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GAMING AND COMPUTER SCIENCE: BRIDGING THE GENDER-GAP

by

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Abstract

**GAMING AND COMPUTER SCIENCE:
BRIDGING THE GENDER-GAP**

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According to the literature, women are still unrepresented in the field of information technology. Although many women study computer science at first year level, the dropout rate for women—before they graduate—is high, and if they graduate many decide neither to continue with their studies nor to work in the field of information technology. Research has shown that women who have been exposed to computing at some point during their school career or early in their lives, tend to be more open to choosing a career in computer science and are in many cases successful at it. The aim of this research is to understand what factors influence women to choose a career within computer science and to consider whether gaming would encourage young women to enter the field. Design Science Research was the methodology employed. It was chosen since an artefact was developed. For each of the five steps of this methodology a different method was chosen to address the research question. Surveys were administered to first year computer science students and both IT high school teachers and computer science honours students were interviewed. Non-computer science students were involved in the participatory design process. The study provided insights into what girls knew about IT, what motivated them to study IT and their

experience and relationship with computer games. A gaming framework was developed specifically designed as an intervention to encourage girls to study computer science. The evaluation of the gaming framework revealed that girls would play a computer game specifically designed for them and that it is important to included girls in the development of these games. A lack of exposure of girls to Computer Science was revealed as many non-Computer Science students knew what Computer Science was and were unaware that like gaming, Computer programming consists of problem solving.

Keywords

computer science, gender, information technology, STEM, gaming

ACM Classification

• **Social and professional topics~computer science education** • **Social and professional topics~Women** • *Social and professional topics~Employment issues* • Social and professional topics~Computational thinking • *Theory of computation~Solution concepts in game theory* • **Theory of computation~Convergence and learning in games**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DECLARATION

I, *Saira-Banu Adams*, declare that *Persuasive technologies, gaming and computer science: How to bridge the gender-gap* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Signed.....  Date:. 15 March 2019

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GLOSSARY

Android. An open-source mobile operating system developed by Google that runs on devices such as mobile phones and tablets with touchscreens.

C#. An object oriented programming language created by Microsoft

CE. Computer engineering

CS. Computer science

DSR. Design Science Research- A methodology commonly used within computer science and information systems industries. DSR is defined by Gregory as a '*general research approach with a set of defining characteristics that can be used in combination with different research methods*' (Gregory, 2011, p. 5)

GameSalad. A game development authoring tool used by teachers and non-programmers.

Heuristic. A usability principle used during an expert review to ensure that the software product corresponds with the appropriate usability principles.

HTML 5. The fifth revision of the Hypertext markup language(HTML). It is a code language that defines wed pages.

ICT. Information and Communications Technology

iOS. A mobile operating system that was developed by Apple inc. strictly for use on Apple devices.

IDE. Integrated Development Environment

IS. Information systems

IT. Information Technology

Justinmind. A drag and drop prototyping tool for software development.

Participatory Design. Participatory design is a methodology that involves stakeholders in the design process in order to ensure that the end product meets the needs of the intended users**.**

SABC. South African Broadcasting Corporation

SAS Programming. Syntactical Analysis System. A programming language used for the analysis of data.

SG. Serious Games- A game that is designed with the primary focus such as for education rather than just entertainment.

STEM. Science, Technology, Engineering and Mathematics

Systematic literature review. *A review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyse and summarise the results of the included studies (CRD, 2001, p. 25)*

USA. United States of America

C h a p t e r 1

SKETCHING THE BACKGROUND

INTRODUCTION

The world is now again on the brink of a revolution—the so-called fourth industrial revolution (Silja, Dutta, & Lanvin, 2016). It is postulated that this new technological revolution will fundamentally and exponentially change the way people live and work. Some of the aspects that will drive this new revolution are: artificial intelligence; 3-D printing; the Internet of Things; quantum computing; storage capacity and knowledge being accessible to all at the click of a button (Silja, Dutta, & Lanvin, 2016). All of these technologies are closely linked to computer science (CS) and thus this field of study will continue to play an important role in the future.

According to the World Bank (The World Bank, 2017) 49.5% of the world's population are women. Since this so-called revolution will require computing skills and insight of everyone, it is becoming more important that women are involved in computing (Silja, Dutta, & Lanvin, 2016).

> *If half of the users of technology products are women, then one would think that having women not just on the staff, but in positions of leadership--to define future directions--to be important. (Khanna, 2013)*

According to the literature, women are still underrepresented in the field of computer science and information technology (IT) in the United States of America (USA) (Galvin, 2016)—in 1984 37% of computer science majors were women and by the year 2014 the percentage had dropped to 18 % (Galvin, 2016). In South Africa, the South African Broadcasting Corporation (SABC) News also reported in 2017 that the percentage of women in academia in the computer science/ information and communication technologies (ICT) field was below 10% (Tshangela, 2017). This has been reflected by the number of women who

have enrolled for an undergraduate degree in the computer science department of the University of the Western Cape too—the number has remained consistently below 20% each year from 2013–2016. Currently, technology and technology products are created from a male perspective only, and if they consistently lead and develop the tech industry, they will not address the vision of the masses—more input is therefore required from females (Newmark, 2014).

A study that considered why people choose a career in computing showed that the ratio between women and men who chose a career in computing based on their interest in gaming was statistically significant. The number of males who had an interest in gaming outnumbered women significantly (Vu, 2017). To understand this ratio, the researcher considered the top selling games for the year of 2017 (Kain, 2018). These top selling games were games that would appeal to men rather than to women. The games focused largely on war, fighting and sports such as basketball and soccer. When researching games played by girls, it was noted how difficult it was to find computer games that were developed for women. The games that were designed for women were extremely *girly*. For example, they used bright feminine colours, such as shades of pink and purple, the characters were female and dressed in an overly feminine way. Hartmann and Kimmt did a study in which they considered gender when comparing frequently played games. War games were predominantly played by males while there was a close gender ratio for life simulation games such as the *Sims*. This study showed that games that women enjoy do not necessarily have to be *girly* , and could even be games that appeal to both men and women (Hartmann & Klimmt, 2006)

Gaming is said to develop problem solving skills which is the primary skill needed in computer science. Video games are complex and yet enjoyable. They require the player to have a wide set of skills and abilities (Nieler, 2015). Children are not aware that they are actually learning when playing video games which may be the reason why they find them enjoyable (Nieler, 2015). However, as they play and

the levels of the game become more challenging, they develop a problem-solving way of thinking (Nieler, 2015).

RESEARCH PROBLEM

The aim of this research is to understand why so few women enter the IT field. Furthermore, to consider whether computer games designed for women would change women's perceptions of computer science and would interest them to follow a possible career in this field.

The main research question is:

Would computer games designed to interest women, encourage them to play and thus create an interest in computer science?

This research question can be broken into the following research sub-questions:

1. Why does gaming lead men more than women to study computer science?
2. What aspects of computer science attract women?
3. Can gaming be a non-structured learning technique to attract girls to CS/IT?
4. How should computer games be designed to interest women?

RESEARCH APPROACH

Design science research was the chosen methodology for this research effort. This methodology is common within the information systems and computer science industry and is followed when dealing with the design of an artefact to solve a particular problem (Vaishnavi & Kuechler, 2015) (Vaishnavi & Kuechler, 2006) (Gregor & Hevner, 2013). Methods that were implemented were: a systematic literature review; surveys; semi-structured interviews and participatory design.

ETHICAL RESEARCH

Research was executed based on Lund's five principles for ethical research (Lund, 2017):

1. To minimize the risk of harm, the participants were regular users of the equipment in the IT laboratory and thus knew the environment;
2. Informed consent was obtained from each participant;
3. The participants were informed that their responses would be anonymous and the data collected would be confidential; that is, it would only be used by the researcher and would be destroyed once the research had been completed;
4. The researcher took care to avoid deceptive practices; and finally,
5. The participants were given the right to withdraw (Lund, 2017). Ethical permission for this research was received from the university's ethical committee (HS1 7 / 9 / 24)

OUTLINE OF THE THESIS

In Chapter 1 the background of the research was sketched. Chapter 2 will deal with the literature in terms of the keywords and concepts required to understand the research problem. In Chapter 3 the methodology and research design will be elaborated upon. In Chapter 4 the research findings will be presented and lastly, in Chapter 5 the results will be discussed and analysed. This will conclude the thesis.

Chapter 2

LITERATURE REVIEW

INTRODUCTION

In the previous chapter the background of the study was sketched and the research question posed. In this chapter, the literature related to the research will be dealt with in terms of the key concepts of the research as well as the research questions posed.

The key concepts on which this research was built are: information technology, computer science and computer science education, gender, Science Technology Engineering and Mathematics (STEM) and computational thinking, gaming, solution concepts in game theory; convergence and learning in games, persuasive technologies.

INFORMATION TECHNOLOGY

There are many definitions for IT, CS and IS. According to Spraul (2005) IT is a broad term that encompasses several disciplines such as: Information Systems, Computer Engineering as well as computer science (see Figure 1) .

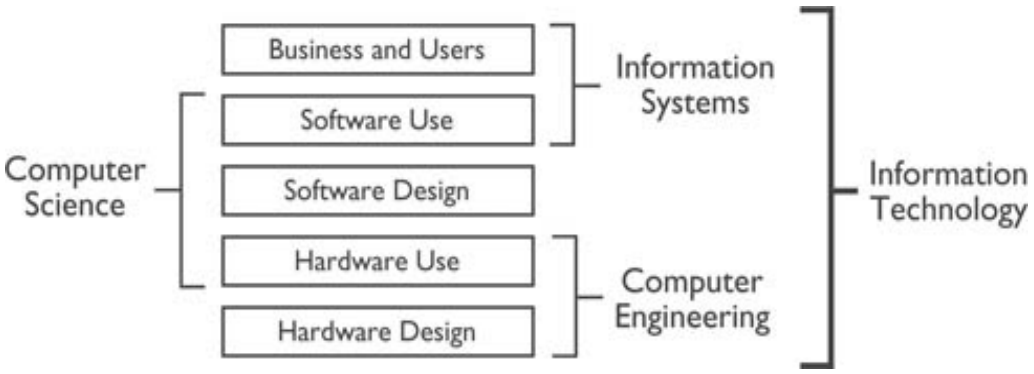

Figure 1: Depiction of how computer science fits into Information Technology (Major Fields in Computing, 2017)

The ACM define these fields (IT, CS and IS) in terms of theory and application from organisational issues to hardware (see Figure 2, Figure 3, and Figure 4,).

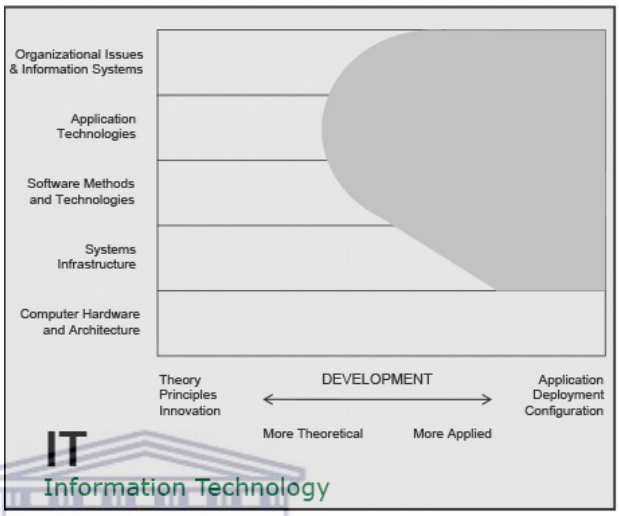

Figure 2: Depiction of how Information Technology is defined by ACM (The Association for Computing Machinery (ACM), 2005, p. 20)

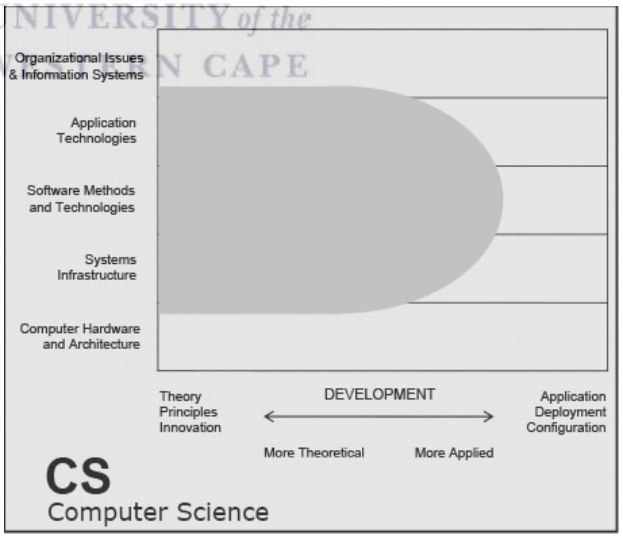

Figure 3: Depiction of how computer science is defined by ACM (The Association for Computing Machinery (ACM), 2005, p. 18)

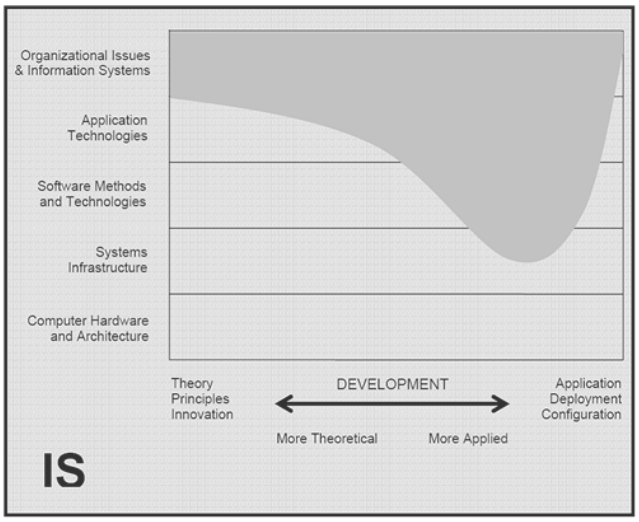

Figure 4:: Depiction of how Information Systems is defined by ACM (The Association for Computing Machinery (ACM), 2005, p. 19)

The definition of IT also varies in different higher education institutions. The University of Cape Town describes their IT degree as comprising of computer science programming and engineering within the context of business computing such as information systems and commerce (UCT, 2017). The University of Pretoria defines IT as the following disciplines: computer science, informatics and information science (Pretoria, 2017) and high schools in South Africa define IT as computer science.

According to iTechBlogspot CS, IT and IS are defined as the following: the term IT refers to the design, development and implementation of computer software and hardware (Major Fields in Computing, 2017); Computer engineering (CE) focuses on the analysis and design of computer hardware; Computer science (CS) is concerned with the development of software, from hardware use to software use; Information systems (IS) is the understanding of the way in which computer technology is used within businesses and focuses on how computer technology can be used to solve business problems (Major Fields in Computing, 2017).

Within this proposal, IT will be seen as an encompassing term similar to the Spraul (2005) definition (see Figure 1).

Computer science and computer science education

Within the study of computer science, graduates should have a technical understanding of computer science as described by the body of knowledge of the ACM (IEEE, 2013). Problem solving skills are taught through a variety of programming languages and paradigms. These skills aim to enable students to solve real problems such as to improve and design a system. The study of computer science is a lifelong learning cycle because technology and computing are continuously advancing and changing (IEEE, 2013). It is therefore important that computer science graduates ensure that they are able to adapt their skills so that their skillset will remain relevant throughout their careers (Reid, 2014).

Project experience is emphasized in computer science as it is very important that students are familiar with and understand the software development lifecycle. Furthermore, project experience allows for effective communication, the honing of organizational skills, such as time management and how to work effectively in teams. In a nutshell, computer science does not only focus on computing but also puts a heavy emphasis on the development of soft skills, which are needed for industry (IEEE, 2013) (Carter, 2011).

STEM AND COMPUTATIONAL THINKING

There is definitely a link between computer science and mathematics, however computer science is not purely mathematics. Mathematics courses are included in the computer science curricula at introductory or first year level. Since a mathematical foundation is required and is relevant to specific areas of computing. For example, the understanding of linear algebra is needed in graphics and the analysis of graph algorithms in computing. Thus the understanding of particular mathematics is needed to write these kinds of programs. According to the ACM (2013) students are not required take

mathematics further than first year level. It is only those students who progress towards advanced coursework in specific areas of computing that need the grounding of mathematics in those relevant areas, who need to study mathematics at a second or third year level (IEEE, 2013). A study called Trends in International Mathematics and Science Study (TIMSS) is a cross-national study that calculates science and mathematics achievement. Within the study, 11,969 pupils within 285 South African schools during the years 2010 and 2011 were tested (Wilkinson, 2015). Forty-eight countries participated in this study and South Africa was placed 48th for science and 47th for mathematics (Wilkinson, 2015). It was also found that the least poor schools, which covered 20% of the study, did significantly better than the remaining 80% in both mathematics and science (Wilkinson, 2015).

GENDER

Historical perspective of women in computer science

During the 1800's, Ada Lovelace was named the world's first computer programmer (Ada Lovelace, 2017). She realised that it would be possible for Charles Babbage's Analytical Machine to be used for applications beyond pure calculation. She created the first algorithm for this machine (Ada Lovelace, 2017). Another well-known pioneer was Grace Murray Hopper (born in 1906) who identified the importance of higher-level languages in the future of computing, Hopper was also responsible for the development of the FLOW-MATIC programming language (Gurer, 2002). The FLOW-MATIC programming language was the only implemented business data processing language at its time (Gurer, 2002). It was common for women to be involved in the computing industry in the early 20th century and a number of women made significant impacts on the industry. Computer science, therefore, was not always a male dominated field. Due to World War 2, almost all of the earliest computer programmers were women and were stereotyped as being strong programming

candidates with their ability to consider detail, their persistence and patience. These are traits which are required for computer programming (Gurer, 2002).

Gender mismatch

The number of women enrolling for a computer science major has decreased over the years. In 2014, in Silicon Valley, United States, 70% of the top tech employees within large corporate companies were male (Andrews, 2017). These top tech companies are Twitter, Facebook and Google. The gender ratio within technical roles is even more pronounced. For example, 10% of Twitter's technical employees are female (Andrews, 2017). In the 21st century, computer programming is said to be one of the highest paid skills, however, this still does not draw women into the field. Elizabeth Ames from the Anita Borg Institute for Women in Technology said that one of the primary reasons for the gender gap in computer science goes back to the close relationship between computing and gaming during the 1980s (Andrews, 2017).

> *A lot of early computers were used for game playing, Ames says. Those games tended to be aimed more at boys and men than girls and women, so it was easy for boys to get a leg up in that area through gaming (Andrews, 2017).*

POSSIBLE REASONS FOR THE MISMATCH

A study by Hanton describes computer science as being challenging and that women who have not being exposed to computing at some point during their schooling career would not be open to choosing a computer science major at university (Hanton, 2015).

It is not clear why very few women enrol for studies in computer science. There are many suggestions as to what computer science is and why women avoid studying computer science. Two of these suggestions are: one is that women are afraid to enter an industry that is male dominated (Scragg & Smith, 1998); another is the belief that computer science requires an advanced proficiency in mathematics. Since many women have math anxiety, they perceive computer

science as challenging and this psychologically, leads to a low confidence in their ability to deal with computer science studies (Scragg & Smith, 1998). According to the World Bank report, a gender gap exists at home and in the educational system even before girls enter university—with only 5% of 15-year-old girls (compared to 18 percent of boys) in Organisation for Economic Co-operation and Development (OECD) economies considering a career in STEM (OECD, 2009).

Research has shown that the majority of the few women, who do enrol for an introductory computer science course at first year university level, do not have, at the beginning, the intention of majoring in computer science (Scragg & Smith, 1998). The question thus is *Why do so few of those few women complete their computer science major*?

HOW ARE WOMEN PERCEIVED BY OTHERS WITHIN THE IT INDUSTRY?

Retaining women within male dominated industries remains a challenge (Martin & Barnard, 2013). This is probably because it can be difficult for women to find their identity within a male dominated industry. A female software engineer in Minnesota, United States (US), Jane Lansing, describes (Lansing J. , 2015)—as one of the few women working as a software engineer—how her male project managers still insisted that a male colleague review her code. Lansing recalls customers being unable to look the women in the eye when speaking to them and some were even unable to speak to them at all. Instead, male clients would prefer to pose questions to male colleagues even when it was obvious that the women had the relevant expertise. If a male was not present in a meeting, clients requested that a male colleague be called to answer their questions. Women were frequently requested to perform menial tasks outside their job description, such as to make photocopies and coffee for unknown male clients. There were even instances where women's contributions in a meeting were not acknowledged. These are the kind of professional experiences that women working within IT

and male dominated industries find very difficult to cope with. Due to these experiences, many of the few (40%) women working in the technology field in 2015 in the US, decided to quit their jobs after only working in the industry for five years. In order for women to succeed in a male-dominated industry they need to trust their instincts, always remain confident and support each other (Lansing J. , 2015).

Information technology in schools

Prottsman suggests that women, who have been exposed to computing at some point during their school career, tend to be more open to choosing a career in computer science (Prottsman C. L., 2011). Female scholars are not necessarily exposed to information technology at school. For example, in Cape Town, there are seven girls' schools, five out of these seven schools offer information technology as a subject choice. Two of these five schools offer information technology only as an extramural subject where students attend classes at a boys' school in the afternoons. The fact that it is at an unfamiliar and male dominated venue might deter girls from taking the subject. Furthermore, the subject is offered extramurally which may not suit all learner's schedules and this may be a reason why some girls decide not to take IT as a subject. At high schools within South Africa, every student has to take seven subjects (four are compulsory and three are chosen at the end of grade 9) from grades 10 to matric, and each student has the choice of choosing an extra 8th subject if they so wish. Schools that offer IT as an extramural subject only allow it to be taken as an additional 8th subject (Subject Choice and Career Pathing, 2017). Since matric has a full curriculum and thus a heavy workload, students may not be comfortable with taking an extra subject.

Computer science at university

For women who do enrol to study computer science as a major, their first year of study, specifically the first semester, is the most influential in determining

whether they will continue with their major or drop out (Miliszewska, Barker, Henderson, & Sztendur, 2006). The encouragement of peers has been shown to be more effective than the support of staff, including lecturers and tutors (Miliszewska, Barker, Henderson, & Sztendur, 2006). The majority of the staff within computer science departments are male, and females have shown to be more comfortable with asking a female for help or assistance with course work rather than asking a male (Miliszewska, Barker, Henderson, & Sztendur, 2006). This may result in female students not asking for assistance when they are struggling with course work or doing poorly overall, causing the situation to worsen which could lead to dropping out or failing the course.

In a study by Fuentes *et al.* it was found that teachers are of the opinion that females often encounter difficulties during first-year programming courses, more so than their male counterparts (Fuentes, Andersson, Johansson, & Nilsson , 2005). However, there is a lack of studies to confirm this. It was also seen that women had lower self-confidence than males. This was evident within computer science first year group assignments where a male student would come up with a solution and the female student would isolate their responsibility by rather taking up a passive role. Within universities worldwide, women studying computer science are the minority (Fuentes, Andersson, Johansson, & Nilsson , 2005). Within a study, women said that they did not like their computer science programming course because although they spent considerable time studying course work and preparing practical work when the exams came, women still struggled to complete their examination papers (Fuentes, Andersson, Johansson, & Nilsson , 2005). Most computer science introductory courses require programming assignments to be completed individually. Because of this, women view computer science as a competitive industry. It is suggested that if pair programming is implemented within introductory courses, women may begin to view computer science as a collaborative environment rather than as a

competitive environment and not as a socially isolating industry (Werner, Hanks, & McDowell, 2004).

Most women who study computer science, have only been introduced to programming at university level. Part of women's under representation at university is due to the fact that only a few girls take computer science or IT during their secondary schooling (Prottsman C. L., 2011). Women's interest in and confidence towards computer science during undergraduate studies may be low because they are being taught and have to learn new skills in a structured way. (Google CS Ed Research, 2014). When children learn new skills by playing and exploring, they learn naturally because the learning is un-structured. Once children enter school this changes to a more structured way of learning which sometimes can be stifling. Similarly playing computer games could give scholars and students the opportunity to learn computing in an un-structured manner.

GAMING

The relation between computer science and gaming

Computer games may be defined as a contest of mental or physical skills and strengths required by the participants to follow an outline of rules to achieve an end goal, that is, to win (Ke, 2009). In order to achieve the end goal of winning, several stages of problem solving are required. (Ke, 2009). Games teach code literacy, and develop critical thinking skills; these form a solid platform for children to begin to explore programming. As mentioned previously, problem solving is the primary skill of computer science. According to Granic *et al.* video games are said to be good at developing problem solving skills (Granic, Lobel, & Engels, 2014) since all video and computer games are centralized around problem solving. Game designers often provide the players with very basic instructions and very little or hardly any information on how to solve the problem, providing the player with the space to come up with their own way to solve the problem. Problem-solving may be defined as taking time to collect information, evaluate

multiple options, create a plan and consider changing options or goals before continuing further (Granic, Lobel, & Engels, 2014). A similar approach is followed when solving a programming problem, programmers are required to design through the use of expressions, programming constructs and statements to assemble] the right logic and meaning of those constructs, statements and expressions to solve the programming problem successfully (Havenga, Breed, & Mentz, 2013). According to Havenga *et al.* the process of programming problem solving is: planning the solution, monitoring the design and development of the programming and evaluating the solution. Where there are errors, the problem solving process starts again until the errors are fixed and the problem has successfully been solved. Likewise, within a game, if the player loses a round, they will attempt the round again through a strategy different from before, until they win and progress to the next round (Havenga, Breed, & Mentz, 2013).

Game theory

Game theory may be defined as —*a competitive activity in which players contend with each other according to a set of rules* (Osborne M. J., 2004, p. 1). A formal definition defines it as a group of several players whose outcome is influenced by their information, their preferences and strategic actions (von Stengel & Turocy, 2001). Game theory in a nutshell explains how people interact within decision making processes (Magazine, 2015). The players in a game may be firms, individuals, groups or a combination of these (von Stengel & Turocy, 2001). The concepts of game theory provide a language to formulate structure, analyse, and understand strategic scenarios. The mathematical foundation of game theory, makes it an ideal modelling and designing automated decision-making processes within environments that are interactive (von Stengel & Turocy, 2001). An example of this may be an implemented bidding system on an auction website. Thus, game theory provides a methodology for analysing and organising problems of strategic choice as a mathematical tool for decision-making systems and functions (von Stengel & Turocy, 2001).

Game development

The development of computer games consists of many more aspects than just computing (Overmars, 2004). These aspects include computer human interaction, artificial intelligence, graphic design, simulation, music composition and software engineering. Thus, in order to be a part of game design and development, you do not need to be a coder. Game development platforms have been created in order to introduce those, who do not have the skills of coding, to game development. Such platforms do not require a knowledge of coding and only use drag and drop or basic HTML 5 concepts (Overmars, 2004).

Game development platforms

Several platforms exist for game development such as: Unity; GameSalad; Stencyl; GameMaker: Studio; etc. Unity and *GameSalad* will be discussed in a bit more detail. *Unity* is a cross platform game engine with a built-in Integrated Development Environment (IDE) that is used to create games and web-plugins for mobile devices, desktop devices and game-consoles (Polsinelli, 2013). *Unity* allows for game developers to create and run games in a variety of environments (Polsinelli, 2013). The game engine includes a code platform where developers will write their lines of code which will create a game once complete. A significant background and knowledge of computer programming is needed in order to use *Unity* to develop games. There is no drag or drop option, all games are created using extensive computer programming. Unity supports the programming language C# (Unity 3D, 2018).

GameSalad (See Figure 5) is a drag and drop game creation platform/ engine for the development of HTML 5 and Android or iOS games (Business of Apps, 2015). No coding is required to make use of this software. *GameSalad* consists of a testing tool as its main feature. Although no coding is required, developers still follow the code development process of design, create and test (Business of

Apps, 2015). There are numerous *GameSalad* tutorials available on *YouTube* where children may learn how to use the application.

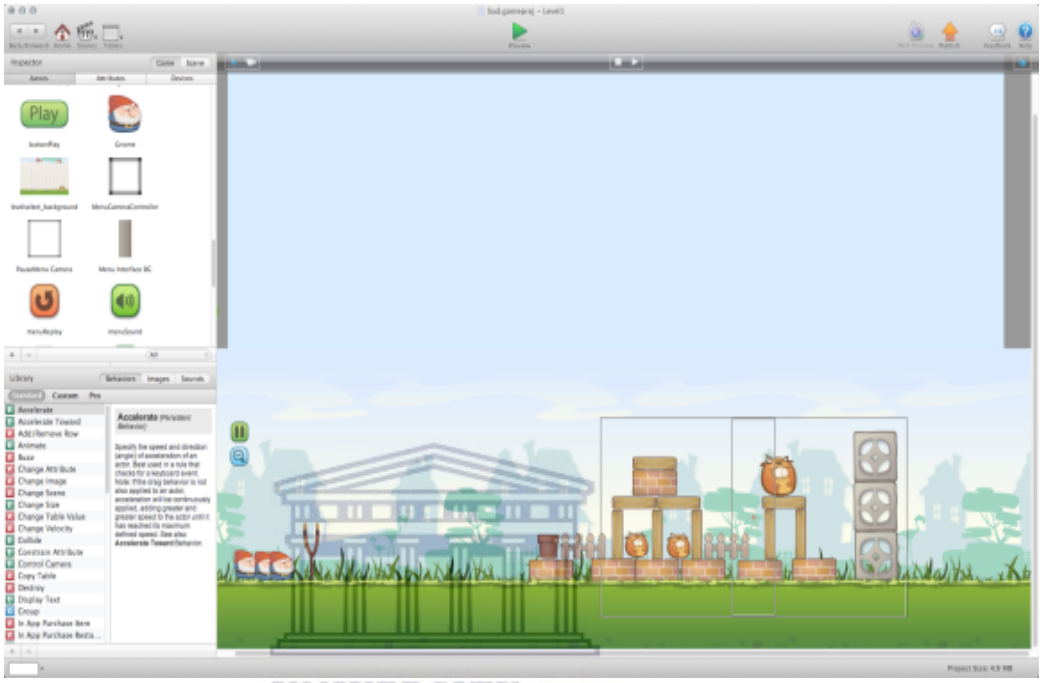

Figure 5: *GameSalad* game creation tool (Grubb, 2013)

Burke et al. mentioned four goals for children who develop games (Burke & Kafai, 2014). These goals are:

1. Learn programming: Children learn the fundamentals and basics of computer programming as they create a game. They learn informally about the coding process.
2. To making coding more appealing to females, children should be exposed to CS from a young age and will learn how to code whilst developing games. This will inform them about CS career choices.
3. Learning content in other academic fields – game-making is a fun way to learn rather than teaching in the conventional way. This method can be applied to other subjects too.

4. Understanding design concepts- The art of game-making does not only apply to creating games. It may be applied to all areas of life because children use aspects of life to create games and talk about games which drives the game making process (Burke & Kafai, 2014).

CONVERGENCE AND LEARNING IN GAMES

There are many learning models that have been developed for games. Many learning models define processes that lean towards the Nash equilibrium (Levin, 2006). The Nash equilibrium is achieved when in a non-cooperative game—which involves a minimum of two players—each player is assumed to know the equilibrium strategies of the rest of the players. If every player has decided on a strategy and no player can gain anything by changing strategies, the rest of the players' strategies remains unchanged. The current collection of strategic choices and matching payoffs results in a Nash equilibrium. The Nash equilibrium is stated to be one of the basic concepts of game theory (Osborne & Rubenstein, 1994). Learning models in games differ in terms of how a player makes decisions while playing and how advanced the other players are.

LEARNING MODELS IN GAMES:

Fictitious play is one of the oldest learning models in games. It is also known as a *belief based*-learning. This means that the players create beliefs about their opponents play and behave rationally according to these beliefs (Levin, 2006).

Reinforcement learning is a psychological model which states that players will choose a strategy that has been successful in the past. Strategies that gamers used previously to win a game allow them to progress successfully to a new round (Levin, 2006).

THE EFFECTIVENESS OF PERSUASIVE TECHNOLOGIES

Persuasive technology is defined as a class of technologies that has been purposely designed to change a person's behaviour or attitude, or both (Wijnand, et al., 2006). Persuasive technologies require user interaction through the use of persuasive techniques rather than one-way interactions- such as a user's context, needs and input (Wijnand, et al., 2006). This makes the technology more powerful (Wijnand, et al., 2006).

Persuasive technologies are the most popular amongst computer applications which sell products or services, and over time, there has been an exponential growth in the development of persuasive technologies to increase human well-being and health (Wijnand, et al., 2006). Applications developed for mobile devices that promote, support and motivate healthier lifestyle changes such as diet, stress management, smoking moderation and exercise could possibly prevent the onset of a variety of medical problems and improve a person's quality of life (Wijnand, et al., 2006). For example, the Apple Watch activity application is an application for the Apple Watch that monitors if the wearer of the wearable technology is getting enough exercise for the day (Stables & Allison, n.d.). The application also monitors the user's heart rate throughout the day and will send the user a warning if their heart rate is too high or low. The Apple Watch activity app allows the user to set a total amount of calories to burn daily through exercise and the app will monitor if the user has burned these calories daily (Stables & Allison, n.d.). Throughout the day, the watch sends the user push notifications to motivate them such as: *Well done, you have burned half of your calories for the day or you have x calories to go*. This application also sends the user push notifications which tells the user to stand for a minute when they have been sitting for too long or to take a minute to breathe where the watch guides the user through a one-minute

breathing meditation. All of these push notifications interact daily with the user and promote a healthier lifestyle (Stables & Allison, n.d.).

Persuasive technologies have also been created for educational purposes. A persuasive technology was developed to improve the motivation of children, between the ages of 8 and 11 years, to read and write (Lucero, Zuloaga, Mota, & Muñoz, 2006). The software aimed to improve these skills through a game rather than via a testing approach. The software was tested by children and was shown to have motivated children to read and write in a fun and enthusiastic way (Lucero, Zuloaga, Mota, & Muñoz, 2006).

Serious games as persuasive technologies

Serious games (SG) may be defined as digital games, that use the same characteristics and technologies as video games, but focus more on the emphasis of educating rather than entertainment (Romo , 2011). SG may also be defined as *a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives* (Zyda, 2005, p. 26). Educational games are designed to encourage students to persevere and at the same time educate them (Romo , 2011). Within computer science education, SG's are being used within programming courses to solve the problem of a student's lack of motivation and to improve overall learning (Romo , 2011). Many projects display positive outcomes and reactions to educational games, however more research is still needed in the area of SG's (Romo , 2011). Currently, there are results that suggest that video games are likely to be an influential tool that will transform education and possibly change the conventional education system (Romo , 2011).

A SG was developed at a university in Portugal for an introductory course in computer programming (Coelho, Kato, Xavier, & Gonçalves, 2011). The SG aimed to teach students the basics of computer programming using a game rather than the conventional way of teaching through class exercises, which often

become tiresome. The game was designed with the focus being on programming and code understanding with a playful mechanic. As errors in code are part of the programming process, the objective was to aid the player when errors arose and not to penalize the player too much for these errors (Coelho, Kato, Xavier, & Gonçalves, 2011). Lecturers were also able to track the students' progress and provide feedback. The platform was tested by a group of students and the feedback was very positive (Coelho, Kato, Xavier, & Gonçalves, 2011).

SUMMARY

In this chapter, the literature was reviewed that relates to the key concepts of the research. The history and background of women in computer science was discussed. Games and game theory were discussed in order to understand the relationships and similarities between computer science and games. In the next chapter, the research approach as well as the methodology adopted for this research will be discussed.

Chapter 3

RESEARCH APPROACH

INTRODUCTION

In the previous chapter, an overview was given of the literature that deals with the gender gap in computer science and persuasive technologies. The concept of gaming, gaming for learning and game theory was also discussed. In this chapter, the methodology of the research will be described. The methods chosen to perform data collection and how it will be analysed, will be motivated. Prior taking part in this research, each survey participant was given a consent form to complete, in order to adhere to the ethical standards (see Appendix A, Page89).

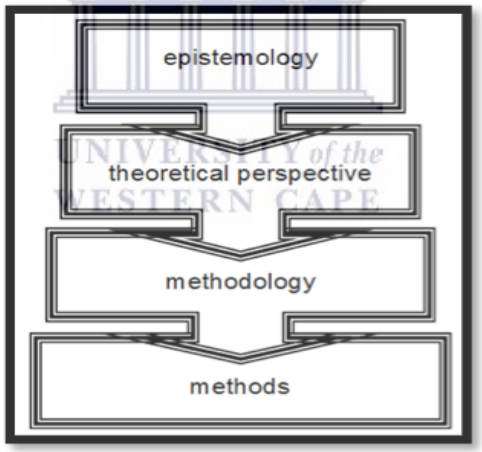

Figure 6: The four elements as proposed by Crottyas part of research design (Crotty M. , 1998, p. 4)

RESEARCH PHILOSOPHY

According to Crotty (see Figure 6), it is important to answer the following questions (Crotty M. , 1998):

1. What epistemology informs the theoretical perspective?
2. What theoretical perspective lies behind the methodology chosen?
3. What methodology governs how we choose our methods?
4. What methods appropriate and do we plan to use?

Epistemology

An epistemology is concerned with providing a philosophical foundation for determining what type of research is possible and how this research can be shown to be legitimate and adequate (Crotty M. , 1998). Epistemology is linked with ontology. Crotty (Crotty M. , 1998) mentions how an epistemology complements ontology and vice versa. When Crotty cites the ontological notion of realism, he it talking about a psychological belief that realities exist outside of the mind. Its complement is objectivism, which is an epistemological notion that believes that meanings exist and can be explained through measurable properties independent from the mind of the subject and observer. However, subjectivism is the belief that without the contribution of the world, meaning is enforced by the subject's mind and where the observer is not independent of the subject (Crotty M. , 1998).

The definition of an objectivist epistemological stance is the perspective that one's feeling regarding objective knowledge, should be separated from it (Huglin, 2003) (Davies, 2006). This perspective presents a theoretical basis for quantitative research where researchers prefer to conduct quantitative research rather than qualitative research (Huglin, 2003).

Many ongoing debates exist on whether it is possible to merge subjectivism and objectivism. Some researchers believe that the two should complement each other while others believe that they should be regarded as the complete opposites (Huglin, 2003).

CONSTRUCTIVISM

Constructivism, according to Crotty, is an epistemology that suggests that there is no objective truth and that truth only comes into existence when we engage with the realities of our world. *meaning is not discovered, but constructed …. In this view of things, subject and object emerge as partners in the generation of meaning* (Crotty M. , 1998, p. 6).

Since this research adopts both an objectivist and subjectivist stance, constructionism is the chosen epistemology.

Theoretical perspective

A theoretical perspective may be regarded as a model whereby every perspective makes an assumption about society where each one aims to integrate different types of information about society (Long, 2017). There is no perspective that is said to be the best, the chosen perspective will depend on the question being asked. For example, a conflict perspective would be more helpful if one is concerned with social inequality. If one is researching bureaucratic organization, then a perspective concerned with social order may be useful. Some believe that the best perspective may be a combination of many perspectives (Long, 2017).

The functional perspective is the issue of sustaining social order for the problem of understanding society. By understanding society from a functionalist perspective, society is visualized as a system of interconnected parts. Although all parts may be doing something different, they still act cooperatively. Balance is the outcome when all parts of a system work together. The parts of a social system are religion, family, education and institution. When they work together, it results in order in society. This promotes both balance and stability (Long, 2017).

The Conflict perspective sees society less as a cohesive system and more of a place of conflict. Instead of people working together as seen in the social system, people achieve their will at the expense of others by competing against one

another for rare resources. In-equalities between different groups is the main theme of conflict theory (Long, 2017).

CRITICAL SOCIAL THEORY

Habermas (Habermas, 1978) defined three different primary cognitive areas where knowledge is created through human interests: These knowledge interests are: 1. Technical knowledge interest—it is the human need for prediction and control of the world 2. Practical knowledge interest—it is to do with the quest for the understanding social forms of life and in so doing improving social consciousness and humanity. 3. Emancipatory knowledge interest—is concerned with the freedom from mental and physical restrictions (Ngwenyama, 1991).

These knowledge interest are categorized in terms of how knowledge is interpreted. The term *knowledge constitutive* refers to how knowledge is discovered and determines whether the knowledge claims can be warranted. The different aspects of social existence—work, power and interaction— are areas that define learning domains or cognitive interests.

The theoretical perspective of this research is based on the critical social theory of Habermas.

Table 1: Habermas' Three Domains of Knowledge (Habermas, 1978)

Type of Human Interest	**Kind of Knowledge**	**Research Methods**
Technical (prediction)	Instrumental (casual explanation)	Positivistic (empirical analytic methods)
Practical (interpretation & understanding)	Practical (understanding)	Interpretive research (hermeneutic methods)
Emancipatory (criticism & liberation)	Emancipation (reflection)	Critical social sciences (critical theory methods)

Methodology

A research methodology may be defined as a systematic method of solving a particular problem. It is a series of steps, followed by a researcher when explaining, describing and predicting phenomena (Rajasekar, Chinnathambi, & Philominathan). A research methodology provides the researcher with a work plan of methods to follow to answer the research questions. Knowledge is gained through the study of various chosen methods (Rajasekar, Chinnathambi, & Philominathan).

DESIGN SCIENCE RESEARCH

The Design Science Research (DSR) methodology is commonly used within the computer science and IT industry. DSR is defined by Gregory as a *general research approach with a set of defining characteristics that can be used in combination with different research methods* (Gregory, 2011, p. 5) . Within this research, DSR will be used as the methodology to address the proposed research question.

The DSR according to Vaishanvi and Kuechler comprises of five steps (See Figure 7) (Vaishnavi & Kuechler, 2015). The methodology focuses on design science and the creation of an IT artefact. An IT artefact is developed to address the research question and is evaluated to assess whether or not. the design goal of the artefact has been achieved.

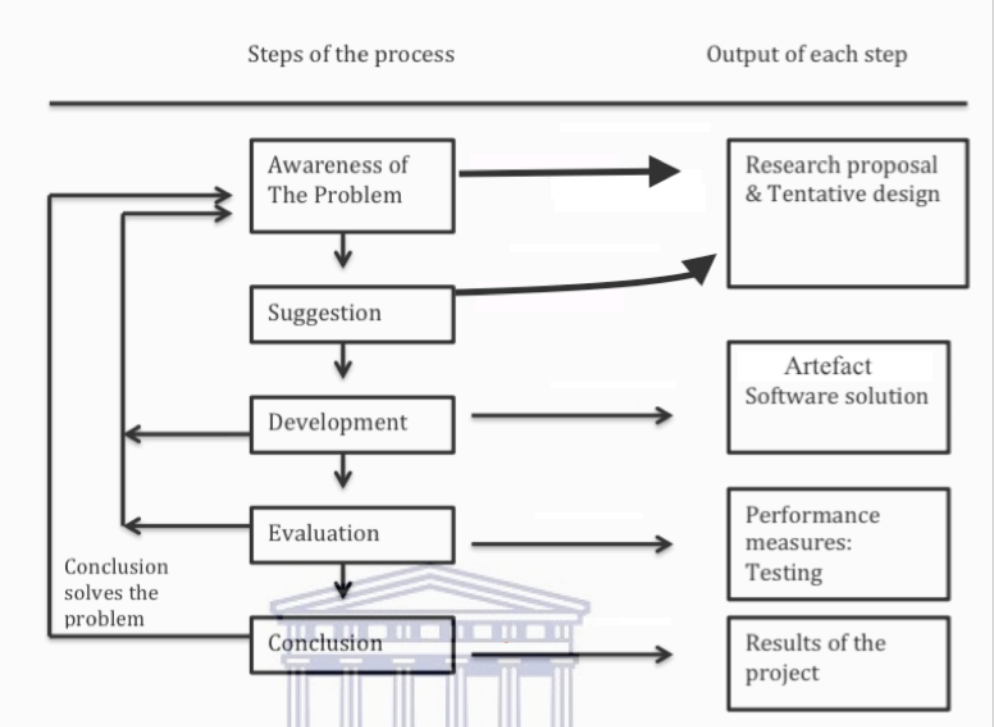

Figure 7: Steps and Methods of DSR (Vaishnavi & Kuechler, 2015)

Methods

Research methods may be defined as procedures or techniques that are used to collect and analyse data related to a specific research question or hypothesis (Crotty M. , 1998). There exist many different methods that can be used within research. However, the method adopted needs to be appropriate for the underlying theoretical perspective.

The methods which will be used for this research are mentioned below.

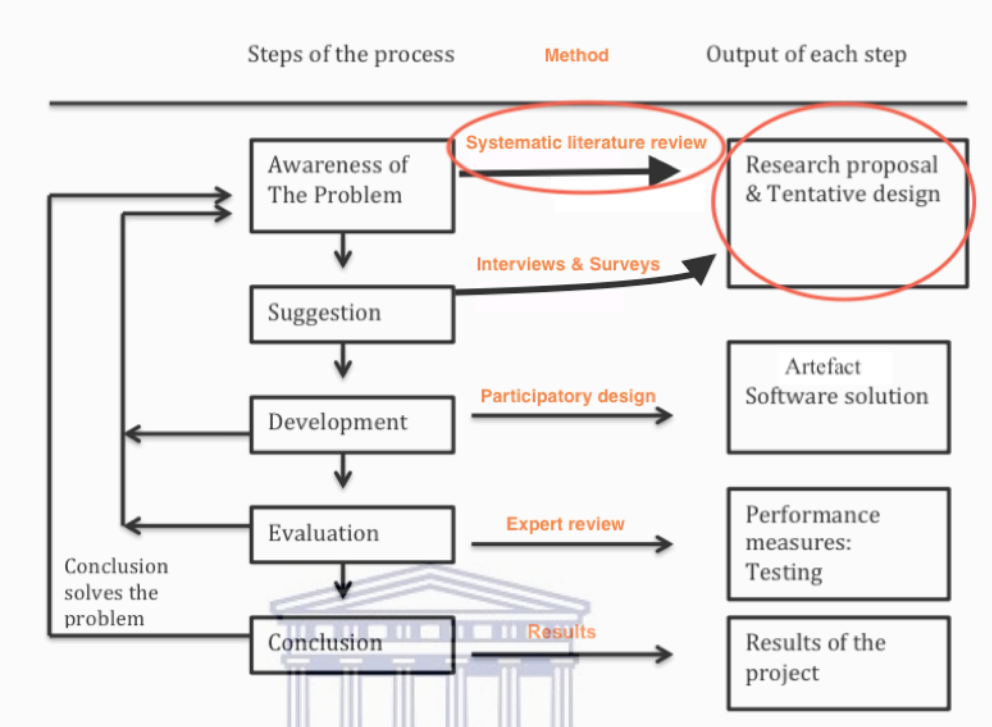

Figure 8: DSR and systematic literature review

SYSTEMATIC LITERATURE REVIEW

> *this is a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyse and summarise the results of the included studies (CRD, 2001, p. 25)*

By integrating, evaluating and identifying relevant findings and studies, a systematic literature review aims to address one or more research questions. It may be pictured as a piece of research on its own because it answers the research questions within a much broader context (Siddaway, 2014). Systematic literature reviews have been said to provide the most significant practical implications out of all other research designs (Siddaway, 2014). They consist of a systematic process of searching to discover studies such as papers and journal articles which address the research question/s. The inclusion and exclusion criteria are

objective and are explicitly stated and implemented throughout this method to make it clear to researchers and other readers with the same criteria, which findings and studies will be included and excluded (Siddaway, 2014). The aim of this method is to minimize any bias and to allow the reader of the review to evaluate the authors conclusions, assumptions, procedures and evidence. This form of a literature review allows the reviewer to update the review in future with new and relevant findings (Siddaway, 2014).

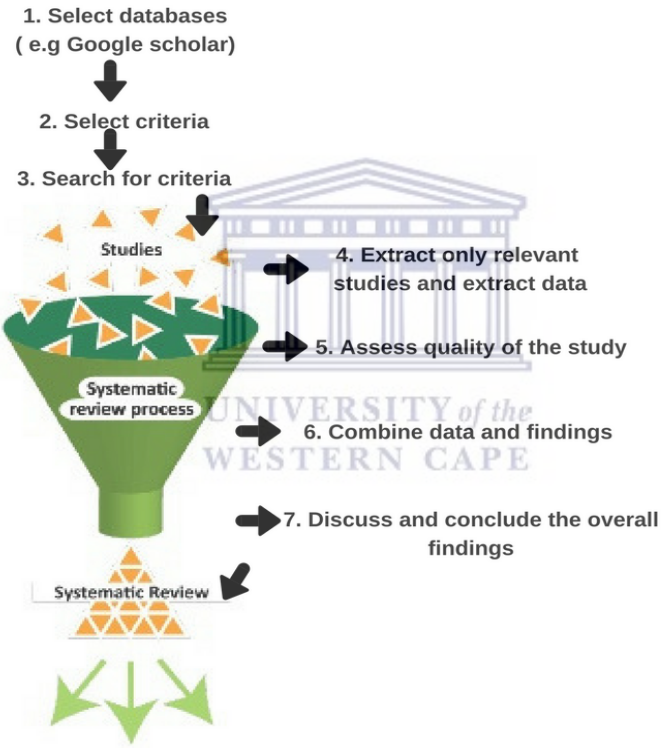

Figure 9: Systematic literature review (Cochrane Consumers and Communication, 2016)

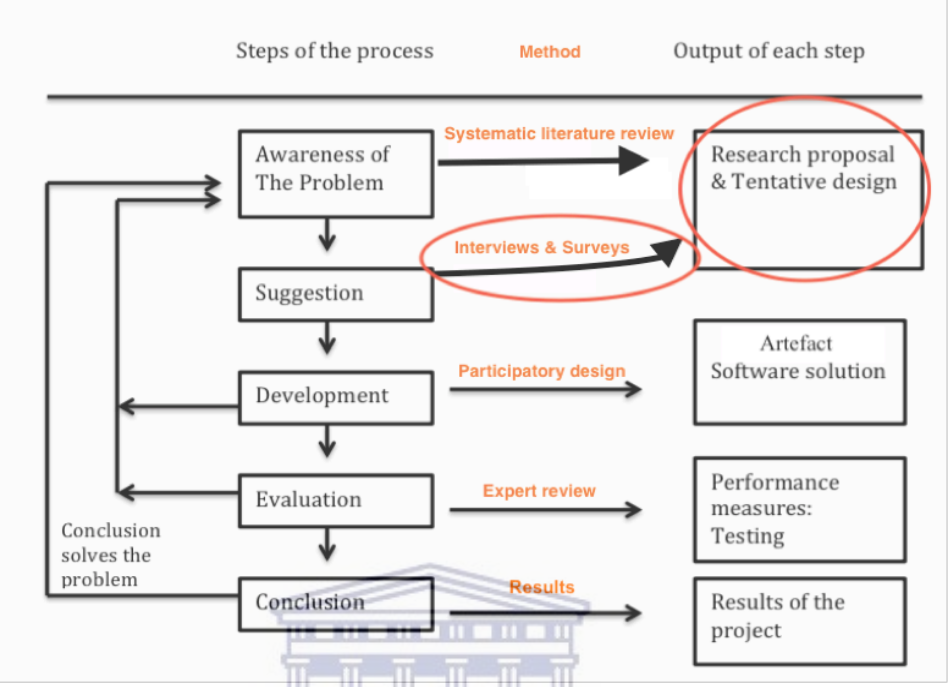

Figure 10: DSR and Interviews and Surveys

INTERVIEWS

Interviewing is known to be one of the most popular data collection methods for qualitative research (Mason, 2017). Mason has set out three different kinds of interviews: these are: in-depth interviews; structured interviews and unstructured interviews. All of these interview types have some kind of dialog structure between the interviewer and interviewee. Some reasons why a researcher may choose interviews as a data collection method for qualitative research are: interviews are reliant on the interviewee's interaction, verbalisation and memory, the participants always respond from their point of view which provides a real and rich perspective (Mason, 2017). The semi-structured interview methodology as described by Schön (1987) allows for "*reflection-in-action*"—that is when conducting an interview certain probes (or questions) will be used but the interviewee will determine in what direction the conversation goes (Schon, 1987).

SURVEYS

A survey is defined as collecting data from a sample of participants through their answers to a series of questions (Check & Schutt, 2011). Surveys may be used in quantitative and qualitative research and even research that is a combination of both (mixed methods). A survey is conducted through a questionnaire that is self-administered, administered by a professional or by a group (Ponto, 2015). The questions within the questionnaire are created to address the research aim or research questions. Surveys may be conducted face-to-face, over the telephone, via email and via platforms such as Google sheets and SurveyMonkey (Ponto, 2015). Researchers have found that the use of mixed-methods in surveys accomplish a better sample size, reducing coverage error (Dillman, Smyth, & Christian, 2014).

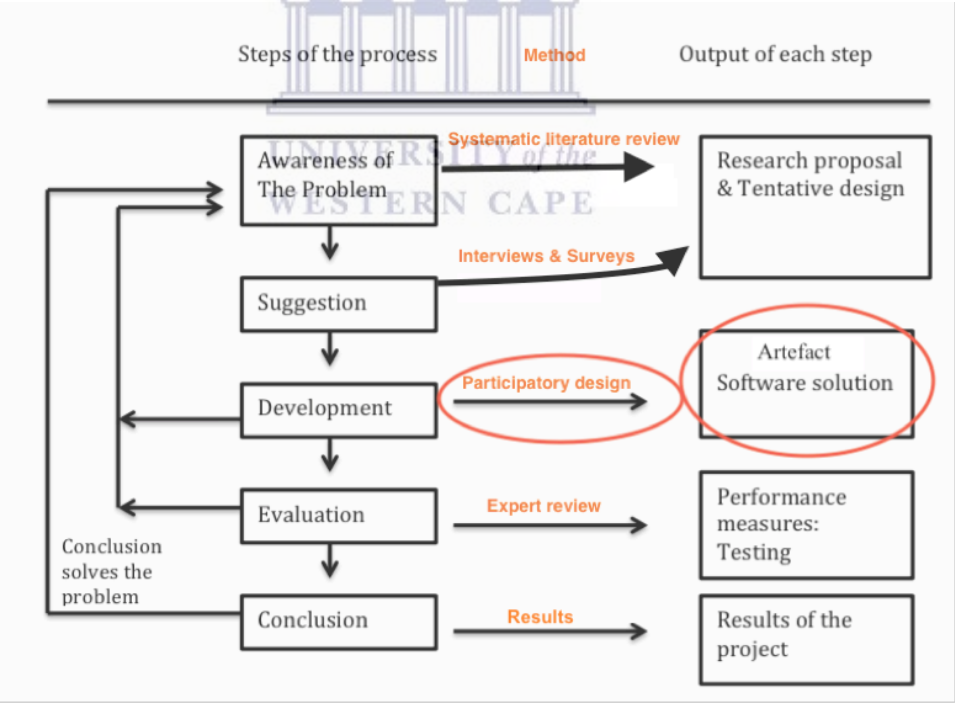

Figure 11: DSR and Participatory Design

PARTICIPATORY DESIGN

Participatory design is a method that involves stakeholders in the design process in order to ensure that the end product meets the needs of the intended users (Muller , 2003). This means that non-designers are also part of the designing process of an artefact. 'Non-designers' refers to intended users, potential users or external stakeholders. A tentative design is implemented within this method (Kuechler & Vaishnavi, 2004). The techniques chosen for implementation will depend on the kind of artefact being created (Kuechler & Vaishnavi, 2004).

Participatory design is an iterative process consisting of 3 steps (See Figure 8):

1. Exploration Phase

   During this step, the designers meet with the intended users to gather requirements for the artefact to be developed.
2. Discovery Phase

   The needs of the user are agreed upon and the requirements of the artefact to be developed is finalized.
3. Prototyping

   The artefact is developed.

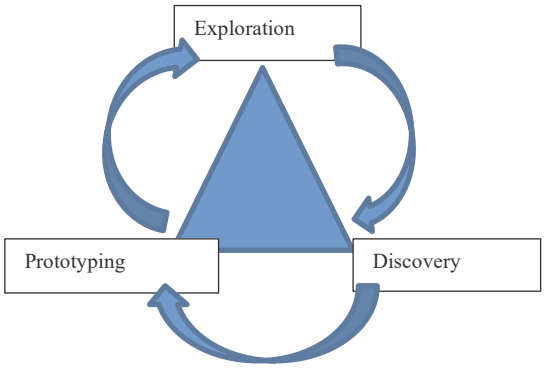

Figure 12: Participatory design process (Muller , 2003)

EXPERT REVIEW

According to the criteria stated in the proposal, the designed artefact is evaluated. All deviations from qualitative and quantitative expectations must be described tentatively. The evaluation therefore consists of 3 phases where the hypotheses are formed about the behaviour of the artefact (Kuechler & Vaishnavi, 2004). Inspection methods are commonly used to examine the usability of a developed product. One of the most popular methods is a heuristic walkthrough also known as an expert review because the knowledge and experience of the evaluators will affect the results of the evaluation (Korhonen, Paavilainen, & Saarenpää, 2009). A set of usability heuristics are chosen and tested by the evaluator. The expert review aims to uncover any usability issues that need to be improved (Korhonen, Paavilainen, & Saarenpää, 2009).

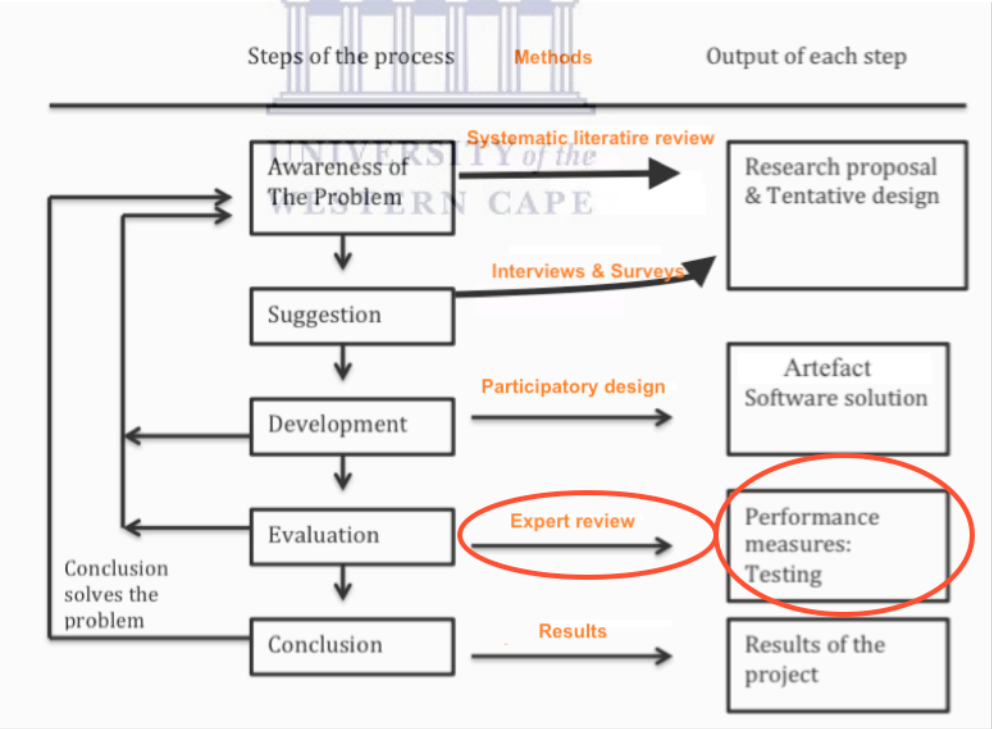

Figure 13: DSR Expert review

And finally, the research will conclude with presenting the results. This will be done in Chapter 4.

RESEARCH DESIGN OF THIS PROJECT

In the following section, the research design of the project will be described in detail, and will explain how each of the DSR steps (refer to the figure) was executed.

Awareness of the problem

To understand why so few women enter the IT field, and to consider whether computer games designed for women would change women's perceptions of computer science the following question was asked:

Would computer games designed to interest women, encourage them to play them and thus create an interest in computer science?

This research question was broken into the following research sub-questions:

1. Why would gaming lead men more than women to study computer science?
2. What aspects of computer science attract women?
3. Can gaming be a non-structured learning technique to attract girls to CS/IT?
4. How should computer games be designed to interest women?

SYSTEMATIC LITERATURE REVIEW

After reading various papers and research about women in the CS and the IT industry, a list of keywords was derived for the literature review.

Specific keywords or key concepts were used to search for relevant papers, journal articles, chapters in books, books and websites that could provide the researcher with data that would inform the survey questions and interview probes.

The search engines used were:	Google Scholar, UWC library and Research Gate
Databases used were:	Databases available to the UWC digital library such as SpringerLink, ACM digital library, Science-Direct Journal and the directory of open access journals.
Patents included:	None
Exclusion Criteria:	Race
Time Range:	2005-2018 (except for seminal articles)
The keywords considered were:	women in CS; stereotypes in CS; women in computer science; computer science and gender; misconceptions of computer science; gaming in teaching; gaming for girls; gender and gaming; computer programming and gaming
Number of papers found:	84
Number of papers discarded:	74
Criteria used to discard papers:	All papers relating to the research questions were retained. They were used to address the research questions. Papers that were not directly linked to address the research questions were discarded.
Number of papers retained :	10

Suggestion

Using the results from the systematic literature review, a questionnaire of 30 questions was designed (see Appendix B) and fifteen probes were identified that were used to elicit comments during semi-structured interviews (see Appendix C). The results of both these interventions informed the design of a framework or artefact.

SURVEYS

Surveys were administered to 40 first-year CS students at UWC: 20 males and 20 females. Some of the questions in the survey were derived from the study of Guzials et al. (Guzdial, Ericson, McKlin, & Engelman, 2012). The researcher attended two first year CS practical sessions—the whole cohort of first-year CS students could be accessed in these sessions—and thus it was arranged by the researcher and the first-year lecturer that the surveys could be administered during these practical sessions. The researcher explained what the study was about before handing out the consent forms and surveys to a random selection of 20 males and 20 females. The completed surveys were collected at the end of the practical session.

The data retrieved from the survey was entered into an Excel sheet and checked for correctness. The statistical package SAS© was used to quantitatively analyse the data (SAS, 2018). The aim of this survey was to understand what made these students decide to study CS and to determine whether gaming had any influence on their degree choice. First-year students were targeted because it was the first time that many of these students would come in contact with CS and it was important to find out what they already knew about CS, their programming background, their interest in computer games and their perceptions of CS. These surveys were completed only three weeks into the academic year therefore the students' responses would be based on what they thought and knew about CS during the very early stages of their degree.

INTERVIEWS

Semi-structured interviews were conducted with five IT school-teachers and 10 CS Honours students as part of the data collection process. These interviews were conducted face-to-face, using e-mails and via telephone calls. The interviews were semi-structured and this provided the researcher with "rich" data. All

interviewees were allowed to answer in as much detail as they wanted and could add anything which they considered would add to the research.

To identify the interviewees, websites of schools in Cape Town (where IT was taught) were identified and the contact details of these IT teachers used to contact them. In the e-mail the teachers were asked whether they would be interested in being interviewed as part of this research. Only one male IT teacher at a girls' high school in Cape Town responded and was subsequently interviewed. This teacher informed the researcher that there was a general directory kept by the Western Cape Education Department of all e-mail addresses of IT teachers in the Western Cape. The researcher used this list to contact all the teachers on the list and to ask whether they would be interested in being interviewed. Only two of these teachers responded and were interviewed. Both were female IT teachers who taught at a co-ed high school. These teachers then referred the researcher to the 4th interviewee who was a male teacher teaching IT at a co-ed school. A 5th teacher who was known to the researcher was also prepared to be interviewed. He also teaches at a co-ed school. Thus in total, five high school IT teachers were interviewed.

The interview probes were structured in such a way that they investigated the following: to understand how girls (compared to boys) coped with IT at school; the ratio of girls to boys in a class; to understand how and what methods teachers use to motivate girls to take IT and to encourage them to follow through with the subject to matric. Teachers were also asked to comment about gaming and what if any, influence it could have had on students' decision to take IT at school. Furthermore, they were probed about whether the problem-solving thinking used for programming is the same as for gaming.

Ten UWC CS honours students (five males and five females) were interviewed as well, using the same probes. The intention was to understand whether the students' background and interest in IT had motivated them to study CS at

University. It was also interesting to determine what persuaded these students to continue CS at a postgraduate level.

During interview sessions, the interviewees were asked to describe what they would believe to be beneficial to add to a computer game in order to encourage girls to study CS and to become more interested in computers.

Development

"*Development*" is Step 2 of the DSR process. The intended artefact was a game tailored according to the input from the interviewees as well as information gathered from the surveys.

PARTICIPATORY DESIGN

Participatory design is an iterative three step method consisting of the following phases: The exploration, discovery and prototyping phases. It is used when users are involved in designing an artefact. Three cycles of participatory design were executed in this research.

Cycle 1 of participatory design

Exploration: Using the data collected from the surveys and interviews, the designer began to list the points, features or skills that the interviewed students and teachers believed could be incorporated into a game to motivate young girls to enter the CS field or to study IT at school. The designer/researcher analysed this data to discover any similarities mentioned by the interviewees. The researcher also researched various computer games that girls seem to enjoy playing (this was mentioned by the female interviewees) to get an idea of how to develop the game framework. Using this analysed data, a set of basic requirements were drawn up for a concept for a game framework.

Discovery: The requirements of the concept for a game framework to be developed was created and finalized based on the findings in the exploration phase. These requirements were the requirements used for the prototype in the next stage of the cycle.

Prototyping: Using the above requirements, a low-fidelity prototype of the game framework was developed. The low- fidelity prototype was created using post-it notes (see Appendix F). The idea was to get a feeling of how the game frameworks would function, what the user interface would look like, and to ensure that all requirements were incorporated into this prototype. Using post-it notes made it easy for the designer to move elements around until the designer was happy with the prototype.

Once the prototype was completed, a software expert evaluated it by having a discussion with the designer. The expert was a computer science Professor at the University of the Western Cape.

Cycle 2 of participatory design

Exploration: The feedback received from Cycle 1 was considered and the requirements of the game framework were revised accordingly. The designer read various articles about game development, especially games that are developed to appeal to females. The designer also looked at online games for girls and played some of them to get an idea of what other game developers believed would appeal to girls. These games had a comment section where the designer could read girls' feedback after playing the games. The intention was to meet the overall goal of creating a game framework that would appeal to girls.

Discovery: With the feedback of Cycle 1 some of the requirements were simplified and refined to be more specific for young girls. A simplified set of requirements for the framework was defined.

Prototyping: Some changes were suggested and the revised design was developed and implemented as a high-fidelity prototype using the free prototyping drag and drop software *Justinmind* (Justinmind, 2014). It was developed to be used on the Android platform because Android is the most popular operating system and can run on a large variety of mobile phones.

Phase 3 of participatory design

Exploration: Since the artefact was aimed at encouraging women to study CS or to take IT as a school subject, it was decided to include 10 UWC students who did not take any IT or CS courses as participants in this phase. This is because the researcher wanted to determine if these students had ever considered a career in CS or IT and whether they even knew what these fields of study were. As this research focuses on trying to encourage females in to the field of CS using gaming, it was only appropriate to use only female students as for this part of the research process.

The researcher randomly approached ten female students—who were relaxing in a common area between lectures. The students were asked whether they took any CS or IT courses and if they did not, they were asked if they would be prepared to give their opinions on game development. The students were from other disciplines such as commerce, education and law.

After completing a consent form, the researcher asked them to complete a questionnaire (see Appendix D). The questionnaire consisted of two sections: the first section consisted of general questions about their knowledge of gaming and computer science

Table 2: Usability game play heuristics

Heuristic	**Source**
The player should clearly be aware of the goals of the game and how it works from early on in the game.	(Federoff, 2002); (Koivisto & Korhonen, 2006) and (Schaffer , 2007)
The player should receive rewards.	(Federoff, 2002) and (Koivisto & Korhonen, 2006)
The game should propose a fair challenge for the player.	(Desurvire, Caplan, & Toth, 2004); (Koivisto & Korhonen, 2006) (Schaffer , 2007) and (Pinelle, Wong, & Stach, 2008)

Heuristic	**Source**
The time spent time playing should be an enjoyable experience.	(Koivisto & Korhonen, 2006)
The game should not stagnate and the levels should progress.	(Koivisto & Korhonen, 2006) and (Schaffer , 2007)
The interface should be attractive and uniform.	(Federoff, 2002) (Desurvire, Caplan, & Toth, 2004) and (Schaffer , 2007)

Discovery: After completing the first section of the questionnaire, the researcher demonstrated the high-fidelity prototype to the students and then asked them to complete the second section of the questionnaire. A few of these questions dealt with the heuristics chosen for the development of the game; these questions were derived from a paper by Koeffel et al. (Koeffel , et al., 2010). The paper discusses heuristics to evaluate various aspects of games. The heuristics chosen for this evaluation are based strictly upon usability and the user experience of game play. The researcher chose six heuristics on which to base the survey (see Table 2).

Prototyping: The information received from the non-CS students was analysed to determine how the framework could be improved/adapted to meet the needs of the intended users.

A proof-of-concept prototype—which was focused on a section of the game—was developed using a game development platform called *GameSalad* (GameSalad, 2018). *GameSalad* is an authoring tool used to develop games and is often used by non-programmers. It is comprised of a logic system and a visual game editor. *GameSalad* is used largely by educators for teaching logic based thinking, problem solving skills and computer science concepts without the complexity of syntax.

The platform is also used by game developers, animators and graphic designers for fast prototyping of interactive media and games. The first level of the game was developed using the *GameSalad* game development platform. The first stage of development was creating the scene which consisted of the background. Next, the focus was on getting the blocks moving across the screen. Within *GameSalad*, there are multiple behaviour controls which allow the developer to create movement within a game scene. Two movements were used in the development. The first movement was the movement of the blocks from right to left across the mobile screen. The second element that involved movement was the animated character (Fox) which needed to be able to move left, right and downwards. Ten blocks were created and then set to move from left to right all at different speeds and for a selected period of time. This was done by setting movement attributes for the blocks by setting the blocks to x-coordinates.

Once this was implemented successfully, the next step was to add the animated character, the fox. Once the fox was added, movement attributes needed to be added to allow the Fox to be able to move left, right and down using swiping on the screen of the mobile phone.

A Constraint needed to be added to the animated character. The constraint was, if the Fox does not jump on a block, the Fox will fall down and the player will be prompted to start again. Once the Fox reaches the house, the player will progress to the next level.

Lastly, the timer was added to the overall scene. The timer was set to 30 seconds at the beginning of the level. If the Fox did not get home within 30 seconds, then the level would start again. If the level was completed within 30 seconds, then the player would progress to the next level.

Evaluation

EXPERT REVIEW

A total of five experts were randomly approached in the UWC CS post graduate lab to partake in the evaluation of the game. The lab was only used by PhD and Masters students. The five experts, all of whom had experience in computer programming and software development—were chosen, since Preece et al. suggest that five or more experts will be able to identify approximately 75% of usability problems, see Figure 14. (Preece, Rogers, & Sharp, 2015),

The researcher began by explaining the research to the evaluators and asked them to sign a consent form. The game was then demonstrated to the evaluators on an Android mobile phone. The evaluators were allowed to play the game on the phone before beginning to evaluate.

The evaluators were asked to evaluate the prototype in terms of a set of four game play heuristics as defined by Desurvire et al.

The chosen heuristics were:

- Gameplay is long and enduring and keeps the players' interest.
- Challenge, strategy and pace are in balance.
- The players have a sense of control and influence on the game world. The game offers something different in terms of attracting and retaining the players' interest.
- The player experiences the user interface as consistent (in controller, colour, typographic, dialogue and user interface design) (Desurvire & Wiberg, 2009).

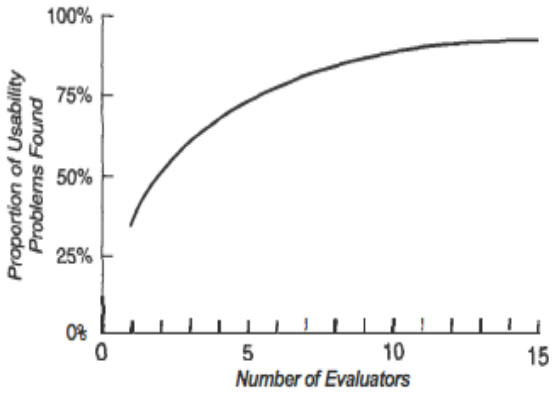

Figure 14: The curve depicts the ratio of problems within an interface identified by a heuristic evaluation using a range of numbers of evaluators ((Preece, Rogers, & Sharp, 2015) p409)

After interacting with the prototype, the experts were handed an evaluator form consisting of a table of the four heuristics. The experts were asked to complete the table based on whether or not they considered that each heuristic had been successfully implemented (see Appendix E).

CONCLUSION

The results will be presented in the next chapter.

SUMMARY

In this chapter, the chosen methodology – DSR was discussed. The methodology was explained and discussed to motivate why DSR was chosen for this research. For every step of the DSR, a method was chosen in order to provide an outcome. Each method was defined and discussed. Lastly, how each method was implemented by the researcher was explained step by step. In the next chapter, the results of each method will be presented.

Chapter 4

RESULTS

INTRODUCTION

In the previous chapter, the methodology of this research was explained. The chosen methodology was DSR. Each step of the DSR was explained as well as the methods that were used for each stage of the methodology. The methods chosen to perform data collection and how the data was analysed, were discussed. This chapter presents the results obtained from each step of the research methodology.

AWARENESS OF THE PROBLEM

A systematic literature review was used as the method to identify an awareness of the problem (see Figure 15).

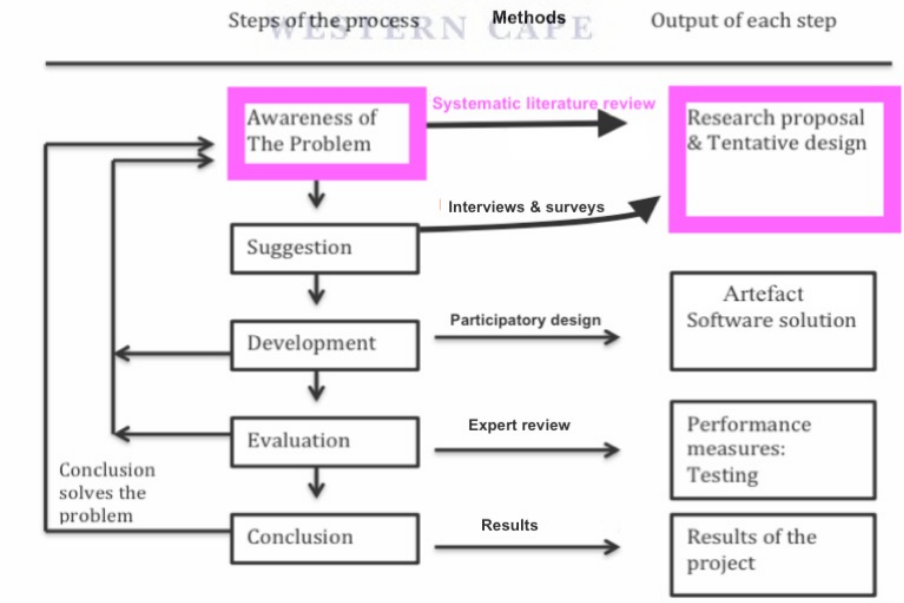

Figure 15: Systematic literature review- used to identify awareness of the problem

SYSTEMATIC LITERATURE REVIEW RESULTS

A summary of the results obtained from the systematic literature review is given in Table 3—using the following keywords: women in CS; stereotypes in CS; women in computer science; computer science and gender; misconceptions of computer science; gaming in teaching; gaming for girls; gender and gaming; computer programming and gaming

Table 3: Results of Systematic literature review

Concepts searched	**Information retrieved**	**Authors or papers**
Women in CS	Several studies identify reasons why there are so few women in computer science and the technology industry (Prottsman C. L., 2011) (Hanton, 2015) (Frenkel, 1990). *"One of the theories as to why there is a lack of women in technology is that there are differences in the way men and women think, making one better at technology related elements than the other"* (Hanton, 2015, p. 9) Computer science is generally perceived as being challenging and therefore it may be that women who have not been exposed to computer science at school would not consider studying it (Hanton, 2015).	(Prottsman C. L., 2011); (Hanton, 2015) (Frenkel, 1990)
Computer science and gender	In a paper by Osunde et al., the various reasons for the underrepresentation of woman in CS are discussed. These reasons and theories are based on biological and inherent differences, structural factors and social-cultural factors. The essentialist theories based on the underrepresentation of woman in CS is caused by the inherent differences between male and females in the skills of mathematics and computational thinking abilities (Strevens, 2000). Based on their natural ability, this means that men will dominate in the field of CS. Therefore, strategies of intervention will not benefit females within the computing industries as they will be disadvantaged and females will remain underrepresented (Osunde, Windall, Bacon, & Mackinnon, 2014).	(Strevens, 2000); (Osunde, Windall, Bacon, & Mackinnon, 2014); (Makoff, 1989) and (Stack, 2004).

Concepts searched	**Information retrieved**	**Authors or papers**
Stereotypes and misconceptions in CS	Society has made profound impressions about CS on woman and young girls. Most images and representation of computer scientists are that of "nerds" or only males, and females struggle to relate to this misconception or stereotype (Makoff, 1989). From a family perspective, woman are seen as being care-givers who may prefer to raise and look after their children at home. This role may be a social reason for the underrepresentation of women in CS (Stack, 2004).	(Makoff, 1989). CS (Stack, 2004).
Gaming in teaching	Games have become popular amongst our cultural and social environment appealing to children. They have become popular platforms for learning tools that have developed into digital learning platforms often used for teaching CS (McFarlane, Sparrowhawk, & Heald, 2002) (Kafai, 2006). Within CS teaching games have been used as a method to acquire content and skills. The reason for using games is that the cycle used in games and that used in computing is similar; in both the player is encouraged to learn and return to the game to continue (Gee, 2007).	(Kafai, 2006). (McFarlane, Sparrowhawk, & Heald, 2002) (Kafai, 2006). (Gee, 2007).

SUGGESTION

For the suggestion phase, the chosen methods were interviews and surveys. These methods were used to provide an outcome which was the tentative design (see Figure 16).

Survey and interview results

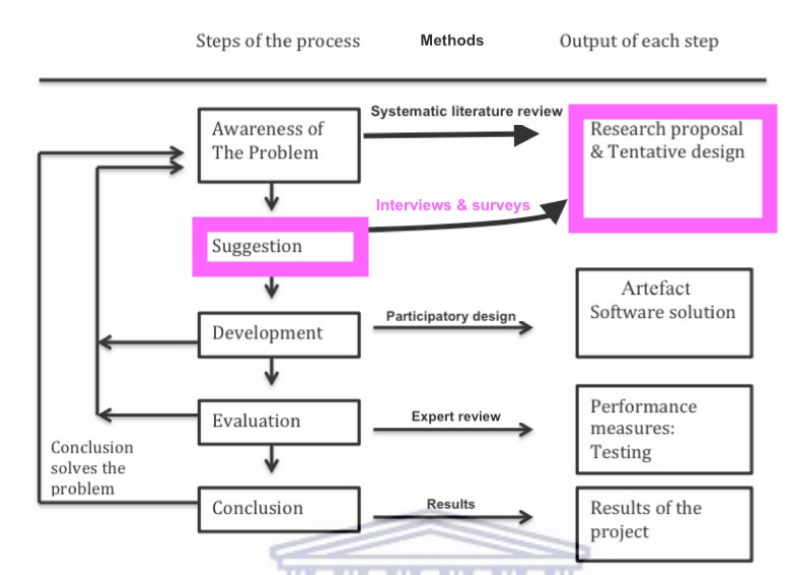

Figure 16 : Interviews & surveys methods used for the suggestion phase

SURVEY RESULTS

None of the first-year students chose a career in CS because they felt that they are good at mathematics or science. The majority of the first-year female students (50%) chose CS because they are interested in solving problems using computers.

Furthermore 65% of the males said they enjoyed working with computers whereas only 25% of the females indicated that they enjoyed working with computers.

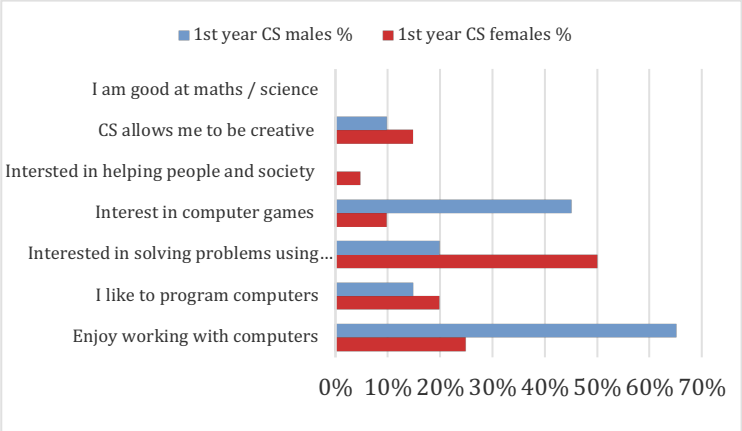

Figure 17: First year students' responses

Significantly more of the first-year males (75%) compared to the females (40%) felt that their interest in CS was influenced by TV shows, movies and online information (Chi^2 =5.01, p=0.0252). Significantly more of the first-year females (40%) compared to 5% of the males, said they make use of persuasive technologies (Fischer-Exact p=0.0197).

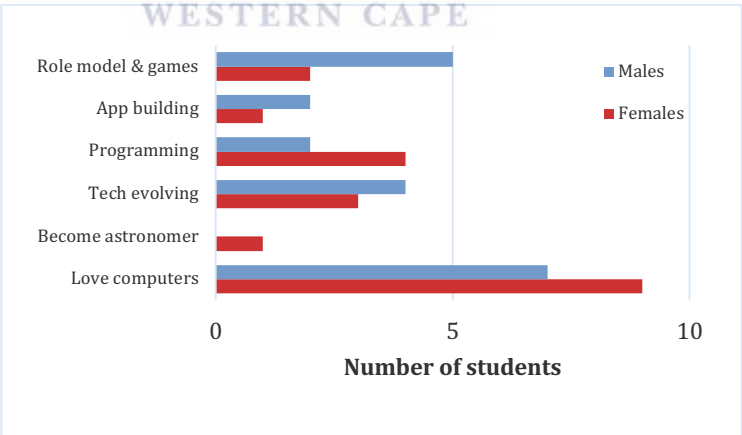

Figure 18: What motivated first-year students to study CS

When asked what motivated them to study CS, the males indicated games and role models as well as the fact that the evolving technology interested them whereas the females felt that they were interested in programming and that they loved working with computers (see Figure 18).

Although not significant, it is interesting to note that 60% of the males chose CS because of their interest in computer games where only 35% of girls felt that gaming influenced their decision to study CS. Most of the first-year students (90% of the females and 95% of the males) indicated that they had played computer games whilst growing up. Seventy percent of both the groups indicated that they still play computer games. Most (80% of the females and 95% of the males) agreed that the available games are probably more appealing to males (see Figure 19).

Forty-five percent of both the first-year males and females surveyed, indicated that they did IT at school, 60% of the males and 50% of the females indicated that IT was offered at their school.

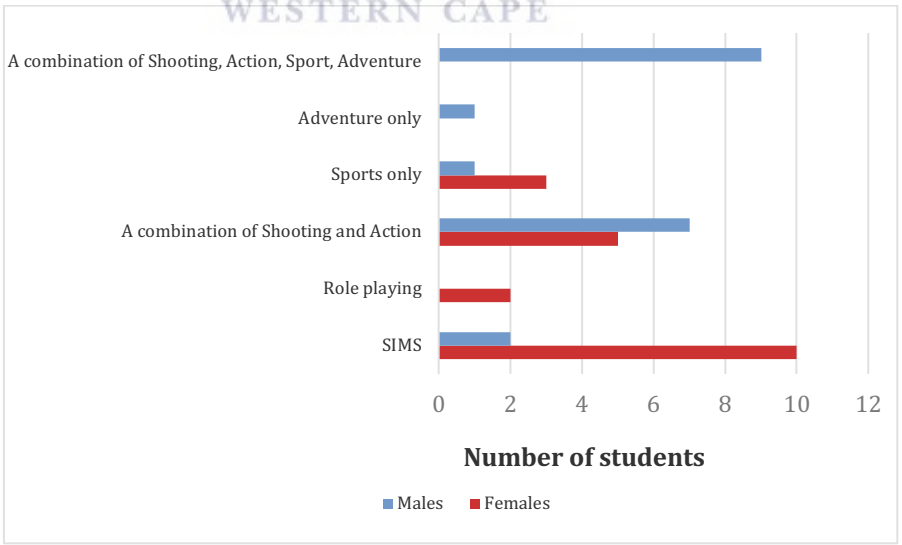

Figure 19: Type of games enjoyed

INTERVIEW RESULTS

It was discovered from the interviews that out of all the girls' high schools in the Western Cape, only one offers IT as an internal subject. This school is Springfield High School. The remaining girls' schools either offer IT as an external subject at a boys' school or at a co-ed school. These classes take place after school.

Of the interviewed honours students, it was discovered that the majority of the male honours students had chosen a career in CS based on their interest in computer gaming and stated that they played computer games when growing up. However, the majority of the female honours students enjoyed working with computers which spiked their interest in CS.

After interviewing five IT school teachers, it was discovered that the IT classes were generally small classes and the boys always outnumbered the girls. Girls also noticeably dropped-out of the IT classes after Grade 10.

The teachers all stressed that the girls seemed to take longer than the boys to grasp the concepts of programming. To make learning more fun and to keep students interested, all teachers said that they taught programming concepts using games. Students are asked to create games based on programming concepts such as if-statements and loops. To create these games, students use programming drop-and-drag frameworks such as Scratch and only progress to writing code in text editors, once they understand the basics of programming. The IT teacher of Monument Park High school said "*most games appeal to boys because they are either car games and fighting games. I asked the students to create a game in scratch and the boys mainly created car games and the girls really struggled to even think of a game concept. It took them days just to come up with a concept.*"

Three of the IT teachers said that their interest in IT spiked due to their interest in computer games. One of the IT teachers said that he started to build his own computer and thus learned more about computer hardware and software. He

explained that when computer gaming becomes serious and competitive, specific types of hardware and software are needed. According to him, boys are serious about games and set aside specific hours for gaming—as they would set aside time for a sport. Girls, so he felt, are more inclined to play games on their phones if they are bored or if they need to pass time. He seems to be of the opinion that girls are not as serious about gaming as the boys. The teachers all agreed that gaming teaches students problem solving and a strategic way of thinking which is essential in programming. Gaming and programming are very similar. When playing a game the player will play the game again and again to improve the score or until he or she wins. This is similar to a programmer who continuously runs and debugs code until the outcome is what he or she had intended.

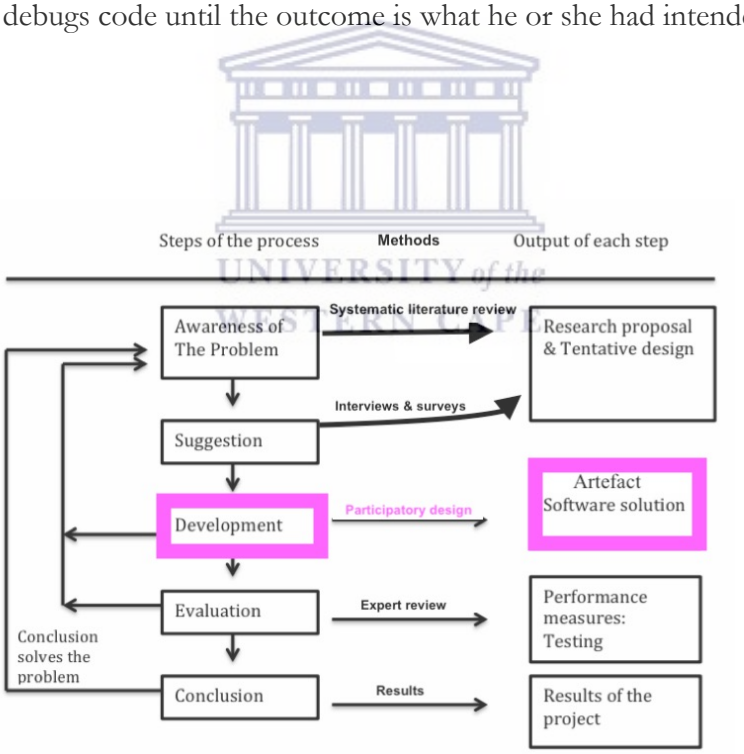

Figure 20 : Participatory design, the method used to develop the artefact

Participatory design results

DEVELOPMENT

Participatory design which comprised three steps: exploration, discovery and prototyping was used to find an artefact solution. This was the chosen method of the development stage of the DSR see (Figure 20).

Cycle 1 of the participatory design

Exploration. The five IT school teachers mentioned:

- They used games as a method to teach students, to keep the subject fun and interesting.
- Students were often asked to create basic games using software such as Scratch when programming concepts were taught. This allowed them to see an output rather than just a terminal that runs code.
- The teachers all suggested that a game be designed that teaches girls a particular way of thinking, similar to the problem solving way of thinking used in programming, but without them being aware that they are learning.
- The male teacher said that his perception is that girls seem to enjoy playing games on their phones rather than on a computer. He felt that it may be because setting up computer games on a computer, especially when it entails setting up a network, is too time intensive for the girls.

Discovery. The exploration phase produced the following requirements for the game, and these requirements were used to design the framework:

- The game framework should require logical thinking
- The levels in the game should require problem solving from a basic level to a more complicated level as the game progresses.
- The framework should develop the understanding of basic programming concepts such as: if and else statements, sequencing and looping.
- To keep the player motivated, rewards should be given or a leadership board should be included.

- The design of the game framework needs to be attractive so that it can be appealing to girls.
- The game must run on a mobile device—specifically Android, as it is the operating system of many mobile phones.

Prototyping. The feedback received from the expert about the low-fidelity prototype was as follows:

- There needs to be more focus on the design of the game to make it more attractive to girls.
- The experts agreed that the idea of incorporating computer science programming elements into the game was good.
- The experts agreed that the game required the player to use problem solving skills.
- The experts suggested that the levels of the game should become more challenging as the player progresses. The experts indicated that the game seemed 'too babyish' even though the framework is designed for young girls, it should not be too simple.

Cycle 2 of the participatory design

Exploration. On a popular online gaming website for girls, the most popular games played were games that mimicked real life activities such as restaurant, shopping, doctor/dentist and dancing games (GirlsGoGame.com, 2018). These are real life activities that girls see and mimic and then play the computer games with the imagination of doing these activates in real life.

To contribute to the online game social community, the (GirlsGoGame.com, 2018), provides girls with a platform to play against their friends online.

Girls prefer to play games that are in a realistic setting rather than in a fantasy world such as the Sims (Denner, Bean, & Werner, 2005).

One study claims that girls prefer to play games with an animated or cartoon feel which depicts an imaginary setting (Van den Abeele, 2009).

Discovery. With the feedback of Cycle 1 some of the requirements were simplified and refined to be more specific for young girls. The simplified requirements were:

- The interface should appeal to girls but must not look 'babyish'.
- The levels of the game should become more challenging as the game progresses.
- The framework should develop the understanding of basic programming constructs such as: if-else statements, sequencing and looping.
- To keep the player motivated, rewards should be given, for example to be elevated to a next level or to have their results posted on a leader board.
- The game must run on a mobile device—specifically Android, as it is the operating system of many mobile phones.

Prototyping. Using the feedback a high-fidelity prototype was implemented using *JustinMind*

The features implemented in this prototype were developed with the game usability heuristics defined in Chapter 3 (see Table 2) in mind.

Every level of the game introduces a new focus or concept.

Each of the requirements, as suggested by the experts, was addressed and these are explained in the next section:

The interface should appeal to girls but must not look 'babyish'.

The interface needs to look childlike but not "babyish" so that not only young girls but also young adults may be interested in playing the game. The decision to incorporate the Fox as an animated character is in order to still make the game look child friendly. The colours of the game are attractive and the animated feel should make the game be fun to play.

The levels of the game should become more challenging as the game progresses.

Within every level of the game, a new concept is introduced and this makes the game more challenging as the game progresses to higher levels. The 30 second timer also challenges the player to complete the challenge within a specific time frame.

To keep the player motivated, rewards should be given or a leader board kept

The leader board is designed to motivate and reward the player. When the player improves their time or completes a number of levels, they move up on the leader board and get a higher score.

The framework should develop the understanding of basic programming construct such as: if-else statements, sequencing and looping.

Level 1 of the game framework: Sequencing

The player is directed to follow instructions in order to complete the challenge (see Figure 24). The player is asked to get Foxy home by jumping on the moving blocks within a 30 second time frame.

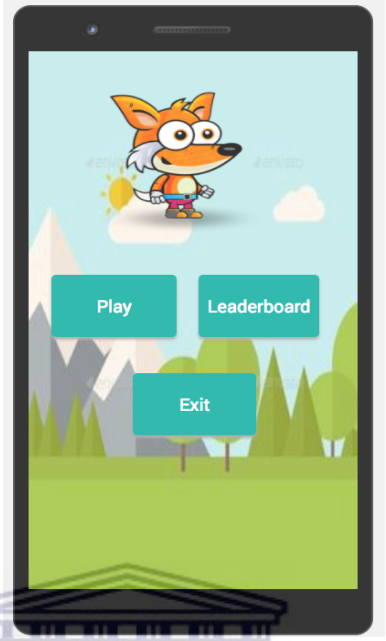

Figure 21: Homepage of the game

The homepage of the game (see Figure 21) allows the player to select between three options: to play the game, to view the leader board or to exit the game. The first screen of the game shows the instructions (see Figure 22). Figure 23 shows the pink blocks that are moving from left to right and the player is requested to swipe down to move the Fox. If the Fox falls to the bottom, the player can start again. If the player does not complete the round within 30 seconds, they may try again. Likewise, in computer programming, when a computer programme is created, is comprised of a series of steps to execute the programme to solve a particular problem.

Figure 22: Instructions of the first level

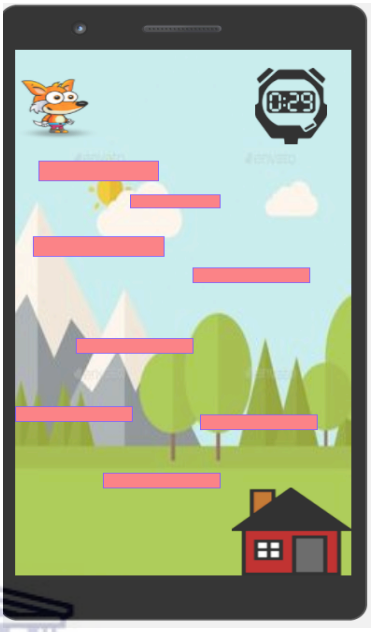

Figure 23: Level 1

Level two of the game framework: Constructs

The aim of Level 2 is to develop thinking similar to the thinking that is required for constructs used in programming. This level gets slightly more challenging as more elements are added to the game and both the idea of sequencing and constructs are added simultaneously.

Once again, the player is instructed to jump on the moving pink blocks to get the Fox home. This time, there are obstacles; floating fireballs (see Figure 24).

If the fox touches the fire ball, the game will start again. The focus is on getting the fox home using the moving blocks but at the same time avoiding the fire balls. The player yet again has a time limit of 30 seconds to complete the challenge (see Figure 25). If the fox touches the fire ball, the player will start over, but if they dodge all fireballs, they will complete the challenge successfully.

Figure 24: Level 2 instructions

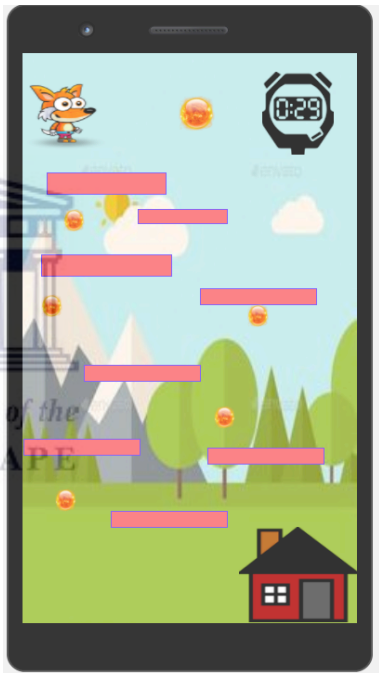

Figure 25: Level 2

This is similar to the **if-else** statements used in programming. For example: IF the fox jumps on the block now, he will hit a fire ball ELSE if he waits for the fire ball to pass, he will complete the level successfully.

Level three of the game framework: Looping

The third level of the game adds an additional factor. The game still incorporates the factors from the first and second level but this time the player is asked to make the fox jump on at least four blue blocks on the way to its home, to complete the challenge. The fox still needs to avoid the fire balls. Failing to jump on at least four blue blocks, will mean that the player has to start over. Similarly, if the Fox falls or touches a fire ball (see Figure 26) the level needs to be restarted. The logic behind this game is to develop a way of thinking similar to the **for - loop** used in programming. In **for-loops** the number of similar executions is determined by a number at the start (see Figure 27).

If a next level were to be developed, it could incorporate blocks that move faster and/or fireballs that move at different speeds.

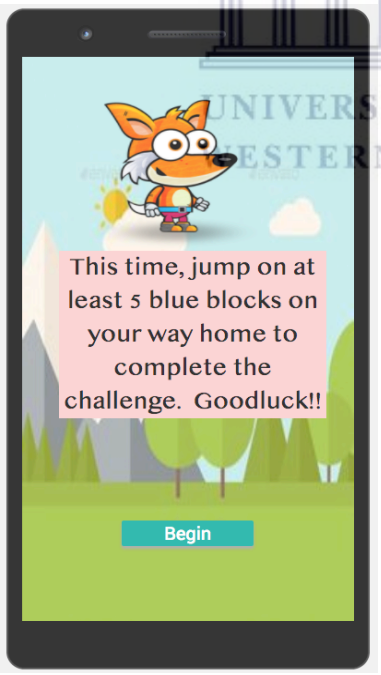

Figure 26: Level 3 instructions

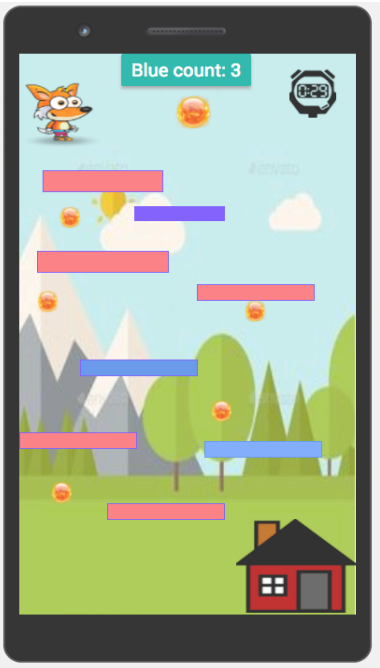

Figure 27: Level 3

Cycle 3 of the participatory design

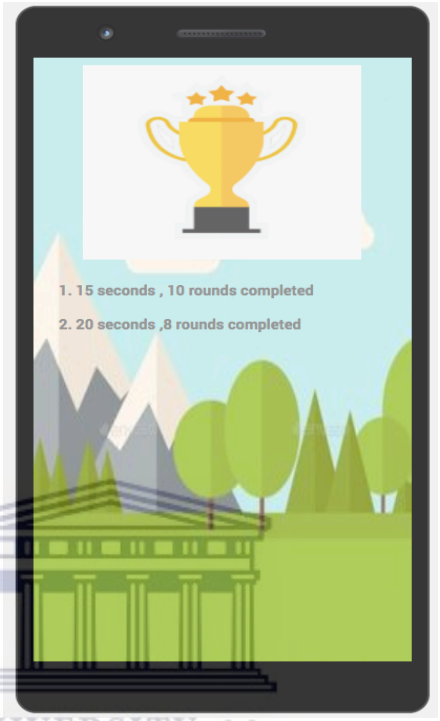

Figure 28: The leaderboard

Exploration: The results of the survey administered to ten UWC students who did not take any IT or CS courses were as follows:

- Five participants spent several hours playing games in the past week and the remaining five participants did not play games in the past week.
- Eight participants preferred mobile games and two preferred desktop games.
- The majority of the participants said that they prefer adventure kinds of games.
- The participants' reasons for playing games were: four said that they only play when bored, three said that it challenges their mind and problem

solving abilities, two said that they enjoy the feeling of mastering and completing a game and one said that she played games to relax.

- Eight of the participants agreed that the popular games appeal largely to men since they focus on activities that men like, for example sports played by men, and most of the characters in these games are men.
- None of the participants took IT as a subject at school and therefore did not consider studying towards a career in IT or CS.
- Seven participants did not know what CS entails, two believed that it was too difficult for them and one said that it consisted of too much mathematics.
- None of the participants hated maths—five participants liked it and the other five said they didn't mind it.

Discovery. The results are depicted in Table 4, and are based upon the students' feedback after evaluating the high-level prototype of the game framework.

Prototyping. A section of the game was developed using a game development platform called GameSalad. GameSalad is an authoring tool used to develop games and is often used by non-programmers. It comprises of a logic system and a visual game editor. GameSalad is used largely by educators for teaching logic-based thinking, problem solving skills and computer science concepts without the setback of syntax. The platform is also used by game developers, animators and graphic designers for fast prototyping of interactive media and games.

The prototype was developed as a proof of concept to display how the game would appear and to prove that it is possible to develop the framework into a fully functional game.

This process may be repeated multiple times to receive feedback.

Table 4: Results of the participatory design cycle

Heuristic	**Result**
The player should clearly be aware of the goals of the game and how it works from early on in the game.	All participants were aware of the main goal of the game and knew exactly what was needed to be done by the player.
The player should receive rewards.	All participants liked that the game rewarded the player. Players received points and a leader board was present.
The game should propose a fair challenge for the player.	All participants agreed that the game is a challenge for the player.
The time playing should be an enjoyable experience.	All participants agreed that the game was encouraging and that the first time playing would be enjoyable. All participants agreed that if developed, they would all play the game.
The game does not stagnate and the levels progress.	All participants were aware that the games progressed to different and more challenging levels. Nine out of 10 participants agreed that the game focuses on problem solving. All participants were unware that computer programming requires a similar way of thinking/ problem solving.
The interface should be attractive and uniform.	Participants liked the design, layout and colours of the game

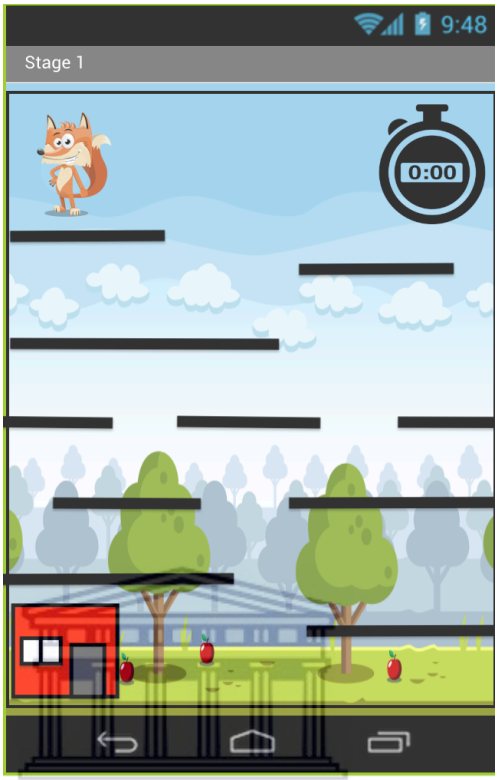

Figure 29: Level one developed

The completed level of the proof of concept game is depicted in Figure 29.

The successful implementation of the first level of the game is a proof of concept, that it is possible for the game to be fully developed. The basics of the game have already been developed and to develop the game further, other elements, to make the game more challenging, would need to be added as demonstrated in the high-fidelity prototype.

EVALUATION

EXPERT REVIEW RESULTS

Where an expert agreed that the gameplay heuristic had been implemented, they placed a tick in the block and where they disagreed, a cross was placed in the block (see Table 5).

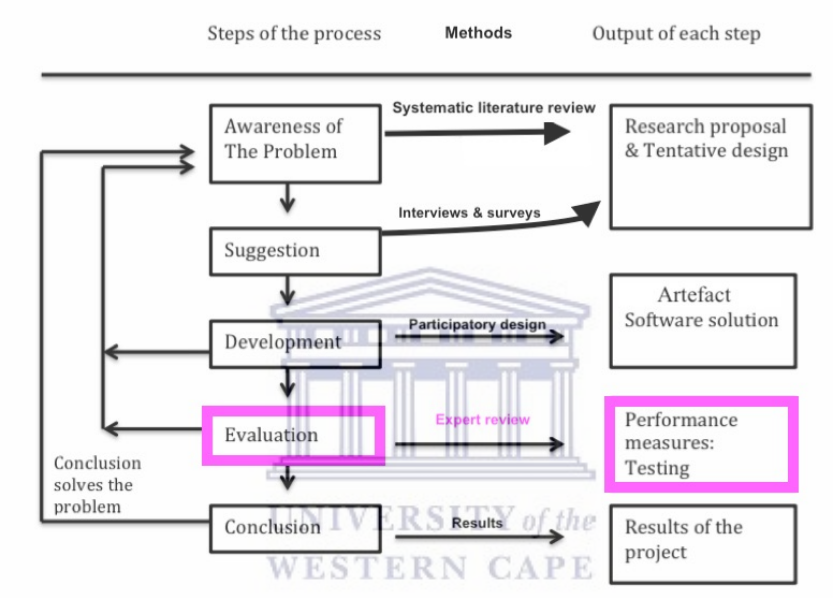

Figure 30: The results of the expert review

Table 5: Expert review results

Heuristic	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**
Gameplay is long and enduring and keeps the players' interest.	✓	✓	✓	✓	✓
Challenge, strategy and pace are in balance.	✓	×	✓	✓	×
The players have a sense of control over and influence on the game world. The game offers something different in terms of attracting and retaining the player's interest.	✓	✓	✓	×	✓
The player experiences a consistent user interface in terms of control, colour, typography, dialogue and user interface design.	✓	✓	✓	✓	✓

SUMMARY

In this chapter, the results were presented for each method that was executed throughout the DSR. Results were given for the systematic literature review, interviews and surveys, participatory design and for the expert review methods. In the last chapter, the research questions will be addressed and discussed, based upon the results obtained in chapter 4.

Chapter 5

DISCUSSION AND FINDINGS

Gaming has its advantages and disadvantages. The advantage of gaming is that it teaches players to follow a series of instructions, which improves the players' problem solving skills, teaches logical thinking and increases hand-eye coordination (Lenhart, et al., 2008). Furthermore, it supports and promotes the learning of new skills as well as collaborative problem solving. According to Preradovic *et al.* digital technologies can assist users with the visualization of difficult concepts and new "*interactive technologies facilitate the creation of an environment in which children can learn through action, providing them with the opportunity to create and explore*" (Preradovîc, Lesin, & Sagud, 2016, p. 130). However, one disadvantage of gaming is that the players are inactive, especially when gaming for long periods of time. Gaming can create eyesight problems and may be the cause of agitated behaviour (Sălceanu, 2014). Furthermore, it can cause sleeping disorders, difficulty in paying attention, and socialization and language development may be negatively affected (Preradovîc, Lesin, & Sagud, 2016). It does however seem as if the impact of gaming on learning is mostly positive.

Computer games, require access to hardware—computers or mobile devices. Since this study is situated in South Africa, the use of mobile devices in South Africa is of interest. According to the Mobile Africa 2015 Survey of South Africa, Kenya, Nigeria, Ghana and Uganda, 40% of Internet browsing is done on mobile devices (Pricewaterhouse-coopers, 2015). A great advantage of the increase in use of mobile devices is that it allows easy access to information and thus educates without the user really being aware of it (Asur & Huberman, 2010).

Children's exposure to mobile phones and devices has increased within Sub-Saharan Africa, even if they do not own their own mobile phone one may be

available within their household. With this increase in access, children have access to and can interact with new media which includes mobile games (Spikol & Milrad, 2008). Mobile games introduce children to problem solving, exploration, collaboration, navigation and content creation. These in turn promote important skills, both social and cognitive (Spikol & Milrad, 2008).

Mobile games are not very costly—in the range of R45.00—and often the phones are issued with a series of free games (hit86game, 2016). This is much more affordable than games for (say) a Play Station 3 (PS3), Xbox or a computer. Games for PS3 are priced at around R600.00 (hit86game, 2016). In Africa, mobile games have become increasingly popular and the mobile gaming revenue is expected to grow at an annual rate of nine percent (Pricewaterhouse-coopers, 2015).

The question is whether this growth and interest in gaming is likely to have an impact on women and how they see the IT and CS field. Nelson proposes that one of the reasons for women's low interest in computing related degrees is due to the profoundly male-dominated gaming culture together with the belief that gaming is for 'geeks' (Nelson, 2014). Furthermore, most games—the popular ones—present the player with rich, emotionally charged and challenging experiences which allow the player to take on new and exciting identities (Hayes, 2008). These experiences appear to be largely more motivating for male players than for female players (Hayes, 2008). In the Haynes study, it is stated that to motivate girls to enter the IT field, they need to play games that interest them and that at the same time provide opportunities for them to learn new skills and ways of thinking that are associated with IT (Hayes, 2008). They also need to participate in the social aspects that are associated with gaming.

> *We need to identify the valued skills and practices associated with IT expertise, how learning these skills and practices can be initiated and scaffolded through gaming and*

> *gaming communities, and find ways to provide girls (and more boys) with opportunities to engage with these games and participate in these communities (Hayes, 2008, p. 187).*

Guzdial et al. conducted a study to determine the reason why students chose a career in computing based on their gender. this study found that male students' " *interest in computer games*" was significantly more than the female respondents (Guzdial, Ericson, McKlin, & Engelman, 2012). It thus seems as if the gender gap in computer gaming is due to the content and game design of trending computer games. Females characters are often portrayed as weak victims and are saved, rescued and protected by strong male characters. These factors presumably attract men, and females may decide not to play these games due to such gender stereotyping (Hartmann & Klimmt, 2006). The common theme of violence in computer games does not attract females either.

Females tend to display a very low preference for observing or participating in conflicts and their resolutions through violence (Hartmann & Klimmt, 2006, p. 4)

The social interaction of single-player games may not appeal to females as they prefer activities that include social interaction. The "Sims" is an example of one of the few computer games that attract female players due to its social interaction between characters and players (Steen, et al., 2006). In this research *Sims* was the most popular game played by females.

In Chapter 1, the background and statistics of women in CS were discussed and the declining trend of women entering the IT field was revealed. The questions that were posed about why this would be the case and how to address it, will now be revisited and the findings for each question, based on the results obtained, will be discussed.

Design science research was considered an appropriate methodology to address the main research problem namely:

Would computer games designed to interest women, encourage them to play, and thus create an interest in computer science?

This question was unpacked as four sub-questions, which were addressed within the DSR research methodology using different methods (see Table 6)

Table 6: Methods used to address research questions

Research sub-question	**Method/s used**
Why would gaming lead men more than women to study CS?	Interviews and systematic literature review
What aspects of CS attracts women?	Interviews and surveys
Can gaming be a non-structured learning technique to attract girls to CS/IT?	Interviews and participatory design
How should computer games be designed to interest women?	Participatory design and expert review

Each of these sub questions will be now be discussed in terms of the findings

Why would gaming lead men more than women to study CS?

Teachers and girls agree that popular computer games appeal largely to males rather than females and this is due to the fact that games are focused on sport played by men, games with a violent undertone such as war games and also the fact that most of the leading characters in games are male. Girls mostly feel that they cannot relate to these games and therefore do not play them. It is not that girls do not also enjoy computer games, but they are interested in games more suited to them–and there are few of these. In a study by Subrahmanyam and Greenfield, it is stated that most children's first encounter with a computer, is when they use it to play a game. When this experience does not interest them, it results in a negative computing experience. This may be the case for many girls (Subrahmanyam & Greenfield, 1998).

An IT teacher who was interviewed, felt that boys put a substantial amount of time into gaming where girls seem only to play computer games when they are bored. This teacher also explained that when boys game, they become very involved with building computers and setting up gaming networks which later interests them in CS or IT. These boys start teaching themselves about software, hardware and networking which draws them towards a computing career. Many of the girls interviewed believe that the popular computing games are more appealing to boys, therefore they do not have this same experience and do not become as curious about the inner working of a computer and networks, as boys do. The systematic literature review, as well as the interviews conducted, confirmed that popular computer games are more appealing to boys than to girls.

What aspects of CS attracts women?

One of the questions within the survey that was administered to first year CS students (both male and female) asked what their reason was for choosing CS as a field of study. This question was derived from a study by Vu, based on his reporting on the reasons for choosing a computing major, by sex (Vu, 2017) (Guzdial, Ericson, McKlin, & Engelman, 2012). Most of the female first year CS students surveyed, had chosen to study CS because they enjoyed using computers to solve problems. None of the men and women surveyed when asked to give the two most important reasons for choosing to study CS chose "*I am good at maths and/or science*".

When comparing the results from this research with the results that Guzdial *et al.* obtained, a similar trend is observed: most males chose CS as a field of study based on their interest in computer games. In both studies the number of males who indicated they chose to study IT outnumbers the number of females who choose to study IT, due to their interest in gaming.

Within this research, girls enjoy working with computers and believe that CS allows them to be creative. These were the aspects that interested UWC first year female students to study CS. In Guzdial *et al.* and Vu's study girls were more likely than boys to choose a CS career based on their interest in helping people and society. More boys than girls were motivated by their interest in solving problems with computing and liking to programme computers.

In this research, significantly more of the first-year males than females felt that their interest in CS was influenced by TV shows, movies and online information. In Shah's study an example supporting this result is given: A television show called "The Office" is a show about the office environment of "geeky" professionals (Shah, 2011). Three of the main characters are male and one is a female. The male characters are shown as 'geeks' and the female character is given the least significant role, a receptionist. This show may cause girls to feel discouraged because the male roles are all intelligent and women may feel less intelligent than men or not capable of doing the same job (Shah, 2011). Within IT, the most famous role models are men such as Bill Gates and Steve Jobs, the founders of Apple and Microsoft. It is difficult to think of similar female role models although there are many— Sheryl Sandberg, the Chief Operating Officer of Facebook, Susan Wojcicki the Chief Executive Officer(CEO) of YouTube and Megan Whitman the CEO of HP are just a few leading women in the tech industry. These women are on the Forbes list of the most influential women of the world in strong positions who have improved things in the tech world (Pomerantz, 2017). Dr Anita Borg who holds a PhD in computer science is another influential woman in tech who aims to inspire women to embrace technology. She founded the Grace Hopper Celebration and the Institute for Women and Technology (AnitaBorg.org, 2018).

In this research more than half of the males chose CS based on their interest in computer games where less than half of the girls felt that gaming influenced their

decision to study CS. A majority of the first-year students indicated that they had played computer games whilst growing up. Seventy percent of both the groups indicated that they still play computer games. Most of the females and most of the males agreed that the available games are probably more appealing to males (see Figure 19).

Forty five percent of the females surveyed, indicated that they had done IT as a subject at school and half responded that IT was offered as a subject at their school. Therefore, a minimum of these female respondents did not take IT at high school although it was offered. Forty five percent of these female students chose a career in CS based on their exposure to IT during high school. This result agrees with the finding of Prottman, where it is stated that most females who are exposed to IT or take IT as a subject at school are open to choosing a computing career (Prottsman C. L., 2011). Females love for computers was the most popular motivation of choosing to study CS in this research. Other motivations were creativity and using computers as a means to help others. It was clear that computer gaming was not a common motivation for girls.

Can gaming be a non-structured learning technique to attract girls to CS/IT?

Teachers indicated that they use game development to teach basic programming concepts prior to introducing students to coding. According to them this makes learning more fun and helps to retain students' interest in the IT classroom. The frameworks and software used for these exercises are predominantly drag and drop platforms that require no programming experience. Male students seem to master these tasks much faster than females due to their experience of playing games. Most girls struggle to begin these tasks due to their low exposure to computer games, therefore they cannot envision how they should start to create their game.

Teachers believe that gaming and computer programming are very similar in the way that they both require the skill of problem solving and strategic thinking.

The IT teachers interviewed admitted that their interest in IT developed from their interest in computer games while growing up. Playing games encourages players to find out more about computers and how they work. When mastering a game that is enjoyable, the player is actually learning by strengthening their problem solving and strategic skills without being aware that they are "learning". This is what is meant by an un-structured learning approach. To conclude this question, the skills developed by playing games are the same skills needed for computer programming. Children are learning in a non-structured way whilst playing games, in a way that they believe to be enjoyable.

How should computer games be designed to interest women?

Ten non-CS female students were approached to participate in the participatory design process. Only a few of these students actually knew what CS was about or even knew of its existence. Due to the fact that only one "girls" high school in the Western Cape offers IT as a subject, it is clear that many girls lack exposure to IT, especially those who attend single sex schools. Most girls make their career choices at school, specifically during high school and this is when there should be an emphasis on exposing girls to the possibility of a career choice in IT. In some studies, it is believed that the reason that women do not enter the computing field, is due to their fear of maths (Scragg & Smith, 1998). Thus many students believe that CS comprises mainly mathematics, however none of the survey participants of this study hated maths and the majority actually enjoyed it. Therefore, this assumption in this research study does not hold ground.

A method such as participatory design during game development for games for girls should be implemented. Girls should be a part of the whole process to ensure that the design meets their overall needs as they will be the intended users.

There is no better feedback than feedback from the actual users of an artefact or software product. Using participatory design allows the intended users to be involved right from the requirements stage to the completion of the gaming application.

Involving IT teachers and students (both CS and non-CS) within the participatory design process to design the game framework allows the framework to be developed to meet the needs of these users. Teachers and students can provide data to inform the requirements of the framework. CS female students and IT teachers said that they are the people who should suggest what elements should be incorporated into a game in order to generate a game that appeals to girls. They stressed that the game should focus on developing a problem-solving way of thinking.

When non-CS students evaluated the high-fidelity game framework prototype, they all agreed that if the game were developed, it would be a game that they would play. It was interesting to note that the non-CS girls were unaware that problem solving provides a way of thinking that is needed in computer programming. However, nine out of ten of these students agreed that the game challenges the player to solve a problem. In conclusion, is therefore evident that game developers must allow girls to participate in the development of computer games to ensure that such games meet the needs of their users.

Attempting to uncover the reasons for the gender mismatch in CS, to understand why so few females enter the field of study and to determine whether gaming could address this issue, were the aims of this research. IT teachers at local schools in the Western Cape and over 50 students at UWC were involved. Ten non-CS students were included in the participatory design process to determine how a game framework could be designed to meet their needs, as an intervention

to address the research problem. A better understanding of women's perspective of CS and what motivated them to study CS, was gained.

The fourth industrial revolution will change the way that we live and work through the trends of upcoming technology, such as artificial intelligence, the internet of things, virtual reality and robotics. This revolution has the potential to change lives, health, safety and being connected to others. As an example, within the garment industry, nine million women are predicted to loose their jobs due to robotic garment sewing machines. However, there will be an increase in jobs in engineering and technology careers, where at the moment women are the minority (Anderson, 2018). It is thus important that girls become exposed to IT from a young age.

Future work

Using the same surveys used in this research, it would be interesting to further this study by investigating female high school learners through surveys to understand their perception of IT and CS. It would be interesting to compare the results obtained in this research of the CS students survey with young high school girls. Continuing the participatory design process with female high school learners who do not take IT as a subject, and as well as those do, would permit the addition of more features to the game, to appeal to younger girls. All levels of the game framework could be developed and tested by young girls. Putting a focus on high school girls' interaction, experience and views of popular mobile games would be interesting, as mobile devices become more and more a part of the lives of younger generations.

APPENDICES

APPENDIX A

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09 November 2017

Ms S Adams
Computer Science
Faculty of Natural Science

Ethics Reference Number: HS17/9/24

Project Title: Persuasive technologies, gaming and computer science How to bridge the gender-gap.

Approval Period: 02 November 2017 – 02 November 2018

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval. Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER - 130416-049

APPENDIX B

Survey for CS students

1. **When were you first exposed to computing?**

2. **Did you have access to ICT at school?**
Mark only one oval.
- Yes
- No

3. **What is your definition of computer science?**

4. **Have you ever learned CS in any of these ways?**
Mark only one oval.
- At school
- Self taught
- Online
- In a club or group
- In a formal learning group outside of school

5. **How interested are you in taking CS further than this/second year?**
Mark only one oval.

	1	2	3	4	5	
Keen						Not keen at all

6. **How interested are you in doing postgraduate studies in CS?**
Mark only one oval.

	1	2	3	4	5	
interested						not interested at all

7. **How confident are you that you have the ability to learn CS?**
Mark only one oval.

	1	2	3	4	5	
Very confident	◯	◯	◯	◯	◯	Not confident at all

8. **How often do you see CS in TV shows and in movies?**

_____

_____

_____

_____

_____

9. **Can you relate to any of the people doing CS in TV shows and in movies?**
Mark only one oval.

- ◯ Yes
- ◯ No

10. **Why do you think that there are so few woman in the CS field?**
Mark only one oval.

- ◯ lack of female interest
- ◯ lack of female CS role models
- ◯ lack of exposure to CS
- ◯ no opportunity to learn CS

11. **Was CS/IT taught at your high school?**
Mark only one oval.

- ◯ Yes
- ◯ No

12. **Did you take IT as a school subject?**
Mark only one oval.

- ◯ Yes
- ◯ No

13. **If yes, how many girls were in your class?**

_____

14. **What do you think girls reasons are for choosing IT as a subject?**

15. **Did you have IT groups at school where students could learn collaboratively ?**
Mark only one oval.
- Yes
- No

16. **Do you know of any opportunities within your community where you can learn CS/IT outside of school? If yes, please explain**

17. **Are you able to do a binary conversion?**
Mark only one oval.
- Yes
- No
- I don't know what binary is

18. **What motivated you to study CS?**

19. **What kind of jobs do you think you can get with a CS degree?**

20. **Did you play computer games when growing up?**
Mark only one oval.

- Yes
- No

21. **If yes, which games did you play?**

_____

22. **Do you still play these games?**
Mark only one oval.

- Yes
- No

23. **Do you believe that current games that are popular are more appealing to males? Explain**

_____

_____

_____

_____

_____

24. **Which of these games appeal to you the most?**
Check all that apply.

- [ ] Shooting games
- [ ] Action games(e.g mafia)
- [ ] Sport games(e.g fifa soccer)
- [ ] Simulation(e.g Comanche)
- [ ] SIMS and similar games
- [ ] Role-playing(e.g Baldur's Gate)
- [ ] Adventure(e.g Monkey Island)

25. **Did gaming have any influence of your choice to study CS**
Mark only one oval.

- Yes
- No

26. **Did gaming spike your interest in computers when growing up?**
Mark only one oval.

- Yes
- No
- Maybe

27. **Select the top 2 reasons for choosing to study CS?**
Check all that apply.

- [ ] I am interested in creating animation
- [ ] I enjoy working with computers
- [ ] I like to program computers
- [ ] I am interested in solving problems with computers
- [ ] Computing offers broad and diverse opportunities
- [ ] I have an interest in computer games
- [ ] I am interested in helping people and society
- [ ] CS allows me to be creative
- [ ] CS provides good financial opportunities after
- [ ] I am good at maths and/or science

28. **Do you make use of any persuasive technologies?**
Mark only one oval.

- ◯ Yes
- ◯ No

29. **If yes, which ones do you make use of?**

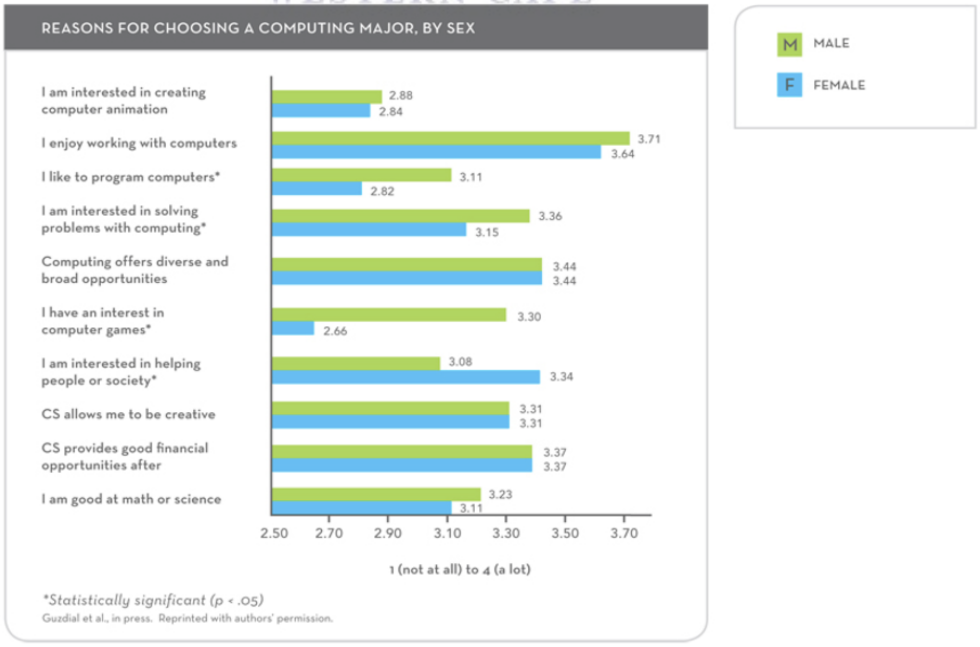
30. **Do you find these persuasive technologies helpful? explain**

APPENDIX C

Probes:
Open-ended

1. When were you first exposed to computers?
2. Did you do Mathematics at school?
3. Was Information Technology offered as a subject in your school?
4. Do you think that the problem solving skills taught at school assisted you with programming?
5. If IT was taught at your school, was it offered at your school or as an external subject?
6. If IT was not offered, why not?
7. How many girls were enrolled for IT?
8. Why do you think girls would want to take IT as a subject choice?
9. What reasons do you think girls have when they decide not to take IT as a subject?
10. Do girls have access to ICT at your school?
11. In your opinion, what do you think are the advantages of girls taking IT as a subject?
12. Are you interested in computer games?
13. Which games did you play?
14. If you still play computer games which do you play now?
15. Question based on Diagram 1 and 2: which factors do you think influenced you to study CS?

Diagram 1:



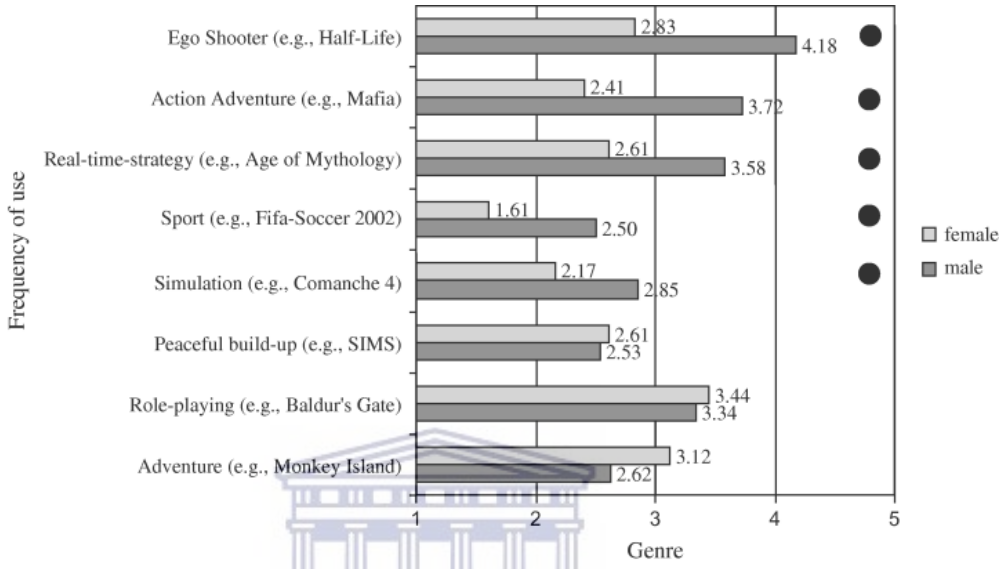


Diagram 2

APPENDIX D

Framework testing

1. **How much time did you spend last week playing video and/or computer games/ and or mobile games?**
   Mark only one oval.
   - ◯ hours
   - ◯ no time

2. **Which platform do you usually play games on?**
   Mark only one oval.
   - ◯ mobile devices
   - ◯ computer

3. **Do you like to play video and/or computer games and/ or mobile games?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

4. **If no, why not?**

5. **What types of games do you play?**
   Check all that apply.
   - ☐ Action
   - ☐ Adventure
   - ☐ Sport

6. **Why do you play games?**
Mark only one oval.

- ◯ I like the graphics/realism
- ◯ to relax
- ◯ It improves my hand-eye coordination
- ◯ It challenges my mind & problem solving abilities
- ◯ It's such a great feeling to master or finish a game
- ◯ I'll play only when I'm bored
- ◯ Other: _____

7. **Do you believe that games can be educational?**
Mark only one oval.

- ◯ Yes
- ◯ No

8. **Do you believe that most games are appealing to males?**
Mark only one oval.

- ◯ Yes
- ◯ No

9. **Please explain the above**

_____

_____

_____

_____

_____

10. **Did you do IT at school?**
Mark only one oval.

- ◯ Yes
- ◯ No

11. **Do you know what computer science is ?**
Mark only one oval.

- ◯ Yes
- ◯ No

12. **If answered yes, what is computer science?**

_____

13. **Would you choose a career path in IT or computer science ?**
Mark only one oval.

- yes
- no

14. **If no, why not?**
Mark only one oval.

- I dont' know what it is
- Its too difficult for me
- Its a mans industry
- Too much maths

15. **What do you think of maths?**
Mark only one oval.

- I hate it
- I like it
- Its okay

Please answer the following questions based on the game framework

16. **Are you aware of the main goal of the game? (what is needed to be done by the player)**
Mark only one oval.

- Yes
- No

17. **Do you like that the player will receive rewards?**
Mark only one oval.

- Yes
- No

18. **Do you think that the game proposes a fair challenge for the player?**
Mark only one oval.

- Yes
- No

19. **If yes, does this challenge seem pleasant ?**
Mark only one oval.

- Yes
- No

20. **If you had to play this game, does it look like the first time playing would be encouraging?**
Mark only one oval.

- Yes
- No

21. **Are you aware that the game becomes more difficult and doesn't become stagnant?**
Mark only one oval.

- Yes
- No

22. **Does this game seem boring?**
Mark only one oval.

- Yes
- No

23. **Is this a game that you would play if developed?**
Mark only one oval.

- Yes
- No

24. **Who could play this game?**
Mark only one oval.

- girls
- boys
- both

25. **Is the game user friendly?**
Mark only one oval.

- Yes
- No

26. **Did you know that this game teaches/ focuses on the player using and developing similar thinking that is used in computer programming?**
Mark only one oval.

- Yes
- No

27. **Do you believe that the game focuses on problem solving?**
Mark only one oval.

- Yes
- No

28. **Please mention any additional comments or features to add or remove from the game**

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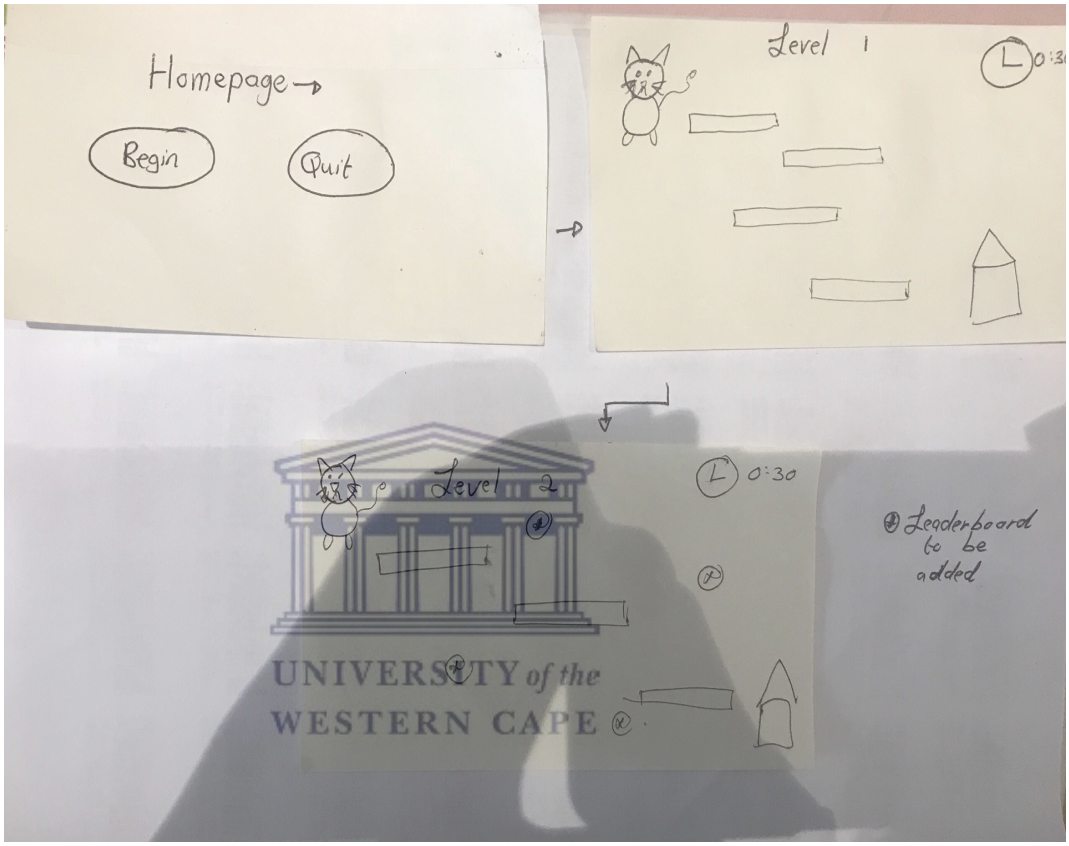
APPENDIX E

Heuristic	✓ / ✖
Gameplay is long and enduring and keeps the players' interest.	
Challenge, strategy and pace are in balance.	
The player's have a sense of control and influence onto the game world. The game offers something different in terms of attracting and retaining the players' interest.	
The player experiences the user interface as consistent (in controller, colour, typographic, dialogue and user interface design)	

APPENDIX F

Appendix F



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