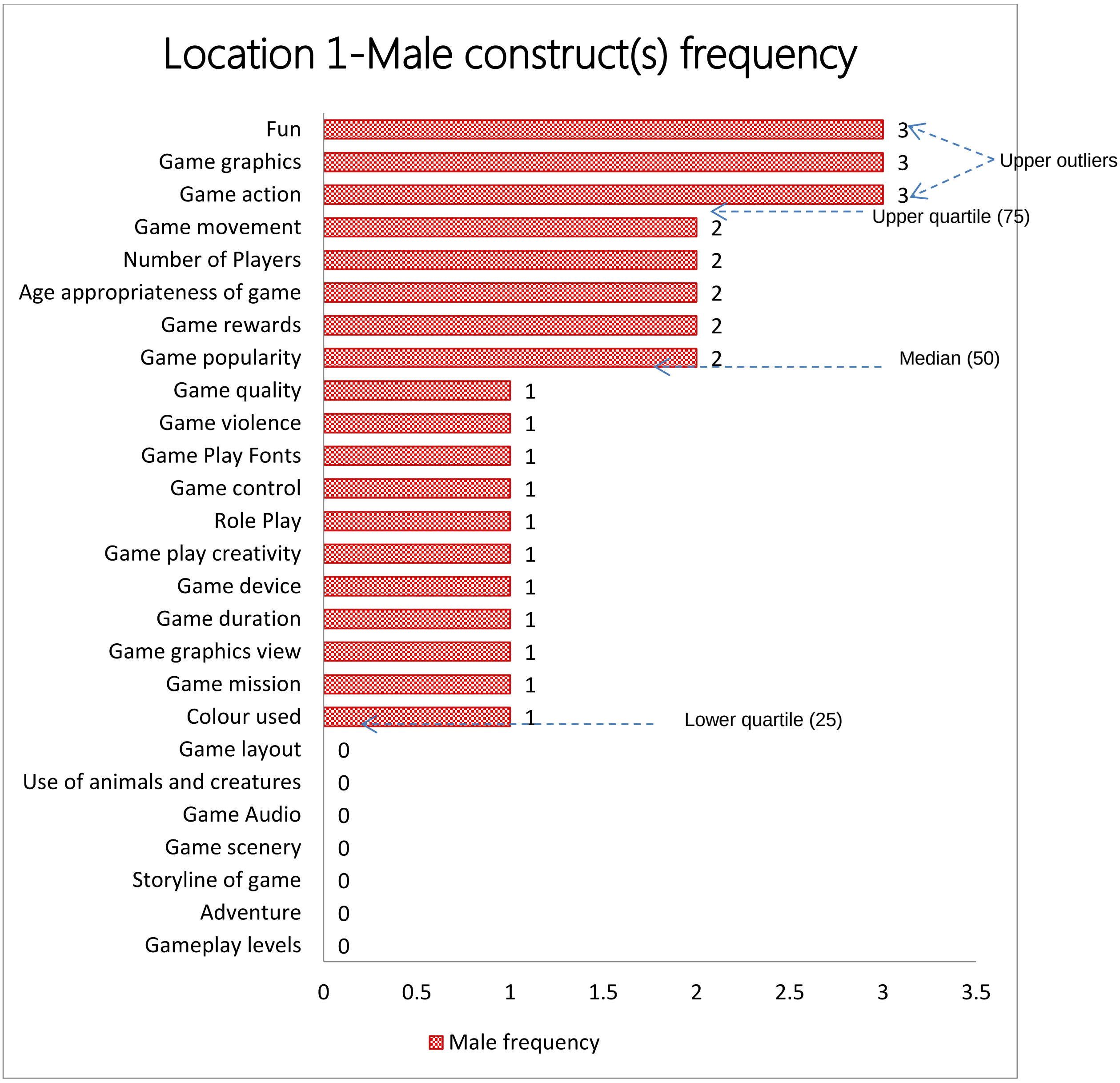

Figure 3.1. Male participants (location 1) construct frequency

A similar analysis for female participants is illustrated in figure 1.2 indicating the lower, median, upper quartile and outliers for girls construct frequency. There is an observed wider spread of variability as compared to the male participants. This might explain the skewed nature of the data as indicated previously. A number of similarities were identified between both genders with the outliers and upper quartile constructs. The similarities in constructs for these include fun, graphics, the number of players and popularity of the game. The differences between both genders were age appropriateness, reward, game mission, colour, storyline and adventure.

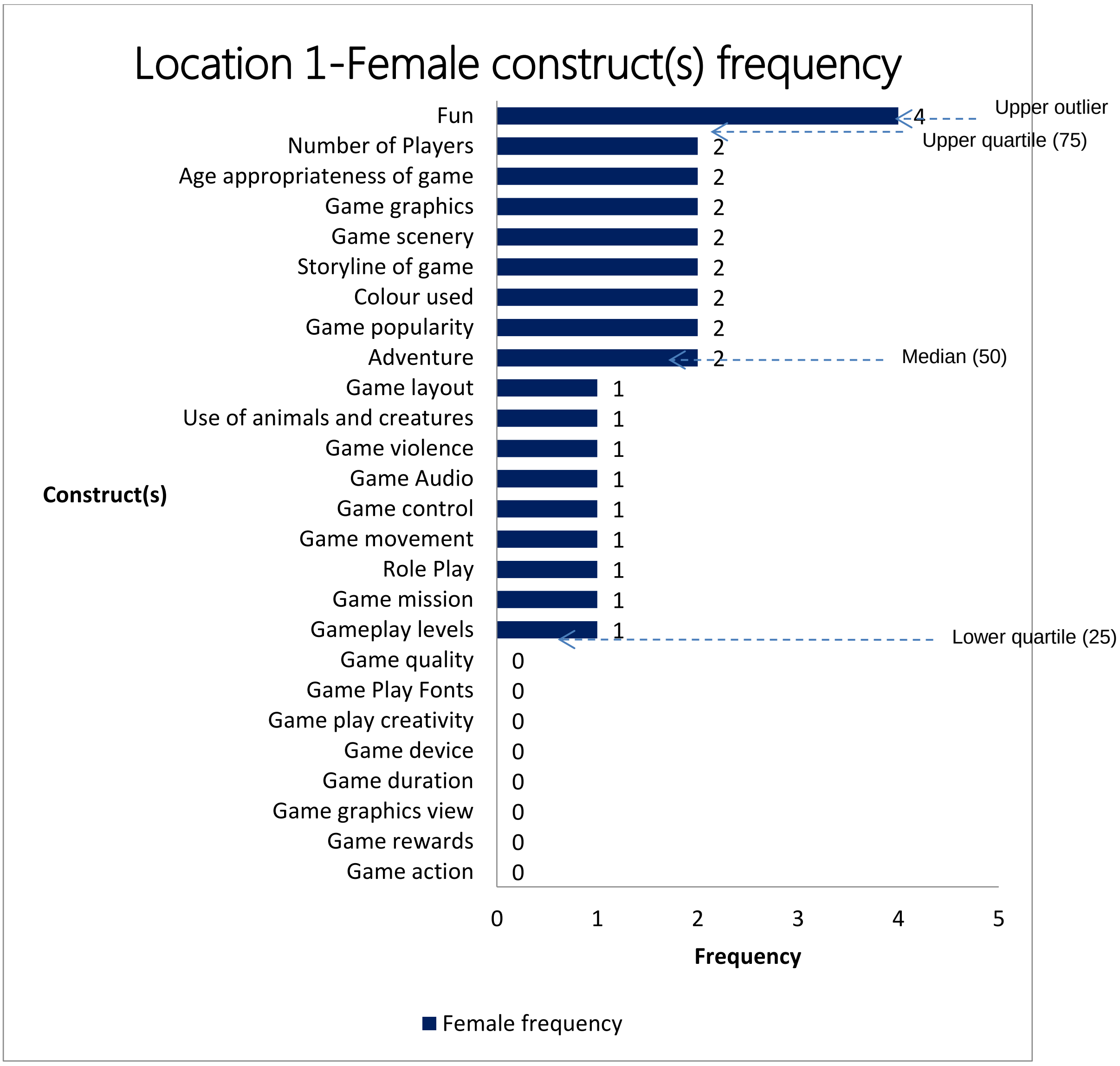

Figure 3.2. Female participants (location 1) construct frequency

Furthermore, the average significance scale for constructs generated by the boys' participants was also analysed. The scale values out of 10 indicated the level of significance attached to the constructs generated by the participants for location 1. Figure 1.3 illustrates the analysis of the data collected for boys' participants from this location. On the basis of this analysis, game colour, game duration, game device and fun were in the upper category. Game graphics, mission, rewards and movement were in the next most significant category based on the values.

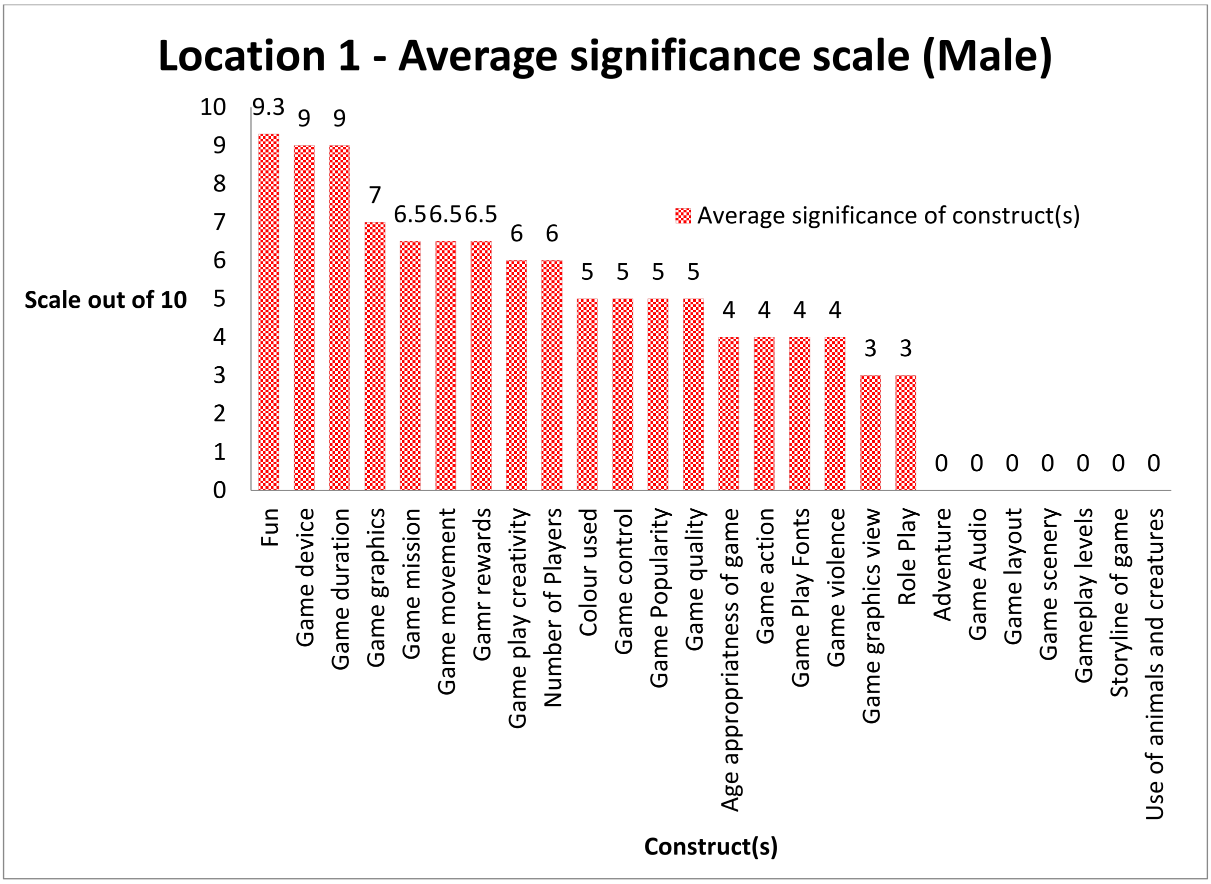

Figure 3.3. Male construct average significance scale out of 10

A similar analysis conducted for the girls' participants is presented in figure 1.4. In the most significant category, gameplay levels, game layout, game popularity, mission, scenery, movement, control, use of animals and creatures and fun were identified. The next most significant category included characteristics such as colour, storyline, graphics, age appropriateness, audio and violence.

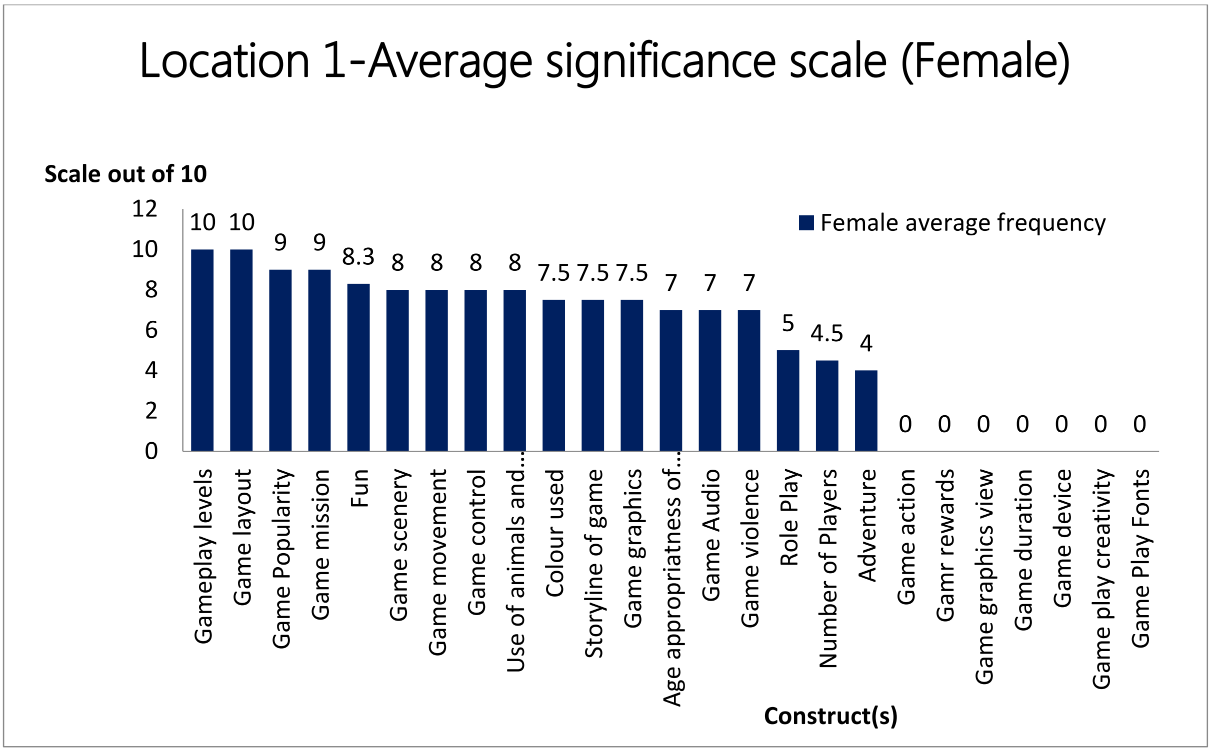

Figure 3.4. Female construct average significance scale

A combination of the frequency of the constructs generated by male and females from the location was produced and analysed. The result is illustrated in figure 1.5. The data indicated that game popularity, the number of players, graphics and fun are significant to both genders from this location.

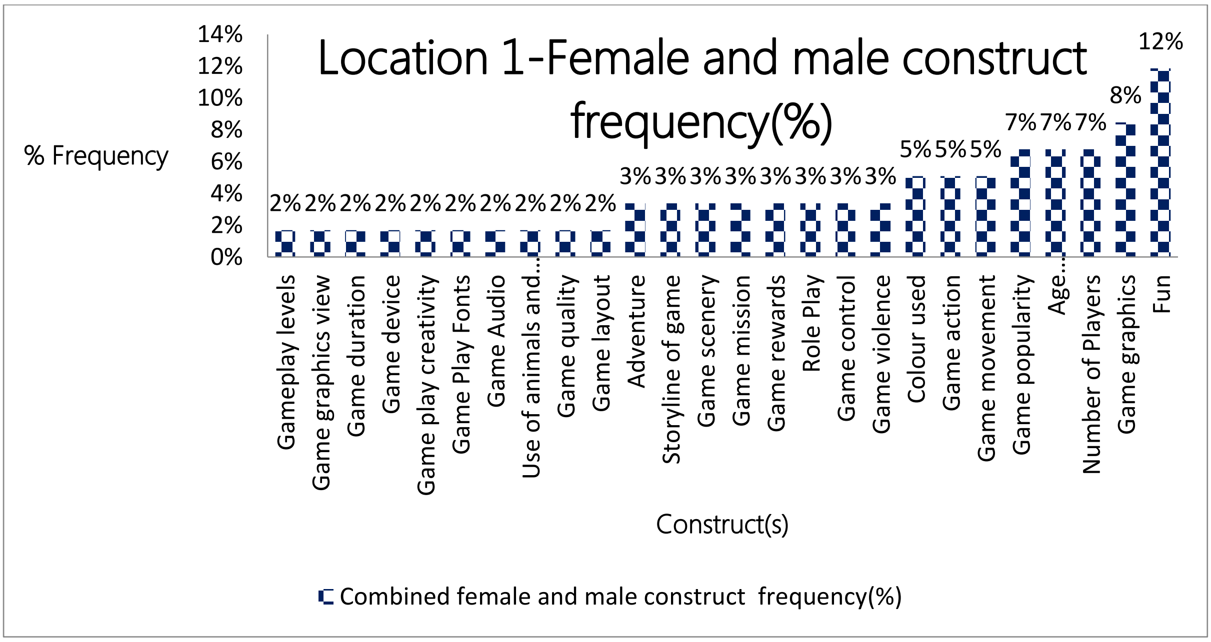

Figure 3.5. Female and male combined construct frequency percentage

3.2 Location 2

This survey location is another mixed gender secondary school with a sample size of eight participants between the ages of 11-14. The distribution of participants for this location was similar to location 1. The mean age of girls and boys participants was 12.5 years old. A total of 40 constructs were generated from both genders ($N_{Total\ Constructs} = 40$). The boys participants generated a total of 17 constructs ($n_{boys\ constructs} = 17$; *Mean* $_{construct\ frequency} = 0.77$; *Median* $_{construct\ frequency} = 1.00$; $SD = 0.88$; *50 percentile* $_{construct\ frequency} = 1.00$ *and 75 percentile* $_{construct\ frequency} = 1.00$).

The girls participants generated a total of 24 constructs ($n_{girls\ constructs} = 24$; Mean $_{construct\ frequency} = 1.10$; Median $_{construct\ frequency} = 1.00$; SD=0.98; 50 percentile $_{construct\ frequency} = 1.00$ and 75 percentile $_{construct\ frequency} = 1.00$). A statistical analysis of location 2 is illustrated on table 4.10.

		Superordinate Construct	**Girls**	**Boys**
N	Valid	31	31	31
	Missing	0	0	0
Mean			1.10	.77
Median			1.00	1.00
Mode			1	0
Std. Deviation			.978	.884
Skewness			1.166	1.096
Std. Error of Skewness			.421	.421
Kurtosis			1.634	.746
Std. Error of Kurtosis			.821	.821
Range			4	3
Percentiles	25		.00	.00
	50		1.00	1.00
	75		1.00	1.00

Table 3.3. Statistical analysis of location 2

From the analysis of the data, both girls and boys distributions are significantly skewed i.e. girls (2.770) and boys (2.603) hence not normally distributed. The data distribution for both girls and boys for this location was also kurtotic i.e. girls (1.990) and boys (0.909). Table 1.5 presents an overview of the total superordinate constructs generated by boys' and girls' participants. The frequency of each construct is also presented in the table. The frequency value *zero (f=0)* indicates constructs that were identified from one gender but absent from the responses of the other gender.

Construct No	Superordinate Construct	Girls frequency	Boys frequency
1	Action	0	2
2	Adventure	0	1
3	Age appropriateness	2	0
4	Character	4	1
5	Colour used	2	0
6	Competition	1	0
7	Complexity	1	0
8	Fun	1	1
9	Audio	0	1
10	Brand	1	0
11	Control	1	2
12	Game environment	0	1
13	Graphics	0	3
14	Movement	1	0
15	Progression	1	0
16	Rewards	1	1
17	Game series	1	0
18	Game type	1	1
19	Violence	3	1
20	Gaming device	3	2
21	Gender based	1	0
22	Internet	1	0
23	Number of players	2	1
24	Play location	0	1
25	Popularity	1	0
26	Price of game	1	0
27	Mission	0	1
28	Role Play	1	1
29	Software platform	1	0
30	Software update	1	0
31	Storyline	2	3

Table 3.4. Construct frequency by gender

Verbatim constructs generated for location 2 is illustrated in table 1.6. In total, seven verbatim constructs with frequency and average significance scale shown in the table.

Construct No	Superordinate Construct	Verbatim construct	Frequency	Average significance scale	Gender
1	Colour used	Colours	2	7.00	Female, Female
2	Number of players	No of players	3	7.00	Female, Female, Male
3	Reward	Rewards	2	9.00	Female, Male
4	Violence	Violence	4	6.75	Female, Female, Female, Male
5	Action	Action	2	6.50	Male, Male
6	Gaming device	device	3	8.00	Female, Female, Male
7	Storyline	Storyline	4	7.25	Female, Female, Male, Male

Table 3.5. Verbatim constructs for location 2

Figure 1.6 illustrates the male constructs frequency for location 2. The lower, median and the upper quartile construct are indicated. The upper outliers' constructs are also presented in the illustration with a range of values (3).

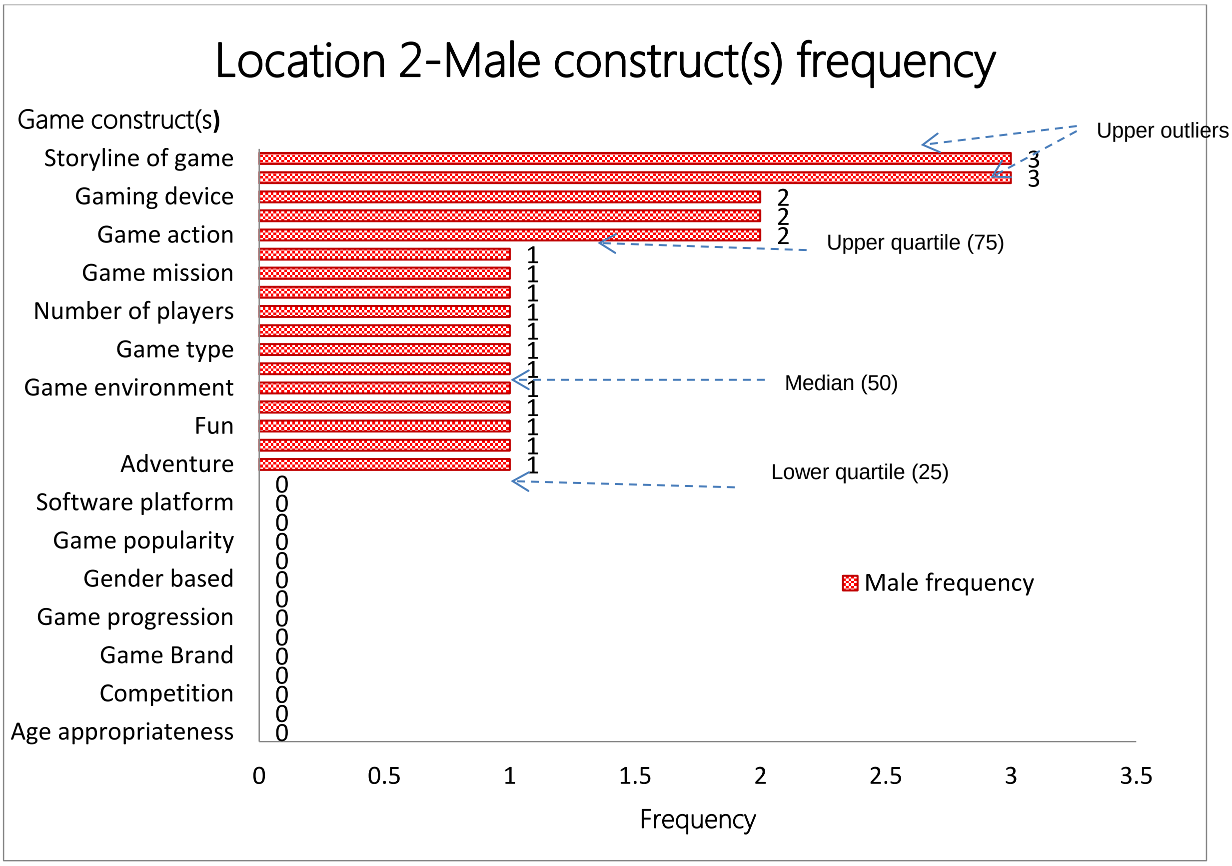

Figure 3.6. Male participants construct(s) frequency from location 2

The distribution and composition of female constructs in location 2 is also presented in figure 1.7. The quartile values and the range of upper outliers (4) are also illustrated.

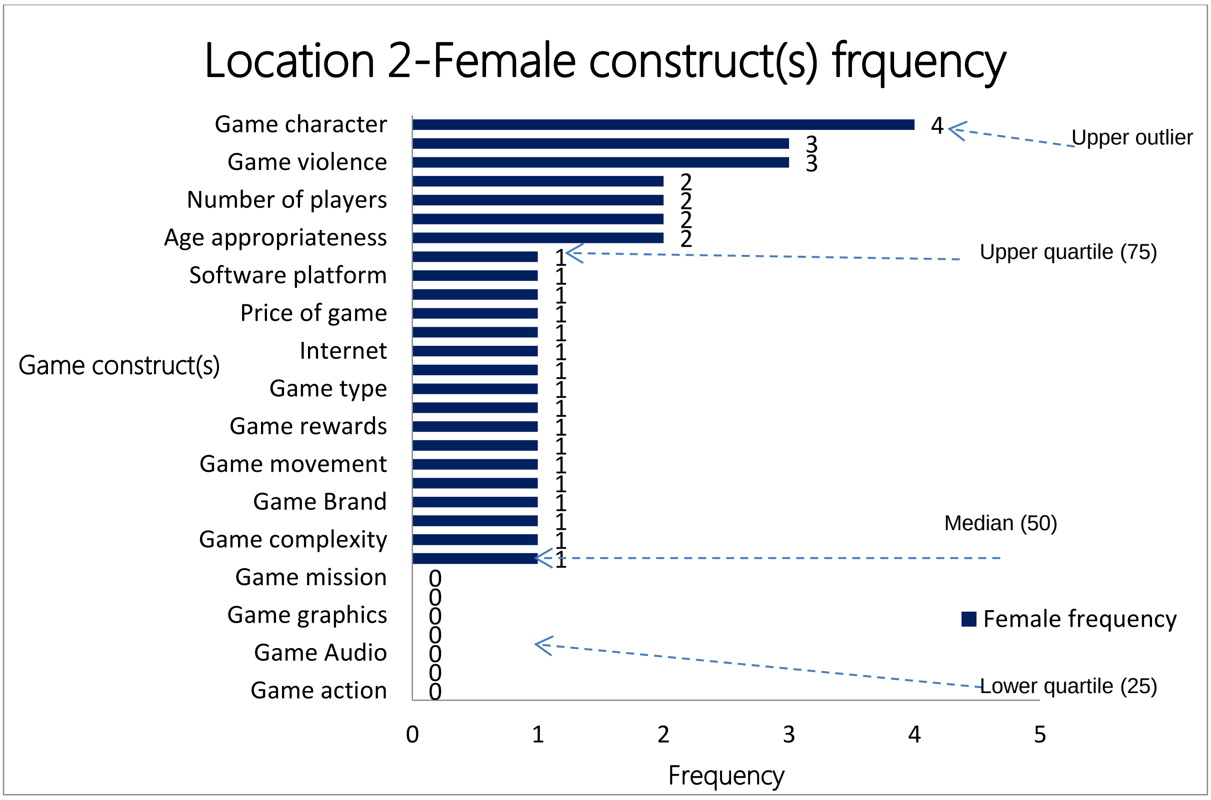

Figure 3.6. Female participants construct(s) frequency from location 2

For location 2, there is also a wider variability between constructs for the girls than the boys. A comparison of the girls and boys construct frequency charts show some similarity of constructs in the upper quartile and the outliers. The similar constructs in these categories were game storyline and device. The differences for this category were game graphics, game control and action for the boys; game violence, number of players, colours and age appropriateness for the girls.

Figure 1.8 illustrates the average significance scale values for male constructs generated by participants in location 2.

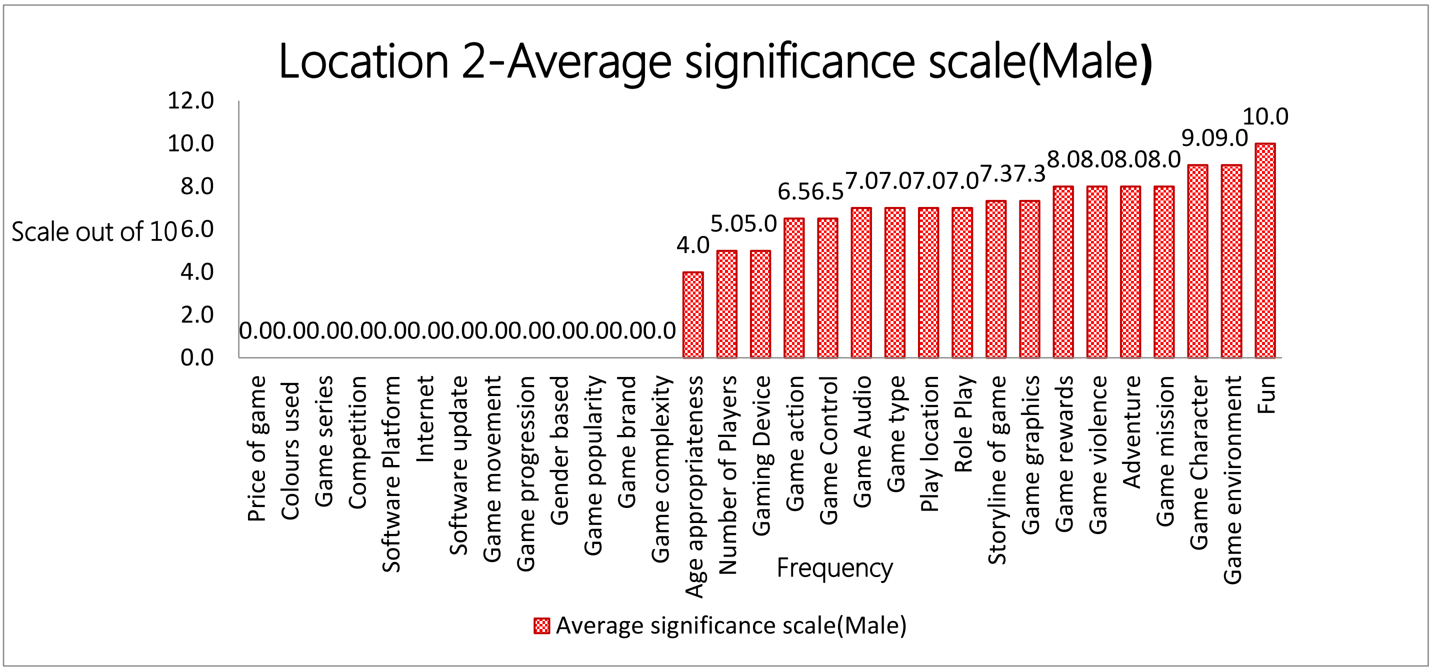

Figure 3.7. Male construct average significance scale

The analysis of the data indicated that fun, game character, game environment, quest, adventure, violence and game rewards are in the upper category for boys' participants.

The analysis conducted for the girls' participants is presented in figure 1.9. The constructs with the highest average values included game rewards, fun, device, brand, type, movement, software update, competition, the number of players and storyline. The next most significant characteristics based on average values were game popularity, gender based games, age appropriateness, game series and colours used.

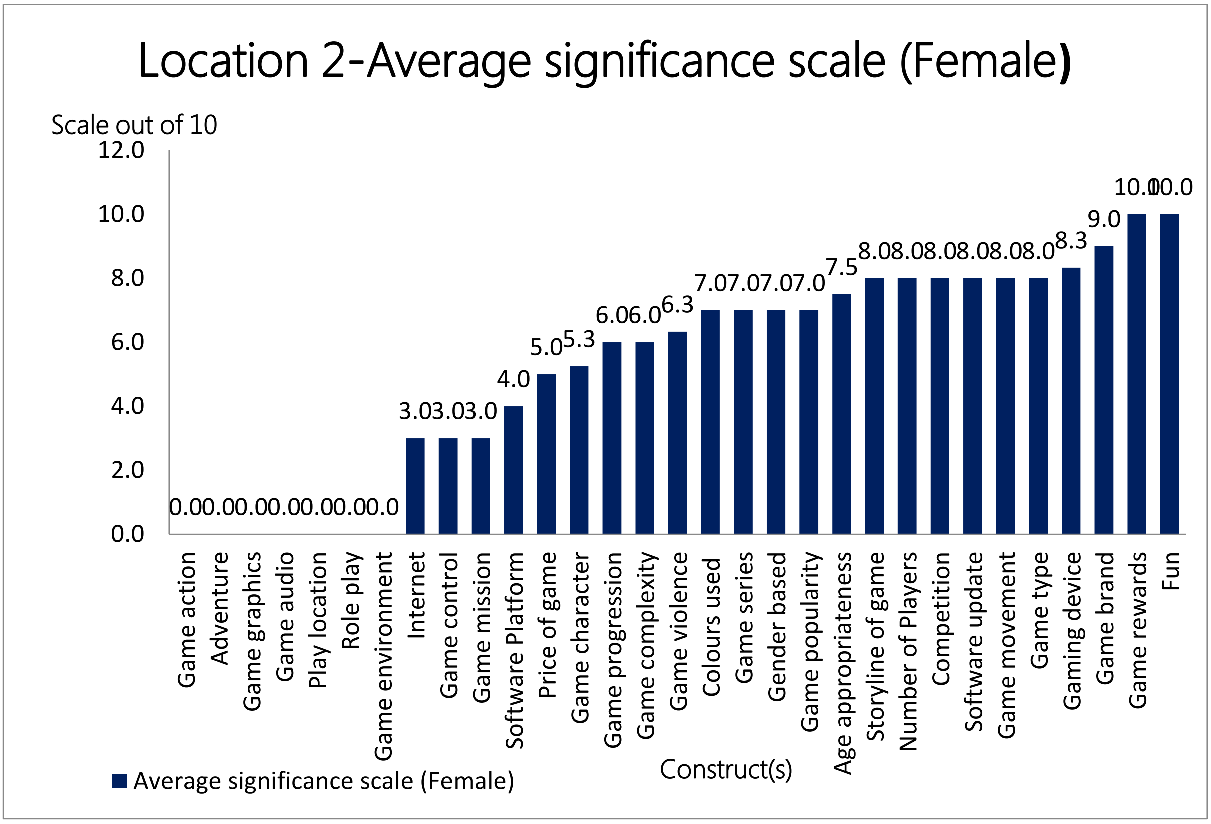

Figure 3.8. Female construct average significance scale

A combined girls and boys average frequency values were calculated for location 2 and the result is presented in figure 1.11. The constructs with the highest average values were game device, violence, character and storyline.

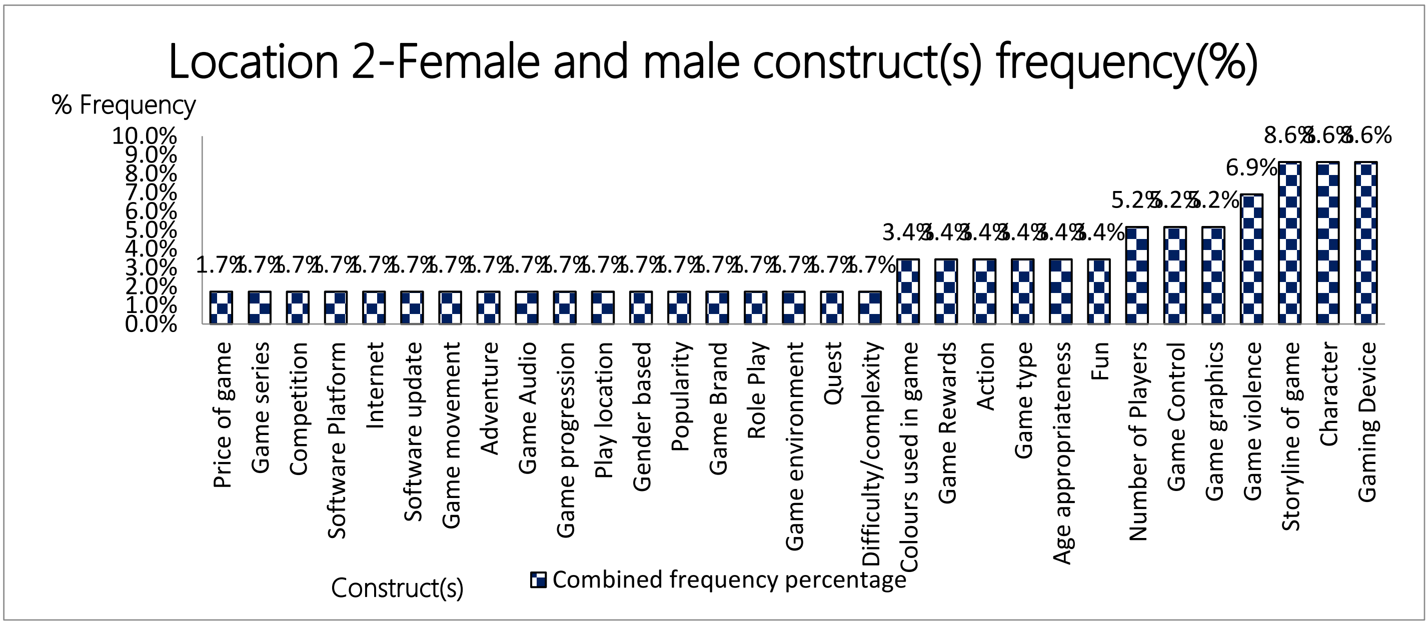

Figure 3.9. Female and male combined construct frequency percentage for location 2

3.3 Location 3

Location 3 is a single gender girls' secondary school with a sample size of eight participants, comprising of eight girls of ages 11-14 year old with a mean age of 12.5 years. A total of 29 constructs were generated from the single gender location ($N_{Total\ Constructs} = 29$). The statistical value of the constructs ($Mean_{construct\ frequency}$=1.83; $Median_{construct\ frequency}$=1.00; SD=1.28; 50 $percentile_{construct\ frequency}$ =1.00 and 75 $percentile_{construct\ frequency}$ =2.50).

		Superordinate Construct	Frequency
	Valid	29	29
	Missing	0	0
Mean			1.83
Median			1.00
Mode			1
Std. Deviation			1.284
Skewness			1.433
Std. Error of Skewness			.434
Kurtosis			.908
Std. Error of Kurtosis			.845
Range			4
	25		1.00
Percentiles	50		1.00
	75		2.50

Table 3.6. Statistical analysis of location 3

The analysis of the data distribution for skewness indicated that the girls (3.301) data was skewed hence not significantly normally distributed. Furthermore, the analysis for kurtosis indicated that the data is also kurtotic.

Table 1.8 illustrates the superordinate constructs generated at location 3 and their corresponding frequency within the sample group. The table clearly indicated the important or most significant constructs with the population.

Construct No	Superordinate Construct	Female frequency
1	Age appropriateness	4
2	Appeal	1
3	Based on character mission	1
4	Challenge	1
5	Colour used	3
6	Control	1
7	Creativity	2
8	Gaming device	2
9	Ease of use	1
10	Educational content	1
11	Feedback	1
12	Violence	4
13	Fun	3
14	Scenery	1
15	Gendered game	1
16	Graphics	5
17	Gameplay levels	2
18	Movement	3
19	No of players	5
20	Player involvement (physical)	1
21	Game powers (improves ability to play)	1
22	Mission	2
23	Game objective	1
24	Rebellion	1

25	Rewards	1
26	Role play	1
27	Screen dialogue	1
28	Audio (soothing & relaxing)	1
29	Storyline	2

Table 3.7. Construct frequency for location 3

From the superordinate constructs, the verbatim constructs were identified. The total number of verbatim constructs generated for location 3 was seven. Table 1.9 presents the verbatim constructs generated, frequency distribution, average significance scale.

Construct No	**Superordinate Construct**	**Verbatim construct**	**Frequency**	**Average significance scale**
1	Fun	Fun	2	10.00
2	Violence	Violence	3	4.33
3	Colour used	Colour	3	7.33
4	Graphics	Graphics	2	8.00
5	Age appropriateness	Age appropriate	2	8.50
6	No of players	No of players	4	6.75
7	Mission	Mission	2	6.50

Table 3.8 Verbatim construct s for location 3

Figure 1.12 illustrates the girls construct distribution and frequency for location 3. The illustration also includes the lower, median and upper quartiles. The upper outliers' values are also indicated.

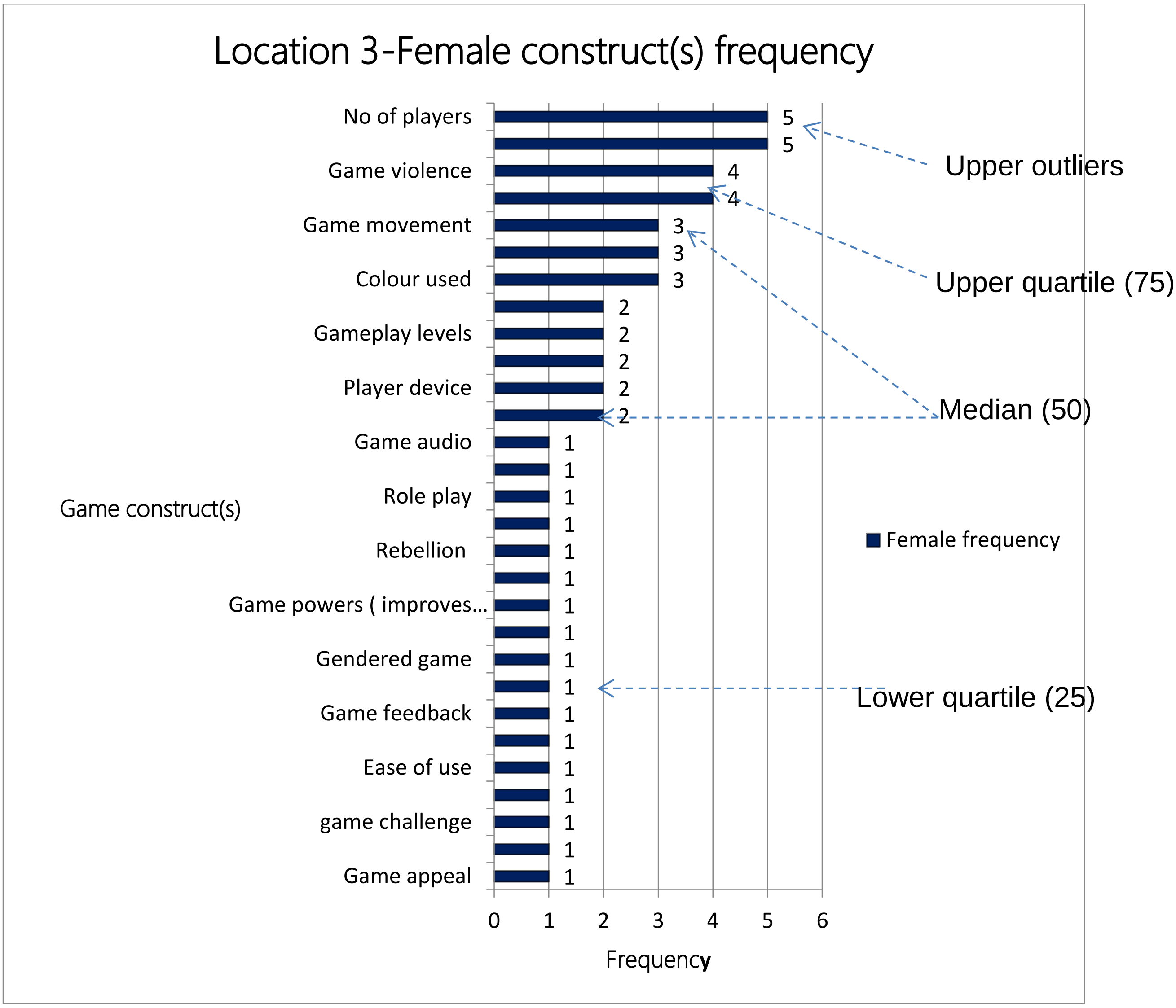

Figure 3.10. Female participants construct(s) frequency from location 3

The variability between the construct frequencies was high. The outliers and upper quartile constructs were the number of players, game graphics, fighting, age appropriateness, movement, fun, colour and quest.

Figure 1.13 presents the average significance values of the constructs generated in this location. The constructs with the highest average values included game fun, objective/purposefulness, game control, ease of use, movement and educational content. Other constructs with high average values included age appropriateness, screen dialogue, storyline, appeal, player device and feedback.

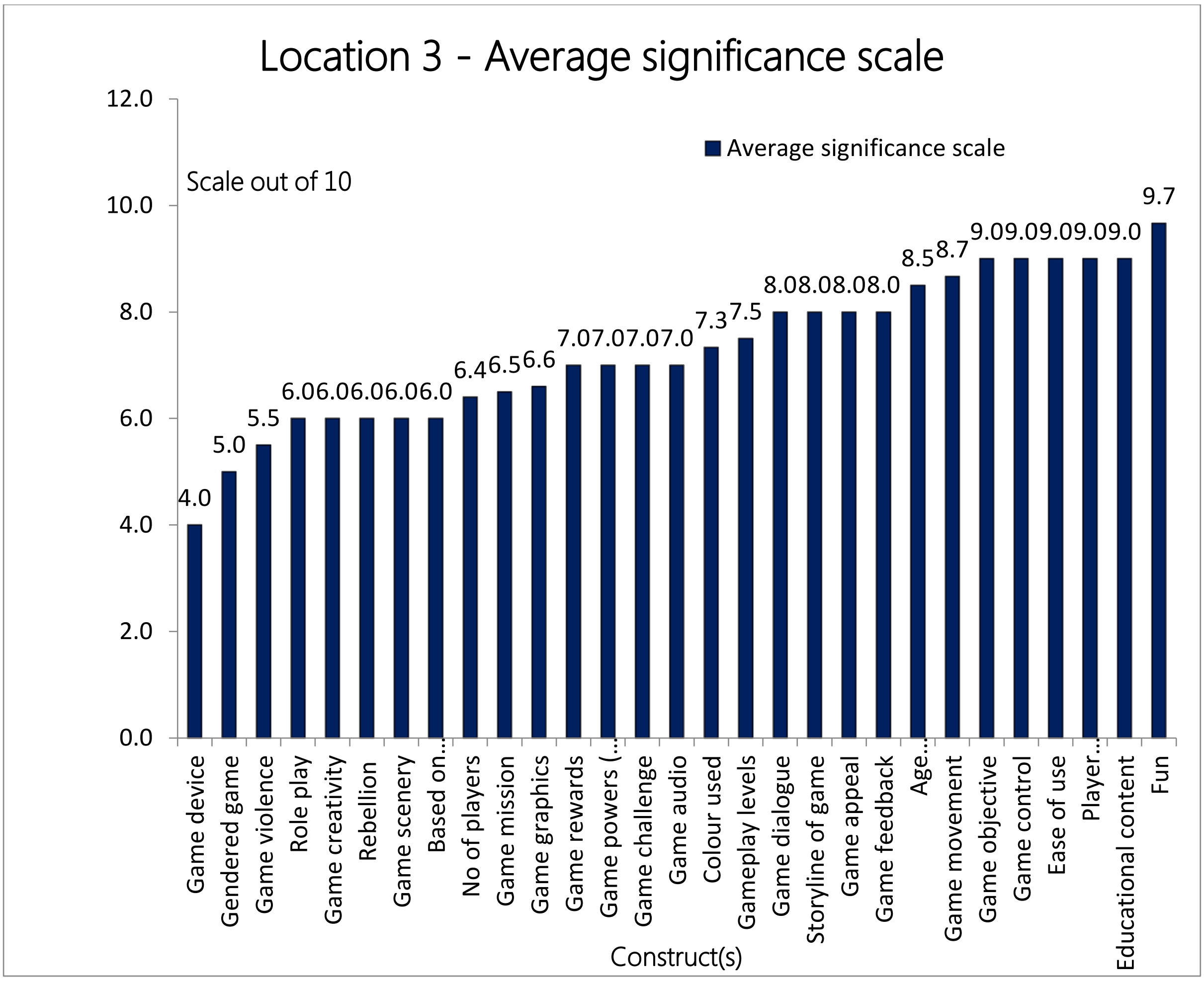

Figure 3.11 Female construct average significance scale for location 3

3.4 Location 4

This location is another single gender girls' school with a sample size of eight participants between the ages of 11-14 year old. The total number of constructs generated was 24 ($N_{Total\ Constructs} = 24$) from this location. The statistical value of the constructs ($Mean_{construct\ frequency}$=2.63; $Median_{construct\ frequency}$=2.50; SD=1.47; 50 $percentile_{construct\ frequency}$ =2.50 and 75 $percentile_{construct\ frequency}$ =4.00).

		Superordinate Construct	Female frequency
N	Valid	24	24
	Missing	0	0
Mean			2.63
Median			2.50
Mode			1
Std. Deviation			1.469
Skewness			.271
Std. Error of Skewness			.472
Kurtosis			-1.376
Std. Error of Kurtosis			.918
Range			4
Percentiles	25		1.00
	50		2.50
	75		4.00

Table 3.9. Statistical analysis of location 4

From the analysis of the data distribution, it is not significantly skewed (0.574) and the kurtotic value of 1.263 is not significant.The superordinate construct table indicates that game fun, game popularity, violence, the number of players, graphics and appropriateness of the game are significant constructs for the age group sampled.

Construct No	Superordinate Construct	Female frequency
1	Role play	2
2	Objective	3
3	Fun	5
4	Violence	4
5	Colour used	3
6	Theme	1
7	Graphics	4
8	Age appropriateness	4
9	No of players	5
10	Dialogue	4
11	Gameplay levels	3
12	Feedback	1
13	Rewards	1
14	Challenge	2
15	Storyline	3
16	Audio	2
17	Gaming device	1
18	Player involvement	1
19	Character	2
20	Title	1
21	Game scenery	2
22	Game popularity	5
23	Game complexity	4
24	Software platform	1

Table 3.10. Construct frequency for location 4

From the superordinate constructs data, nine verbatim constructs were generated in this location. Table 1.11 presents the data including the frequency and the average significance of the verbatim constructs.

Construct No	Superordinate Construct	Verbatim construct	Frequency	Average significance scale
1	Fun	Fun	4	10.00
2	Violence	Fighting	3	6.00
3	Popularity	Popularity	4	8.80
4	Graphics	Graphics	2	7.20
5	Age appropriateness	Age	3	9.00
6	No of players	No of players	4	8.50
7	Objective	Aim of game	2	8.00
8	Complexity	How difficult	2	9.00
9	Dialogue	Dialogue	2	6.75

Table 3.11. Verbatim construct s for location 4

Figure 1.15 presents the superordinate constructs from location 4 and their frequencies. The illustration also indicates the lower, median, upper quartiles and the upper outliers' values. The varied range of values is also presented from the chart, indicating the frequencies of the constructs.

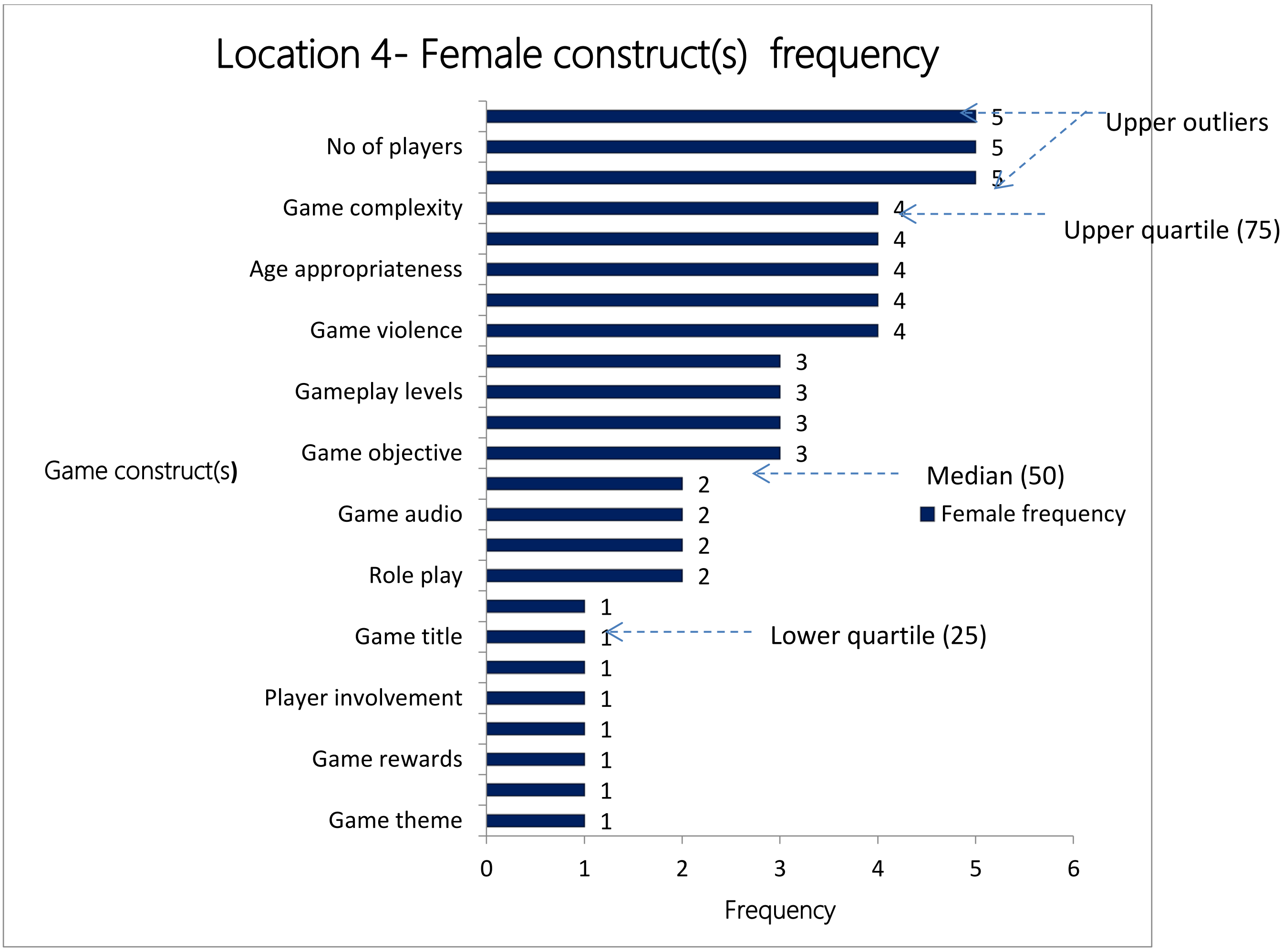

Figure 3.12. Female constructs and frequency for location 4

The constructs that occurred in the outliers and upper quartiles were game popularity, the number of players, fun, the game complexity, age appropriateness, game graphics, violence, game storyline, levels of play, colour and game objective.

The average significance values for constructs were also analysed for this location in figure 1.16. The constructs with the highest average values were game fun, complexity, popularity, age appropriateness and the number of players. The higher average value constructs included game objective, violence, dialogue, gameplay levels and game device.

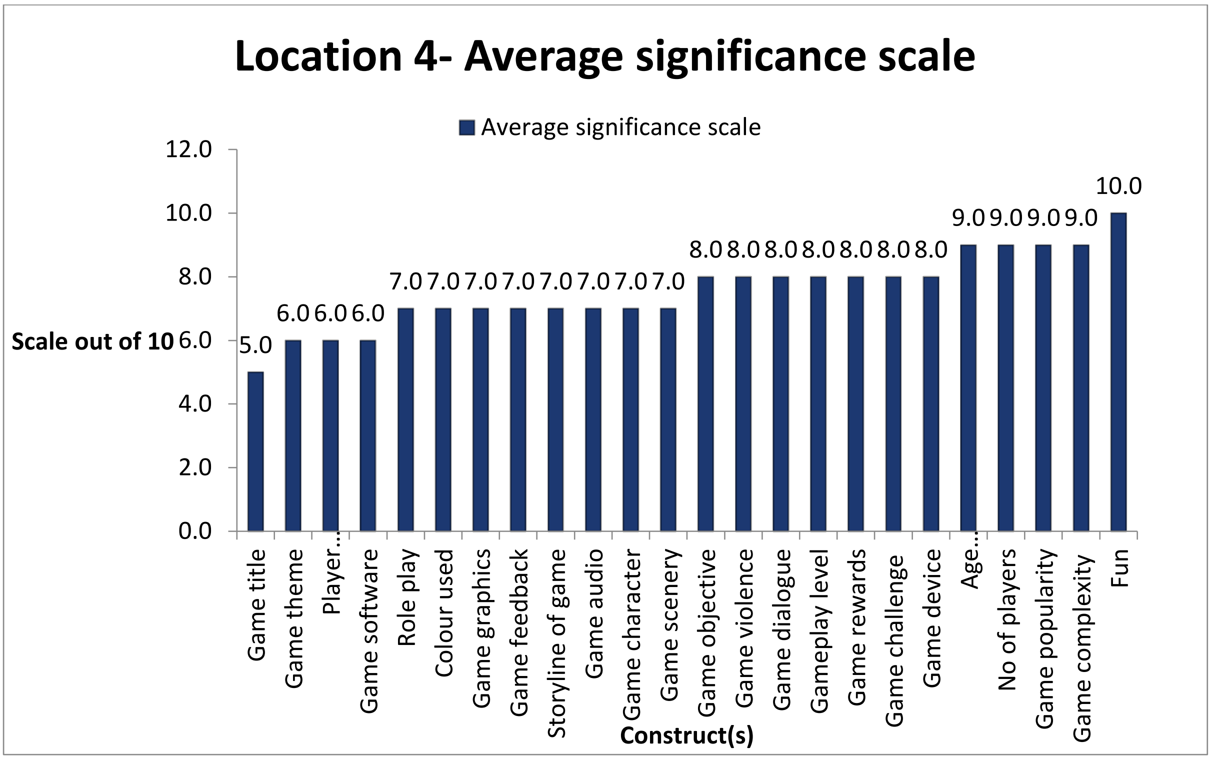

Figure 3.13. Female participants construct(s) average significance from location 4

APPENDIX 4
EXPLORATORY STUDY -LIKELIHOOD DATA TABLE

Female Likelihood data table where Female (N=24)					
Game construct #	**Construct**	**Significant Category**	**Likelihood %**	**Weighted Likelihood**	**Analysis comment**
1	Adventure	Excellent, Good, Moderate and Poor and No adventure	25.0, 50.0, 33.3, 2.1 & 0.00	5.0, 20.0, 5.0, 2.0 & 1.1	5 categories identified with good adventure the most appealing.
2	Age appropriateness	All ages/ Everybody, 12, 11-12, 11, 14, 13-14, 12-14, 12-13, 13, 11-14 & 11-13.	100.0, 60.2, 61.0, 62.0,65.0,63.0, 60.0,59.9,63.1, 60.8 &62.4	93.7, 56.2, 51.0, 52.0,55.0,43.0, 40.0,39.9,43.1, 45.2 & 32.4	10+ categories with all ages the most appealing construct.
3	Colour used	Very bright, bright, not so bright, dark, not so dark and very dark colours.	70.3, 83.5, 60.2, 40.1, 30.0, & 2.1	65.0,70.1, 30.4,30.1 & 4.4	6 categories with bright colours the most appealing construct.
4	Challenge	Very challenging, Moderately challenging and Not challenging	0.00, 66.7 & 33.3	0.00, 44.4 & 8.3.	3 categories for Challenging construct with moderate challenge as the most appealing.
5	Rewards	Progression, items & points	58.4, 50.0 & 29.0	38.5, 29.0 & 8.5.	3 categories identified with progression as the most appealing construct.
6	Competition	Highly competitive, moderately competitive and no competition.	25.0, 25.0 & 25.0	8.3,25 & 4.2	3 categories identified with moderate competition the most appealing construct.
7	Game control	Full control, moderate control, some control & no	38.9, 41.7, 39.1 & 11.1	12.9 ,20.8 , 19.3 & 2.2	Moderate control as the most appealing construct.

		control.			
8	Gameplay creativity	Highly creative, Moderately creative and No creativity.	100.0, 87.5 & 0.0	37.5, 32.1& 1.1	3 categories for creativity, with highly creative most appealing.
9	Game device	None Portables, Portables, Specialised and Any device.	20.6 ,45.8, 37.1 & 52.2	16.9, 18.6,14.6 & 22.2	4 categories with any device as the most appealing construct.
10	Complexity	Complex, Moderately complex and Not complex.	0.0, 25.0& 50.0.	0.0, 8.3 &20.0	3 categories for the complexity of game (plot, mission etc.) with the Not complex games the most appealing.
11	Ease of use	Easy to play, Moderate and Not easy to play.	100.0, 0.0 &0.0.	100.0, 0.0 & 0.0.	The most appealing category is the easy to play games.
12	Fun	Lots of fun, Moderate fun and No fun.	64.5, 62.5 &0.0	44.4, 37.2 &0.0.	3 categories with Lots of fun the most preferred.
13	Feedback	Feedback given and None.	62.5 & 20.8	37.5 & 10.4.	Feedback given is the most appealing.
14	Violence	Very violent, Moderately violent and No violence.	46.2, 61.2 & 80.1	19.7, 46.7 & 53.7	3 categories identified with no violence most appealing.
15	Character	Human in real scenario, human in fantasy scenario, animals in real scenario, animals in unreal scenario.	66.7, 34.0, 25.0 & 23.3.	33.3, 20.0, 11.1 & 8.3.	4 categories, with humans in real scenario most appealing.
16	Scenery	Adventure, Travel, Fantasy and	75.0, 0.0, 66.7 &33.3.	45.0, 0.0, 19.0 & 11.1.	4 categories with Adventure scenery

		Non Fantasy.			the most appealing.
17	Gender based	Male, Female and Anyone.	66.7, 0.0 & 100.0	33.3, 0.0 & 42.9.	Three categories identified with the Anyone type game (Non- gendered) preferred. The likelihood of the games selected for play was more male type games than female games.
18	Game type	Adventure, Action, Simulated and Puzzle.	33.3, 0.0, 16.7 & 0.0.	13.3, 0.0, 8.3 & 0.0.	4 categories identified with adventure the most appealing.
19	Graphics	Cartoon, Real and Scary	71.7, 41.6 & 0.0	47.3, 22.9 & 0.0.	3 categories identified and cartoon most appealing.
20	Internet	Internet dependent, partial and none.	0.0, 50.0 &25.0.	0.0, 14.3 & 12.5.	3 categories with partial dependence as the most appealing.
21	Game levels	Games with levels and without levels.	66.7 & 55.8	19.5 & 15.9	2 categories with the levelled games most appealing.
22	Mission	Based on character mission and Not based on character mission	25.0 & 50.0	5.0 & 20.0	2 categories identified with games with not based on character mission most appealing.
23	Movement	A lot of movement, Some movement and No movement.	50.0, 51.7 & 0.0.	21.8, 27.2 & 0.0.	Most appealing was some movement.
24	Audio	Catchy theme and repeat music.	100.0 & 33.3.	75.0 & 16.7.	2 categories identified and the catchy relaxing music more appealing compared to repeat audio like drones in games

					environment.
25	Number of players	Interactive and non-interactive	70.0 & 42.3.	41.5 & 11.8	2 categories with the interactive play more appealing.
26	Software platform	Cross platform & Specific platform	50.0 & 25.0.	14.3 & 8.3.	The cross platform was more appealing.
27	Player involvement	Physical involvement and None involvement.	20.9 & 62.5.	20.9 & 20.9.	The construct refers to the amount of involvement by a player in the gaming environment physically. Two categories identified and none physical involvement appear to be relatively more appealing.
28	Popularity of game	Very popular, Fairly popular and Not popular.	75.0, 32.2 & 0.0	43.4, 23.5 & 1.2.	3 categories identified with the very popular games most appealing.
29	Price of game	Free and Not Free	33.3 & 33.3.	33.3 & 5.6	2 categories identified from analysis. The Free games are most appealing.
30	Game objective	Good objective, Satisfactory objective and No clear objective.	87.5, 0.0 & 0.0.	52.5, 0.0 & 0.0.	Games with good objectives are most appealing.
31	Rebellion	A lot, Some and None.	0.0, 58.4 & 19.4	0.0, 23.0 & 9.7.	3 categories with some rebellion most appealing.
32	Role Play	Role Play and No Role Play.	80.7 & 33.3.	33.9 & 6.7.	2 categories and from the analysis of the data and the role play game most appealing.

33	Dialogue	A lot, Some and No dialogue.	66.7, 33.3 & 0.0.	33.3, 11.1 & 0.0.	A lot of game dialogue most appealing.
34	Storyline	Include a definite storyline, Include some storyline and no storyline	69.5, 30.5 & 20.9	51.5, 8.1 & 4.6.	3 categories identified with include a definite storyline most appealing.
35	Software update	Update required, Sometimes required and not required	0.0, 50.0 & 25.0.	0.0, 14.3 & 12.5.	3 categories with Sometimes required most appealing.
37	Educational content	Educational and non-educational games	63.4 & 56.2	23.5 & 20.1	2 categories with educational games more appealing.
38	Theme	Themed and non-themed games	34.3 & 23.5	12.9 & 10.4	2 categories with themed gamed more appealing.
39	Game series	Games with series and those without	56.4 & 60.3	23.1 & 30.5	2 categories with games without series more appealing.
40	Layout	Excellent, good, satisfactory and poor layout	80.2, 67.3, 56.4 & 20.1	56.3, 48.2, 38.1 & 12.3	Excellent layout is the most appealing category.

Male Likelihood data table where Male (N=8)					
Criterion #	**Criterion**	**Categories**	**Likelihood %**	**Weighted Likelihood**	**Analysis comment**
1	Action	Lots of action, Some action and No action.	66.7, 52.2 & 58.4.	29.8 , 19.5 & 13.5	3 categories identified for the game action construct with lots of action as the most appealing.
2	Adventure	A Lot of adventure, Some adventure and No adventure.	66.7, 66.7 & 0.0.	26.7, 44.4 & 0.0.	3 categories with some adventure the most appealing construct.
3	Age appropriateness	Age range below 12, Teenagers and Any one.	55.5, 100.0 & 0.0.	17.8, 20.0 & 0.0.	3 categories with the teenage type games most appealing.
4	Colour used	Bright and Dark colours.	40.0 & 60.0	30.0 & 65.0.	2 categories with dark colours most appealing.
5	Rewards	Coin/ Money, Range of rewards, Progression, Points & Fighting Powers.	33.3, 0.0, 33.3, 60.0 & 50.0.	6.1, 0.0, 3.3, 45.0 & 10.0.	The most appealing category for reward was Points.
6	Graphics	Cartoon, Photographs & combined	25.0, 66.7 & 13.9.	9.5, 16.7 & 6.1.	3 categories with photographs the most appealing.
7	Character	Human in real scenario, human in fantasy scenario, animals in real scenario, animals in fantasy scenario.	20.0, 32.0, 65.3 & 80.9.	3.0, 4.0, 20.0 & 45.	4 categories with animal characters in fantasy scenario the most appealing.
8	Control	Full, Some and No control.	66.7, 33.3 & 0.0.	33.3, 11.1 & 1.3.	3 categories with full control the most appealing.
9	Gameplay creativity	High creativity, moderate creativity and No	0.0, 50.0 & 50.0.	0.0, 5.0 & 5.0.	The most appealing construct/categories were moderate or no

		creativity.			creativity.
10	Storyline	Include a definite storyline, Include some storyline and no storyline.	46.7, 60.0 & 53.3.	16.1 ,55.5 & 61.7	May or may not include a definite storyline.
11	Duration	Completion and No completion.	0.0 & 100.0.	0.0 & 20.0.	2 categories identified and the games with No completion are more appealing.
12	Movement	A lot of movement, Moderate movement and Restricted movement.	45.8, 25.0, 13.3.	7.0, 2.0 & 1.5.	A lot of movement as the most appealing.
13	Fun	Lots of fun, Moderate fun and No fun.	90.2, 66.7 & 0.0.	80.7, 26.7 & 0.0.	Lots of fun as the most appealing.
14	Gaming device	Specialised (e.g. consoles), Portables and PC.	100.0, 80.0 & 50.0.	60.0, 30.0 & 20.0	The most appealing gaming devices are specialised items like consoles etc.
15	Environment	Good, Moderate and Poor.	100.0, 0.0 & 0.0.	75.0, 0.0 & 0.0.	From the three categories identified, an active environment is classified as good. This is the most appealing environment.
16	Fonts	Large, Medium, Small and None.	50.0, 0.0, 0.0 & 50.0.	5.0, 0.0, 0.0 & 5.0.	Large fonts are the most appealing.
17	Graphics view	3D and 2D	100.0 & 0.0	20.0 & 0.0	The more appealing game view is 3D.
18	Mission	Based on character mission and not based on character mission	100.0 & 0.0.	40.0 & 0.0	2 categories with the based on character mission more appealing.
19	Number of players	Non-interactive an interactive	83.5 & 66.7	21.0 & 18.35.	The more appealing category was the non-interactive.

20	Popularity	Very popular, popular and not popular.	41.7, 58.4 & 0.0.	4.15, 9.15 & 0.0.	Popular games were the most appealing.
21	Quality	Good, Satisfactory and Poor.	66.7, 33.3 & 0.0.	13.3, 3.3 & 0.0.	Good quality games were the most appealing.
22	Role play	Role play and No Role Play.	50.0 & 100.0	30.0 & 20.0	2 categories with role play more appealing.
23	Audio	Catchy theme and repeat music.	50.3 & 60.5	8.9 & 15.2	Repeat music more appealing from the 2 categories.
24	Violence	Very, Moderate and No Violence.	70.0, 50.0 & 3.3.	30.0, 12.2 & 2.0.	3 categories with very violent as most appealing.
25	Play location	Anywhere and Home.	10.0 & 66.7	16.0 & 19.0.	The most appealing location of gameplay is home from our survey.
26	Brand	Popular and unpopular brands	65.2 & 63.2	15.3 & 14.1	The game brand can be popular or unpopular.
27	Appeal	Excellent, moderate, satisfactory and poor	63.2, 50.4, 43,1 & 13.0	25.6, 20.3,15.4 & 1.5	4 categories with excellent appeal most significant.
28	Game type	Adventure, Action, Role Playing, Puzzle and Dancing.	33.3, 43.3, 33.3, 0.0 & 0.0.	11.1, 21.1, 11.1, 0.0 & 0.0.	The most appealing game type are action games.

APPENDIX 5

EXPLORATORY STUDY - CLUSTER ANALYSIS

The analysis indicated the cluster groups of the ten games used in the survey based on the three response groups – '*Most Likely to Play', 'Likely to Play'* and *'Never Likely to Play*'. The cluster information from the girls and the boys can be compared for similarity and differences based on the games within the groups.

Figure 5.1 is a dendrogram from SPSS showing the hierarchal cluster analysis of the girls' responses. Two, three or five cluster groups could be obtained from the analysis based on the relationship between the games used for the study.

In order to explore how the construct/category pairing affected the appeal of the games, the five cluster grouping was used for the analysis of the results. This grouping provided the most detailed relationship between the games. The five cluster groups comprised of the following games:

i) Simulations, casual & adventure;
ii) Action & maze
iii) Role play & strategy
iv) Puzzle
v) Arcade & music

The result of the cluster analysis based on the '*Likely to play' data* indicated the groupings of the games. The result is a representation of how the games are related based on the appeal of game characteristics to the girls' participants of age 11-14.

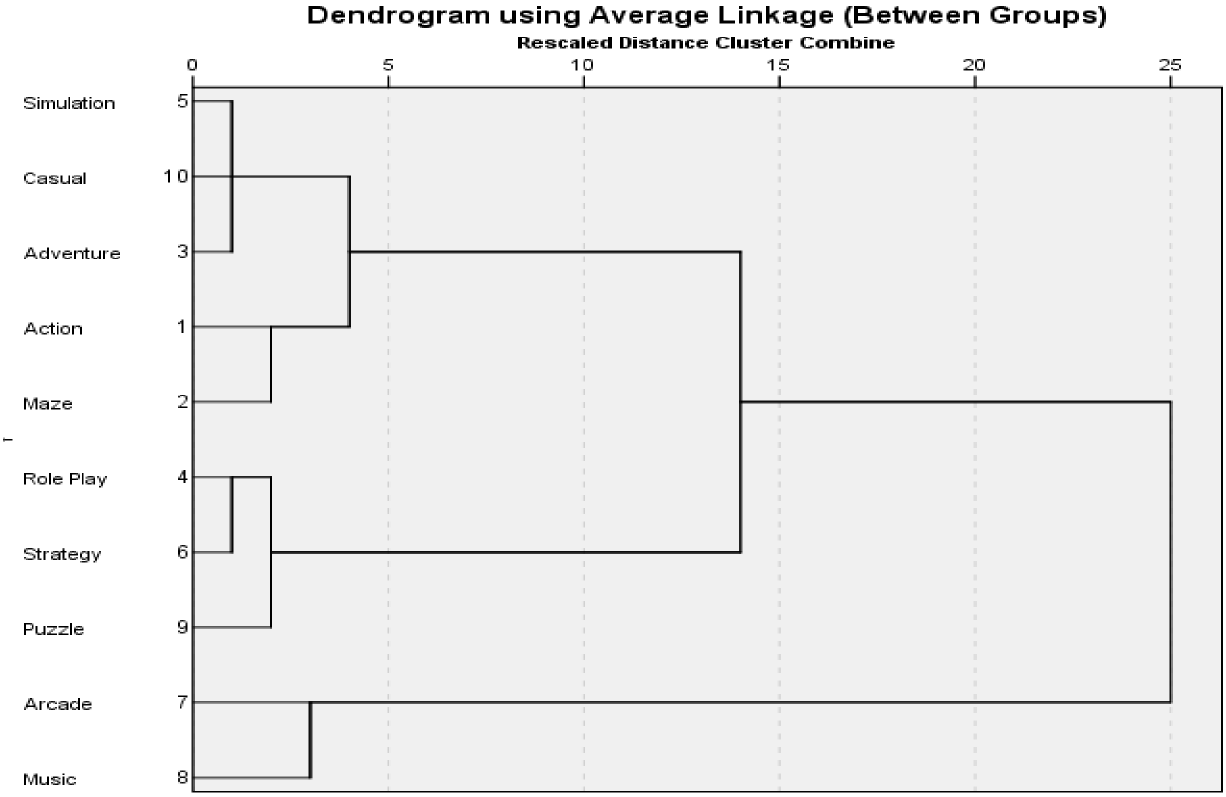

Figure 5.1. A dendrogram cluster analysis of the girls 'Likely to play' *responses*

A similar analysis was conducted for the boys. Figure 5.2 is a dendrogram showing the hierarchal cluster analysis of the boys' responses. Two, three or six cluster groups could be obtained from the analysis based on the relationship between the games used for the study. The six cluster group would be used for the analysis as explained previously. The cluster group comprised of the following games:

- i) Role play & puzzle;
- ii) Adventure & casual;
- iii) Simulation, music & maze;
- iv) Action;
- v) Strategy;
- vi) Arcade.

The only similarity in the cluster groups between the girls and the boys was the cluster groups with a combination of casual and adventure games.

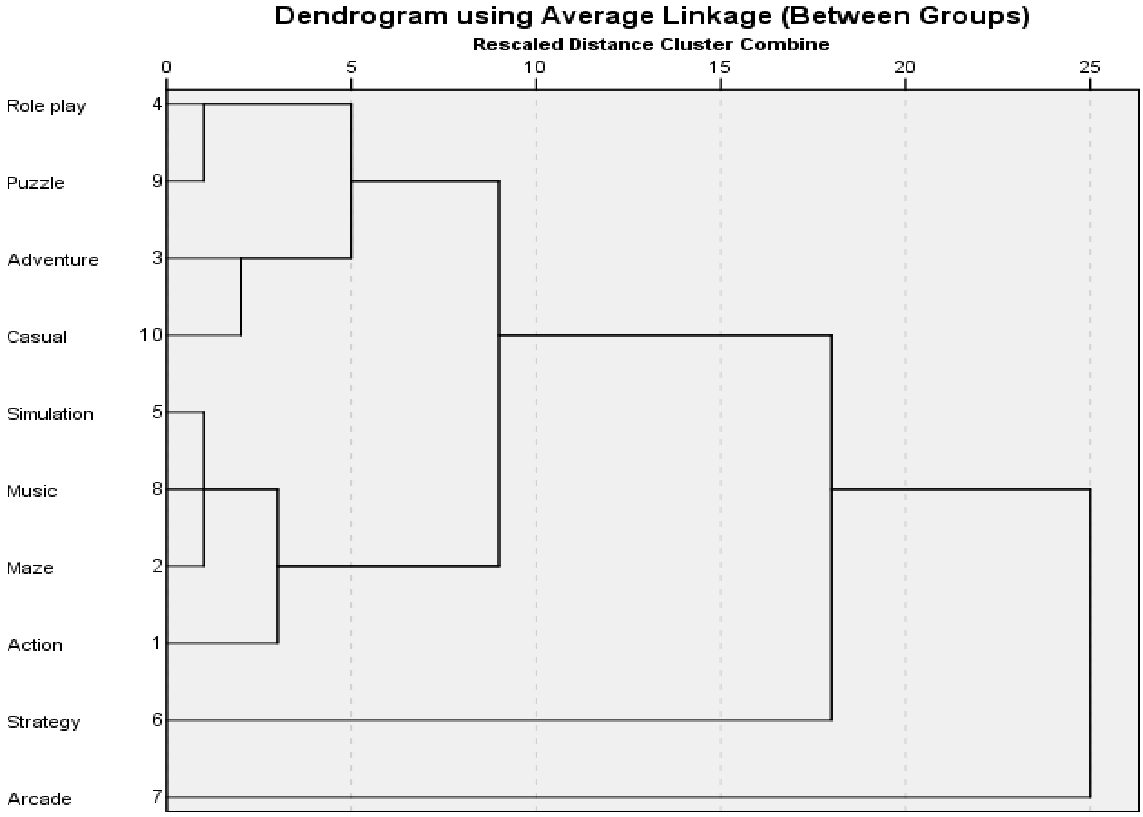

Figure 5.2 A dendrogram cluster analysis of the boys ‘Likely to play’ *responses*

APPENDIX 6

MAIN STYDY - INFORMATION GUIDES AND CONSENT DOCUMENTATION

University of Greenwich
Department of Computing and Information Systems

Guidance for teacher/ contact person

Duration of survey

The duration of the survey is 50 minutes. Two game prototypes – “*The Lost Astronaut*” and “*The Lost Hippo*” will be provided alongside questionnaires. The order in which the games are played is not important. All participants must play both games in the allocated time.

How do you administer the survey?

Before the exercise:

9. Information sheets and consent documentation will be provided
10. Participants and parents/ guardians should read the information sheet
11. The consent forms should be signed by parents/ guardian if they wish to participate in the exercise
12. The age group for the exercise is 11-14 year old boys and girls
13. For single sex schools, 80 girls between this age group are required i.e. 20 girls of age 11, 20 girls of age 12, 20 girls of age 13 and 20 girls of age 14
14. For mixed sex schools, 80 girls and 80 boys are required i.e. 20 boys and girls respectively of age 11, 20 boys and girls respectively of age 12, 20 boys and girls respectively of age 13 and 20 boys and girls respectively of age 14
15. Completed consent forms will be collected by teacher/ instructor and unique reference number starting from WiLG01…..WiLG80 allocated to participants.

During the exercise:

1. Each participant should be provided the unique reference number and this should be entered in the allocated sections of the questionnaires by participants before completion
2. Participants will complete an online pre-study questionnaire that should last 5 minutes and submitted
3. Participants will then play prototype game 1 for 15 minutes
4. An on-line post-study questionnaire for this game should be completed in 5 minutes
5. Participants will then play prototype game 2 for another 15 minutes
6. An on-line post-study game 2 questionnaire should also be completed in 5 minutes and submitted
7. Another evaluative post-study questionnaire should be completed in 5 minutes and submitted to complete the exercise.
8. Participants can decide to withdraw from the exercise at any point in time during the session.

After the exercise:

On completion of the survey, please contact:

Osunde, Joseph
Department of Computing and Information Systems
University of Greenwich, London
Email: J.osunde@gre.ac.uk

University of Greenwich
Department of Computing and Information Systems

Participants' Parent/Legal guardian Information sheet
(Research conducted by Osunde Joseph MPhil/PhD student University of Greenwich, London)

I am a MPhil/PhD student with the University of Greenwich, London. My research work is focused on engaging more young learners especially girls of ages 11-14 to study Computer Science using computer games. As a mandatory subject of study at Key stage 3 from September 2014, it is imperative that educational software for learning is appealing to young learners.

What is this study about?

The purpose of this study is to verify the game features that will make computer educational games for learning computer science appealing to learners of age 11-14.

What do we want you to do?

I would like you to read carefully the participant information sheet provided to your child or ward. The information sheet clearly informs you and your child/ward of the survey procedure. If you are happy with this, we would like you to give your consent by signing the consent form.
Please be assured that the anonymity of your child/ ward is guaranteed. He/She will be allocated a unique number which cannot be traced back. He/She is not required to include names in the feedback. He/She is only required to provide details of gender and age at the beginning of the exercise. Answers will never be shared with the school's staff and any other party. If at any time he/she wishes to withdraw from the study, the supervising staff should be informed and he/she will be free to leave. No reasons need to be provided. Please be assured that the choice to participate or not in this exercise will have no effect on studies.
What are you going to do with the answers?

The data collected will be analysed and will be held securely by University of Greenwich in accordance with Data Protection laws until the expected date of completion of the research project in June 2016. We will keep the data for research purposes only and I intend to generate statistical information from this data. Some of the data gathered may be published as part of the project report; however individuals will not be identified and information will be kept confidential. If you wish to be updated on the result of the study, please contact me using the email address below from April 2016.

This project is supervised by:
Windall, G F
Principal Lecturer
University of Greenwich, London
Email: G.F.Windall@gre.ac.uk

University of Greenwich
Department of Computing and Information Systems

Participants' Information sheet
(Research conducted by Osunde Joseph MPhil/PhD student University of Greenwich, London)

I am a MPhil/PhD student with the University of Greenwich, London. My research work is focused on engaging more young learners especially girls of ages 11-14 to study Computer Science using computer games. As a mandatory subject of study at Key stage 3 from September 2014, it is imperative that educational software for learning is appealing to young learners.

What is this study about?
The purpose of this study is to verify the game features that will make computer educational games for learning computer science appealing to learners of age 11-14.

What do you want me to do?
I would like you to take part in an exercise that will take about 50 minutes to complete. The structure of the exercise:

1. You will be allocated a unique number
2. You will be expected to complete a pre-survey questionnaire (5 minutes)
3. You will then play a prototype game 1 on introductory algorithms (15 minutes)
4. At the end of the game session, you will complete a post-study questionnaire (5 minutes) and submit the information
5. You will play prototype game 2 (15 minutes) and also complete post-study questionnaire 2 (5 minutes)
6. Finally you will complete a comparative questionnaire at the end of both sessions which should last about 5 minutes
7. You will not be scored on the completed exercise.

Please be assured that your anonymity is guaranteed. You have been allocated a unique number which cannot be traced back to you. You are not required to include your name in your feedback. You are only required to select your gender and age at the beginning of the exercise. Your answers will never be shared with your school's staff, your parent or legal guardian and no attempt will be made to identify you. If at any time you wish to withdraw from the study, please inform your ICT teacher and you will be free to leave, no reasons need to be provided. Please be assured that your choice to participate or not in this exercise will have no effect on your studies.

What are you going to do with my answers?
The information you provide will be analysed and will be held securely by University of Greenwich in accordance with Data Protection laws until the expected date of completion of the research project in June 2016. We will keep the data for research purposes only and I intend to generate statistical information from this data. Some of the data gathered may be published as part of the project report; however individuals will not be identified and information will be kept confidential.

This project is supervised by:
Windall, G F
Principal Lecturer
University of Greenwich, London
Email: G.F.Windall@gre.ac.uk

APPENDIX 7

MAIN STUDY PRE AND POST-STUDY QUESTIONNAIRES

Pre-study questionnaire

Select an option from each question in each section

Section 1: Participants' Identification and background details

1.1 **Participant ID ***

- **Provided by teacher or instructor**

1.2 Age:

- ☐ **11**
- ☐ **12**
- ☐ **13**
- ☐ **14**

1.3 **Gender:**

- ☐ **Male**
- ☐ **Female**

Section 2: About Computer games (Entertainment games)

2.1 How often do you play computer games?

- ☐ **Daily**
- ☐ **Weekly**
- ☐ **Every 2 weeks**
- ☐ **Monthly**
- ☐ **Never**
- ☐ **Other, specify**

2.2 **How much do you like computer games?**

- ☐ **Like very much**
- ☐ **Like moderately**
- ☐ **Like slightly**
- ☐ **Neither like nor dislike**
- ☐ **Dislike slightly**
- ☐ **Dislike moderately**
- ☐ **Dislike very much**

2.3 **How frequently will you play a computer game with the features that you like?**

- ☐ **Very frequently**
- ☐ **Quite frequently**
- ☐ **Moderately frequently**
- ☐ **Neither frequently nor infrequently**
- ☐ **Moderately infrequently**
- ☐ **Quite infrequently**
- ☐ **Very infrequently**

2.5 How much will your view of computer games be influenced if it includes game features that you like?

☐ **A lot**
☐ **Some**
☐ **Little**
☐ **Not A lot**

Section 3: Educational computer games

3.1 How often do you play educational computer games?

☐ **Daily**
☐ **Weekly**
☐ **Every 2 weeks**
☐ **Monthly**
☐ **Never**
☐ **Other, specify** ____________

3.2 **How much do you like educational computer games?**

☐ **Like very much**
☐ **Like moderately**
☐ **Like slightly**
☐ **Neither like nor dislike**
☐ **Dislike slightly**
☐ **Dislike moderately**
☐ **Dislike very much**

3.3 **Would you prefer an educational computer game with features that you like?**

☐ **Strongly prefer**
☐ **Somewhat prefer**
☐ **No preference**
☐ **Somewhat do not prefer**
☐ **Strongly do not prefer**

3.4 How much will your view of educational computer games be influenced if it includes game features that you like?

☐ **Like very much**
☐ **Like moderately**
☐ **Like slightly**
☐ **Neither like nor dislike**
☐ **Dislike slightly**
☐ **Dislike moderately**
☐ **Dislike very much**

Thank you for completing the questionnaire.

Post-study questionnaire (*The Lost Astronaut*)

Select one option from each question

Section 1: Participants' Identification and game play experience

1.2 **Participant ID ***

- **Provided by teacher or instructor**

1.3 **Using the point scale of 1-7 tell us how much you like the following features used in "*The Lost Astronaut*":**

Game feature #	Game feature	7=Like very much	6= Like moder ately	5=Like slightly	4=Neither like nor dislike	3=Dislike slightly	2=Dislike moderat ely	1=Dislike very much
1	Ability to interact with other players (e.g. chat room)	☐	☐	☐	☐	☐	☐	☐
2	Aimed at your age group	☐	☐	☐	☐	☐	☐	☐
3	No violent scenes	☐	☐	☐	☐	☐	☐	☐
4	Use of bright colours (character)	☐	☐	☐	☐	☐	☐	☐
5	Including a definite storyline	☐	☐	☐	☐	☐	☐	☐
6	Use of cartoon images	☐	☐	☐	☐	☐	☐	☐
7	Use of human character	☐	☐	☐	☐	☐	☐	☐

1.4 **Which of the game features were effectively used in "*The Lost Astronaut*"?**

Game feature #	Game feature	5=Excellent	4=Good	3= Fair	2=Poor	1=Very Poor
1	Ability to interact with other players (e.g. chat room)	☐	☐	☐	☐	☐
2	Aimed at your age group	☐	☐	☐	☐	☐
3	Violence	☐	☐	☐	☐	☐
4	Bright colours (character)	☐	☐	☐	☐	☐
5	A definite storyline	☐	☐	☐	☐	☐
6	Human character	☐	☐	☐	☐	☐
7	Cartoon images	☐	☐	☐	☐	☐

1.5 **How much do you like the Game “*The Lost Astronaut*”?**

- ☐ **Like very much**
- ☐ **Like moderately**
- ☐ **Like slightly**
- ☐ **Neither like nor dislike**
- ☐ **Dislike slightly**
- ☐ **Dislike moderately**
- ☐ **Dislike very much**

1.5 Having played “*The Lost Astronaut”* game, would you consider playing this game or a similar one again?

- ☐ **Very much consider**
- ☐ **Moderately consider**
- ☐ **Slightly consider**
- ☐ **Neither consider nor not consider**
- ☐ **Slightly not consider**
- ☐ **Moderately not consider**
- ☐ **Very much not consider**

1.6 Main reason for your answer in 1.5: ☐

1.7 How much has this game influenced your perception of educational computer games?

- ☐ **A lot**
- ☐ **Some**
- ☐ **Little**
- ☐ **Not A lot**

1.8 Main reason for your answer in 1.7: ☐

1.9 How much do you like the “*The Lost Astronaut*” game compared to similar educational computer games?

- ☐ **A lot**
- ☐ **Some**
- ☐ **Little**
- ☐ **Not A lot**

1.10 Main reason for your answer in 1.9: ☐

1.11 Would you like similar educational computer games to include some of the features in “*The Lost Astronaut*”?

☐ **Yes**
☐ **No**

1.12 List the features that should be included in similar educational computer games:

1.13 **How can *"The Lost Astronaut"* game be improved?**

<Type your comments here>

Thank you for completing the questionnaire.

Post-study questionnaire (*The Lost Hippo*)

Select one option from each question

Section 1: Participants' Identification and game play experience

1.1 Participant ID *

- **Provided by teacher or instructor**

1.2 Using the point scale of 1-7 tell us how much you like the following features used in "*The Lost Hippo*":

Game feature #	Game feature	7=Like very much	6= Like moderately	5=Like slightly	4=Neither like nor dislike	3=Dislike slightly	2=Dislike moderately	1=Dislike very much
1	No interaction with other players (e.g. chat room)	☐	☐	☐	☐	☐	☐	☐
2	Aimed at your age group	☐	☐	☐	☐	☐	☐	☐
3	Including violent scenes (explosions)	☐	☐	☐	☐	☐	☐	☐
4	Use of dark colours (character)	☐	☐	☐	☐	☐	☐	☐
5	Not including a definite storyline	☐	☐	☐	☐	☐	☐	☐
6	Use of real images (photographs)	☐	☐	☐	☐	☐	☐	☐
7	Use of animal character	☐	☐	☐	☐	☐	☐	☐

1.3 Which of the game features were effectively used in "*The Lost Hippo*"?

Game feature #	Game feature	5=Excellent	4=Good	3= Fair	2=Poor	1=Very Poor
1	Ability to interact with other players (e.g. chat room)	☐	☐	☐	☐	☐
2	Aimed at your age group	☐	☐	☐	☐	☐
3	Violence	☐	☐	☐	☐	☐
4	Dark colours (character)	☐	☐	☐	☐	☐
5	No definite storyline	☐	☐	☐	☐	☐
6	Animal character	☐	☐	☐	☐	☐
7	Real images (photographs)	☐	☐	☐	☐	☐

1.4 How much do you like the Game "*The Lost Hippo*"?

- ☐ **Like very much**
- ☐ **Like moderately**
- ☐ **Like slightly**
- ☐ **Neither like nor dislike**
- ☐ **Dislike slightly**
- ☐ **Dislike moderately**
- ☐ **Dislike very much**

1.5 Having played "*The Lost Hippo"* game, would you consider playing this game or a similar one again?

- ☐ **Very much consider**
- ☐ **Moderately consider**
- ☐ **Slightly consider**
- ☐ **Neither consider nor not consider**
- ☐ **Slightly not consider**
- ☐ **Moderately not consider**
- ☐ **Very much not consider**

1.6 Main reason for your answer in 1.5: ☐

1.7 How much has this game influenced your perception of educational computer games?

- ☐ **A lot**
- ☐ **Some**
- ☐ **Little**
- ☐ **Not A lot**

1.8 Main reason for your answer in 1.7: ☐

1.9 How much do you like the "*The Lost Hippo*" game compared to similar educational computer games?

- ☐ **A lot**
- ☐ **Some**
- ☐ **Little**
- ☐ **Not A lot**

1.10 Main reason for your answer in 1.9: ☐

1.11 Would you like similar educational computer games to include some of the features in "*The Lost Hippo*"?

- ☐ **Yes**
- ☐ **No**

1.12 List the features that should be included in similar educational computer games:

1.13 How can *"The Lost Hippo"* game be improved?

<Type your comments here>

Thank you for completing the questionnaire

Post-study questionnaire (Comparative)

Select one option from each question

Section 1: Participants' Identification

1.1 Participant ID *

- **Provided by teacher or instructor**

Section 2: Educational Computer games for learning computer science

1.2 Which of the games ("*The Lost Astronaut*" or "*The Lost Hippo*") do you like the most?

☐ ***The Lost Astronaut***
☐ ***The Lost Hippo***

1.3 Main reason for your answer in 2.1?

1.4 Which of the games was the most fun to play?

☐ ***The Lost Astronaut***
☐ ***The Lost Hippo***

1.5 Main reason for your answer in 2.3?

1.6 How much has this game influenced how you feel about educational computer games for learning computer science?

☐ **A lot**
☐ **Some**
☐ **Little**
☐ **Not A lot**

1.7 Main reason for your answer in 2.5:

Thank you for completing the questionnaire.