DEVELOPMENT OF AN EDUCATIONAL GAME TO TEACH CONDITIONAL AND ITERATIVE CONTROL STRUCTURES

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Declaration

This dissertation is submitted to the University of Bath in accordance with the requirements of the degree of Bachelor of Science in the Department of Computer Science. No portion of the work in this dissertation has been submitted in sup- port of an application for any other degree or qualification of this or any other university or institution of learning. Except where specifically acknowledged, it is the work of the author.

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Abstract

To be written.

Table of Contents

List of Figures

List of Tables

Outline of Project

To be written.

Acknowldgements

To be written.

Chapter 1

Introduction

Chapter 2

Literature Review

2.1 Video Games

The video games industry has grown very rapidly in recent years, and is expected to continue to grow. The current value of the market is predicted as $150 billion USD and is expected to reach $180 billion by 2022 (Newzoo, 2018). In 2006, video games were considered as one of the most popular forms of entertainment in the United States (Sherry et al., 2006; Ritterfeld and Weber, 2006). Now video games can be considered a popular form of entertainment globally.

Botturi and Loh claimed that video games in the 1970s meant "games that were playeable in amusement arcades" (Botturi and Loh, 2009). Since then, a video game can be defined as "a mental contest, played with a computer according to certain rules for amusement, recreation, or winning a stake" (Zyda, 2005).

2.1.1 History

The earliest documented predecessor to video games was observed in 1948, when the "Cathode-Ray Tube Amusement Device" was patented. The amusement device, required players to overlay pictures of targets such as airplanes in front of the screen (*The First Video Game?*, n.d.).

10 years later, physicist William A. Higinbotham was credited for creating the first video game; attempting to display his research at an exhibition, he anticipated that his display would not generate any interest, so he conceptualised and created 'Tennis for Two' (*Tennis for Two*, n.d.). Tennis for Two was created using an analog computer with an oscilloscope for a screen. It was the first game to display motion and allow multiple players to play together (*The First Video Game?*, n.d.).

The rise of modern generation of video games is credited to the development of 'Spacewar!' in 1962, 'Computer Space' in 1971 and 'Pong' in 1972. Spacewar! was developed for academic purposes to test the limits of new hardware, but shortly after became very popular. Spacewar! was played by Nolan Bushnell, who used the idea of the game to create Computer Space, although, Computer Space did not gain much popular traction. This was partly due to its long winded instructions and complex game controls. Learning from these mistakes, the creators of Computer Space decided to create a simpler game and came up with the idea for Pong, which became very popular. Computer Space and Pong were designed solely for entertainment, and Pongs popularity was credited to the simplicity of its design (Lowood, 2009).

In the late 1980s, video games became a mainstream media industry (Williams, 2003).

2.1.2 Impacts

Initially, the majority of research on the effects of playing video games focused on the negative impacts, such as the potential aggression, addiction and depression from 'gaming'. But recently, researchers have argued that a more balanced perspective is needed (Granic, Lobel and Engels, 2014). Studies have now also argued against the potential correlation between aggression and violent video games (Ferguson, 2007). Playing video games has also been linked to an increase in perceptual, cognitive, behavioural, affective and motivational abilities (Connolly et al., 2012).

2.1.3 Uses

Video games are now used for a wide variety reasons. They are becoming ever more important in the global education and training market. Aside from entertainment, they are being used in: military, government, education, corporate and healthcare (Susi, Johannesson and Backlund, 2007).

2.2 Educational Games

The term 'Serious Game' can be used to describe an educational game. A serious game refers to a game that has an educational purpose and is not intended to be played primarily for entertainment (see Abt, 1970).

Serious games became an established academic field of study in 2007, by the founding of The Serious Games Institute (Wilkinson, 2016). The market value of the serious games industry in 2016 was predicted at \$1.5 billion USD, and is predicted to reach \$9 billion in 2023 (AlliedMarketResearch, 2017).

2.2.1 Definition

There is currently no singleton definition for term 'Serious Game'. Susi, Johannesson and Backlund argue that, groups and individuals define the term depending on their perspectives and interests, and that there are a wide variety of groups and individuals focusing on different issues (Susi, Johannesson and Backlund, 2007). The first recorded definition of the term was set out in 1970 by Abt (Wilkinson, 2016), who defined it as follows: "Games that have an explicit and carefully thought-out educational purpose, and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining." (Abt, 1970). In 2005, Michael and Chen re-interpret this definition to "Games that do not have entertainment, enjoyment or fun as their primary objective" (Michael and Chen, 2005). Thus suggesting that serious games are not limited to only educational purposes. The commonly agreed upon definition closely matches the definition by Michael and Chen (see Susi, Johannesson and Backlund, 2007).

Another definition that is often referred to was set out by Zyda (see Susi, Johannesson and Backlund, 2007). This definition however contradicts the one set out by Michael and Chen (Susi, Johannesson and Backlund, 2007). In contrast, Michael and Chen describe that serious games should not, have entertainment or fun as their primary objective. Whereas, Zyda expresses that the entertainment component of the game should come first, and also that the story of the game is more important than the pedagogy (Zyda, 2005). His definition is as follows: "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). However this definition also suggests that serious games can only be digital (Djaouti et al., 2011).

Since there are a variety of definitions for different purposes. For this dissertation, I will use the one provided by Abt and work entertainment around the primary purpose of the game - to teach.

2.2.2 History

Educational games have arguably existed since the 7th century. Among the oldest is the board game 'Chaturgana', which is argued by historians to be the precursor to chess (Wilkinson, 2016). The aim of the game was to teach officers to become better planners for battles (Wilkinson, 2016). Another board game created more recently - in the 20th century was 'Landlord's Game'; a precursor to monopoly. It was designed to illustrate the dangers of capitalist approaches to land taxes and property renting (Wilkinson, 2016). So we can see that, games designed to educate, have existed for a long time.

The interest in digital educational games, has been observed since 1967, when the first educational program was developed, 'Logo Programming' (Hayes and Games, 2008) . Logo programming was an environment that allowed players to utilise the programming language LOGO in order to learn mathematics (Feurzeig et al., 1969). Logo was popular among schools in the US (Lehrer, 1986), and it became a key part of educational strategies research (Hayes and Games, 2008).

Academic interest that games that could be used could be used for purposes other than mere entertainment, was first noted in 1970 by Abt, in his book *Serious Games* (Breuer and Bente, 2010). The rise in digital games around this time created an opportunity for developing serious games (Wilkinson, 2016).

However, serious games did not gain much traction until 2002, when a game developed by the US army, became hugely popular. 'America's Army' was developed as a training and recruitment game for the military. It is now considered as the forefront of modern serious games (Zyda, 2005; Wilkinson, 2016). In conclusion the potential of using games as educational tools has been demonstrated for a long time, and is now being further researched and developed, focusing on training and education in a number of different industries (Wilkinson, 2016).

2.2.3 Benefits

Serious games have become an interesting area for multidisciplinary academic research (Breuer and Bente, 2010). There are interests from fields such as psychology, computer science, pedagogy, sociology and cultural studies (Breuer and Bente, 2010). Many studies have looked into and discussed the benefits of serious games in educational contexts, and I will discuss some of these below.

2.2.3.1 E-learning

E-learning can be defined as an approach to teaching and learning, based on the use of electronic media and devices (Sangrà, Vlachopoulos and Cabrera, 2012). Thus, digital educational games can be seen as a type of e-learning.

Educational games have inherent beneficial properties. For instance, they are able to provide information on demand and just in time, and in the context of actual use and people's purposes and goals, something that does not often happen in schools (Gee, 2003).

Other properties of e-learning include: ease of accessibility; can be used in absence of teachers or instructors; provide opportunities for relations between learners, helping eliminate the potential of hindering participation; low cost per person served; allows self-pacing - allowing student to study at their own pace; high level of interactivity; ability to use attractive graphics, and is an engaging and entertaining activity (Arkorful and Abaidoo, 2015; Girard, Ecalle and Magnan, 2013).

In a study carried out on what university students thought about e-learning, students reported that they expected e-learning to be an integral part of the learning process within higher education

(Connolly et al., 2012). Thus, the use of a digital game in higher education, may not be that much of an alien concept to students.

2.2.3.2 Learning Through Games

Games can be a great learning environment (see Prensky, 2003; Gee, 2003). Despite the vast research on the negative impacts of gaming, playing video games have been argued to foster a host of different skills, such as, visual attention, spatial skills, problem solving skills and creativity (Granic, Lobel and Engels, 2014).

Conventionally when starting out on a new game, players first need to learn the rules and the controls of the game, and then use this newly acquired knowledge to complete objectives or levels. As players progress through the game the objectives require increasingly complex solutions, which in turn tests the player's knowledge and skill. Vygotsky coined the term *the zone of proximal development*, where learning occurs when people are presented with tasks which are just beyond their current level of ability but may require some help to complete (Vygotsky, 1978).

Today's learners have grown up immersed in digital technology (Prensky, 2001); Prensky calls this generation of people "Digitial Natives". They have spent long periods of time playing video games (Prensky, 2003). Today, 2.5 billion people actively play video games worldwide (AAStocks, 2016), and of these roughly 57% are aged between 10 and 35 (Newzoo, 2017). Therefore it seems natural to assume that this generation will be more receptive to computer-based learning (Girard, Ecalle and Magnan, 2013).

Playing games is naturally a fun and pleasurable activity (Prensky, 2001), and research has shown that fun and enjoyment are important to the learning process, as learners can be more motivated and willing to learn (Bisson and Luckner, 1996; Cordova and Lepper, 1996). Learners' enjoyment of a game has also been shown to improve learners' acquisition of knowledge (Giannakos, 2013).

2.2.3.3 Effectiveness of Learning Through Games

Evidence of learning through educational games has been demonstrated (Connolly et al., 2012; Wouters et al., 2013; Girard, Ecalle and Magnan, 2013). However, the effectiveness of educational games is undetermined (Connolly et al., 2012; Girard, Ecalle and Magnan, 2013). There are also different viewpoints when it comes to determining their effectiveness. Two such meta-analyses; Wouters et al. (2013) and Girard, Ecalle and Magnan (2013), looked at the effectiveness of learning through games, and arrived to different conclusions. These studies are compared in Table 2.2.1.

Table 2.2.1: Comparison of meta-analyses on the effectiveness of learning through games

	Wouters et al. (2013)	**Girard, Ecalle and Magnan (2013)**
Types of Games	Serious games	Serious games & video games
Measuring	Learning, retention and motivation	Learning and engagement
Learning Outcomes	Knowledge or skill acquisition	Knowledge or skill acquisition
Instructional Domain	Biology, maths, language or engineering	Various (including: academic knowledge, cognitive skills, professional knowledge, cancer therapies)
Studies Published Between	1990 - 2012	2007 - 2011
Experimental Design of Studies	Posttest or pretest-posttest	Atleast pretest-posttest
Studies Reviewed	39	9
Age Range of Studied Population	Wide range	9 - 47
Results support effective learning through games	Yes	Inconclusive

Wouters et al. found that serious games were more effective in terms of learning and retention when compared to conventional teaching methods, but not more motivating. Whereas Girard, Ecalle and Magnan found that only a few of the games resulted in improved learning, with the others having no difference when compared to traditional methods of teaching. A point to note is that in Wouters et al. (2013), serious games were compared to lectures, reading, drill and practice, or hypertext learning environments, whilst in Girard, Ecalle and Magnan (2013), they were compared to face-to-face lessons, pencil-and-paper studying or no studying at all. The former is a more modern way of teaching, whereas the latter is very limited.

Wouters et al. evaluated a broad spectrum of studies, whereas Girard, Ecalle and Magnan only evaluated randomised control trial studies. Wouters et al. argued that if they only considered the studies with randomised samples with a pretest-posttest design, similar to Girard, Ecalle and Magnan study, the positive effects in favour of serious games may disappear.

In conclusion, there is a need for more empirical research to determine the effectiveness of serious games, and this is starting to be addressed (Connolly et al., 2012).

2.2.4 Examples

There are many existing educational games designed to teach various topics. I will cover some educational games and interesting technologies that help further programming skills.

Scratch

Scratch is a block-based visual programming language and an online community for sharing, discussing and 'remixing' one another's projects. Projects can range from creating your own interactive stories, games, animations or simulations, which users can share with one another online (Resnick et al., 2009). Today, Scratch has accumulated almost 40 million users, with the core audience between ages 8 and 16, which have created and shared more than 40 million projects (Scratch, 2019).

The Scratch language is based on a collection of programming blocks that can be snapped together to create programs. Scratch blocks are shaped in a way such that they can only fit with other blocks to make syntactic sense (see Figure 2.2.1). The creator of Scratch and fellow researchers argued that, the social aspect of Scratch was important for it to succeed, with a user claiming that she learnt a lot about different kinds of programming by looking at, downloading, and modifying the scripts from other peoples games. User's can also work together on projects, helping them develop their collaborative and team leadership skills (Resnick et al., 2009).

Scratch has also been used in higher educational contexts (Resnick et al., 2009). In a study conducted by Malan and Leitner (2007), Scratch was used at Harvard's summer school to introduce students to programming. After a total of 5 hours on Scratch, students transitioned onto Java for the remainder of the course. Malan and Leitner found that more than 75% of students felt that using Scratch, was a positive influence with their transition onto Java; a more complex syntactical language (Malan and Leitner, 2007). It is clear from the student responses that Scratch helped develop their computational thinking skills. This is often hard to do in languages like Java, as students can feel overwhelmed trying to learn the complex syntax, which can hinder their ability to learn to program (Koulouri, Lauria and Macredie, 2014).

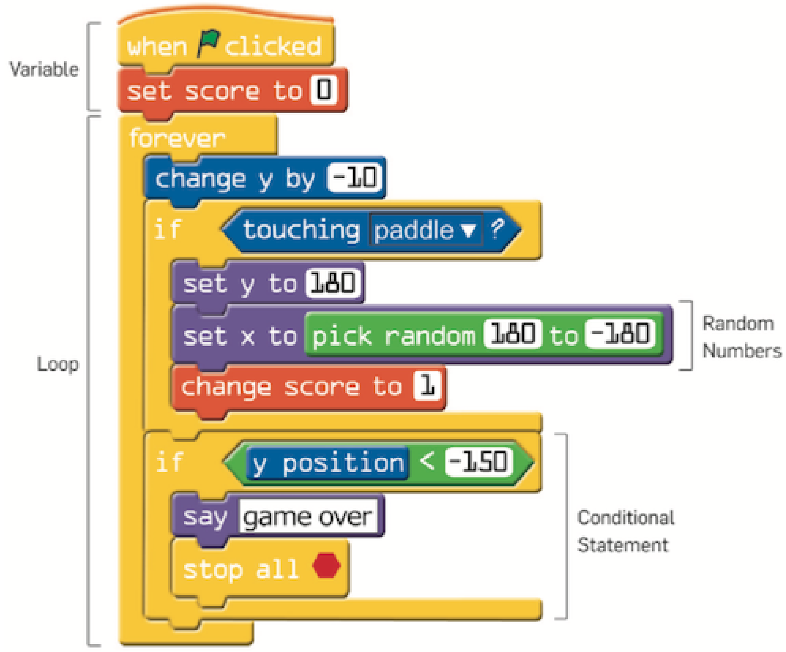

Figure 2.2.1: An example of a Scratch script (Resnick et al., 2009)

Prog&Play

Prog&Play was developed to tackle the issue of student motivation in computer science courses in higher education. Prog&Play is a 3D real-time strategy game, designed to strengthen programming skills. It was built on top of an existing open-source multiplayer game, because of the potential advantage of the game already being robust. The developers of Prog&Play created an API that enabled students to interact with the game through programmable commands, as the original game did not contain any programming (Muratet et al., 2011).

Prog&Play introduced variables, functions and conditional and iterative control structures. The game is based on a war between the factions, 'Systems', 'Hackers' and 'Networks' (see Figure 2.2.2). Players choose a side and give orders to their units through a set of commands. The developers also created a single player mode, where students could be gradually introduced to learning topics and learn how to play. The multiplayer aspect then allowed students to create their own programs and compete with each other (Muratet et al., 2011).

Through examinations conducted by the teachers, Muratet et al. found that students who played the game achieved better marks than those who did not. A greater portion of students, who played the game, went on to choose a computer science course the next semester, compared to those who did not play the game. Interestingly, a majority of students preferred Prog&Play to the original game in which no programming was involved (Muratet et al., 2011).

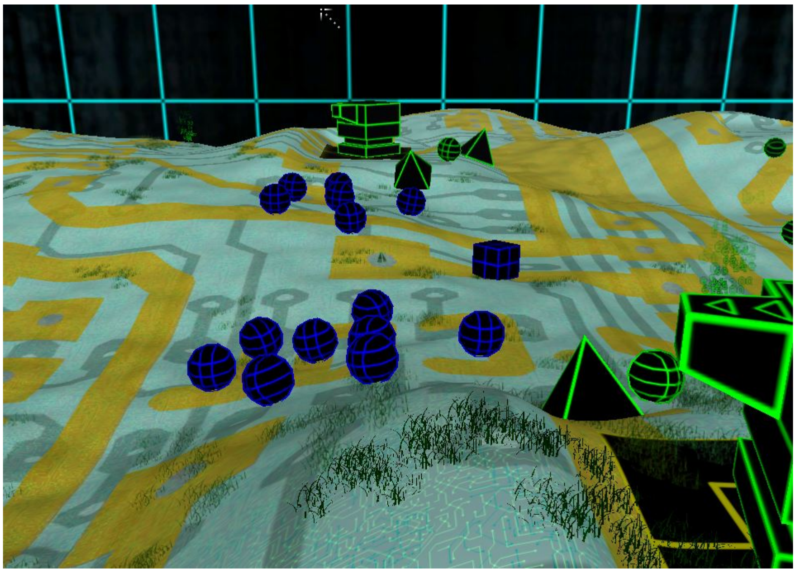

Figure 2.2.2: A screenshot of the game Prog&Play (Muratet, 2012)

Gidget

Gidget is a web-based game, developed as part of a study to improve learning in novice programmers. The study tested the effects of personifying programming tool feedback, for example, displaying programming errors (Lee and Ko, 2011).

In the case of Gidget, you have have to work with a damaged robot, also named Gidget, to help clean up a city and protect it's animals after a chemical spill. The robot, Gidget, acts as a companion and feedback tool. It uses personified language, takes the blame for syntax and runtime errors, and has an emotional face (Lee and Ko, 2011). Lee and Ko claimed that this would change the role of the conventional feedback tool often perceived as an authorative figure, which can be off-putting, to a collaborator needing assistance. The game teaches the design and analysis of basic algorithms in a language designed specifically for the game. Players have to debug the code produced by Gidget to complete the levels (Lee and Ko, 2011).

Lee and Ko carried out a study with 116 participants, using two versions of the game. One version was with a personified Gidget robot (see Figure 2.2.3), and the other with a Gidget that had a faceless screen that provided impersonal feedback. The results revealed that the group using the personified Gidget, completed more levels in roughly the same amount of time in comparison to the group using the faceless Gidget. Suggesting that the personification had a positive effect on participations' motivation to play. Although, the personification of Gidget did not effect the enjoyment felt playing the game (Lee and Ko, 2011).

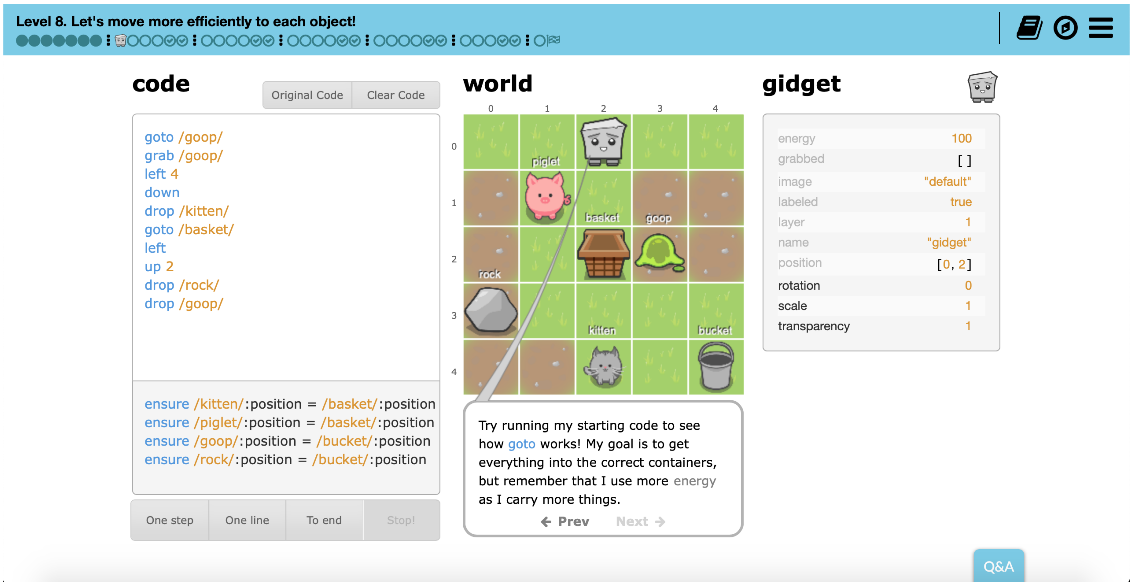

Figure 2.2.3: A screenshot of the game Gidget (Gidget, 2019)

2.3 Teaching Conditional and Iterative Control Structures

In programming language design and implementation, 'control structure' refers to those constructs which determine the sequence of execution, of operations and statements within programs (Riccardi, 1981). This definition is still relevant today (see Wikiversity, 2019). There are three types of control structures; sequential, conditional, and iterative (Leppänen, 2007). A sequential structure is execution of code, line by line. A conditional construct is used to make decisions, for example, *if* and *if else* statements in JavaScript. An iterative construct is used for looping, for example, *for* and *while* loops in JavaScript.

These control structures are likely to be taught in larger introductory units, which cover a wide range of fundamental concepts (ACM-IEEE, 2013). For example, at the University of Bath, conditional and iterative structures are taught in semester 1 of year 1 of a computer science undergraduate degree (UniversityOfBath, 2018).

2.3.1 Methods

At university, introductory programming units are conventionally structured courses based on lectures and practical laboratory work. Students learn about programming concepts through the programming language being that is being taught and used to build programs (Robins, Rountree and Rountree, 2003; ACM-IEEE, 2013). Robins, Rountree and Rountree suggest that this approach is popular, due to the importance of the programming knowledge gained and the sheer volume and detail of language related features that can be covered (Robins, Rountree and Rountree, 2003).

Another method for learning iteration and conditional constructs, which is becoming increasingly popular, are online resources. These resources include; tutorial websites such as Codeacademy and Khan Academy, which have accumulated millions of users; block-based programming environments such as Scratch and Alice, which provide creative visual environments, and educational games (Lee and Ko, 2015).

In contrast, traditional methods of teaching centre on instructors who have control over class content and the learning process, whereas online resources, provide a learner-centred, self-paced learning environment (Zhang et al., 2004). Zhang et al. (2004) argue that e-learning could be used as an alternative to traditional classroom learning. Nevertheless, using e-learning to complement the learning process can make learning more effective and improve the learning experience (Zhang et al., 2004; Concannon, Flynn and Campbell, 2005)

2.3.2 Issues

It is generally accepted that learning to program is a difficult task, and there are several problems associated with this (Koulouri, Lauria and Macredie, 2014). For leaners, the overhead of learning the syntax and semantics of a language at the same time, difficulties in combining new and previous knowledge, and developing their problem-solving skills, all add to the complexity of learning how to program (Koulouri, Lauria and Macredie, 2014).

There also seems to be concern for high drop out rates of University students in computer science courses. This is potentially associated with considerable failure rates in introductory programming units (Koulouri, Lauria and Macredie, 2014). However, researchers have argued that there is little to no high-quality empirical data to support these claims (Bennedsen and Caspersen, 2007; Watson and Li, 2014). In two different studies; Bennedsen and Caspersen (2007), and Watson and Li (2014), both found that the failure rate of introductory units were 33% and 33.3%, from an average of 63 and 51 institutions respectively. Both studies argued that these rates were not "alarmingly high", but there is considerable potential for improvement (Watson and Li, 2014).

Koulouri, Lauria and Macredie (2014) carried out 4-year study and found that certain implementations of introductory units, could improve student learning performance. One finding was that programming proficiency of novice programmers is dependent on the teaching approach of an introductory programming unit. Introductory programming units are also considered difficult (Watson and Li, 2014). In conclusion, choosing an approach that is engaging and motivating to teach fundamental programming concepts, is important.

2.4 Educational Game Design

It is not sufficient to just assume that all forms of games are equally suitable for learning, and that simply presenting material in a game-like setting, will increase the quantity and quality of learning (Breuer and Bente, 2010). Designing educational games requires a focus that is different from general game design; otherwise, we may end up designing fun games with little or no learning value (Barnes et al., 2007).

Breuer and Bente (2010) argue the ideal educational game combines entertainment and learning in a way that the players/learners do not experience the learning part as something external to the game. This idea of stealth learning should inform any approach to designing, using and evaluating educational games (Breuer and Bente, 2010). However, combining compelling and interactive design elements with specific curricular content, that aims to retain learner's interest and attention, is a difficult task (Prensky, 2003).

2.4.1 Games and Learning

Researchers have looked into the many factors that influence learning (Roungas and Dalpiaz, 2015). Below are some of these factors that influence learning in a positive way, and how these are implemented in games. Roungas and Dalpiaz (2015) argue that these following factors are important and should be considered when designing serious games.

2.4.1.1 Motivation

Motivation is a key factor that drives learning. Without motivation, learning stops (Gee, 2003). A key factor of motivation is interest (Rousseau, 1762) (as cited in Roungas and Dalpiaz (2015)). Learning happens effectively when learners are interested in the material being taught and how it is presented.

Games are natural sources of motivation. Games that bring about an optimal balance between challenge and frustration for players, is a very motivating state to be in (Gee, 2003). In his theory of flow, Csikszentmihaly describes that some leaners can become so focused in and absorbed by an activity that they lose track of time and completely ignore other tasks (Csikszentmihalyi, Abuhamdeh and Nakamura, 2014).

Researchers have looked into the intrinsic motivational properties of video games, that is, player motivation that arise due to factors within the players themselves. For example, pleasure and wanting to develop a skill are forms of intrinsic motivations (Roungas and Dalpiaz, 2015). Malone and Lepper (1987) investigated these properties of games, and presented a set of aspects of games that would make game-based learning more fun and engaging. The work by Malone and Lepper is often referred to, but Whitton (2011) noted that Malone's work is not as valid today or as valid when considering adult engagement. With this, Whitton described five aspects that lead to engagement specifically in games targeted for higher education: challenge, control, immersion, interest and purpose.

2.4.1.2 Repetition

Repetition is considered crucial for learning, however some modern researchers do not consider it so important. It is however useful for learning skills such as programming (Roungas and Dalpiaz, 2015).

Repetition is very common in video games. It allows players to learn, memorise and potentially master some rules or controls of the game. Once players are familiar with these skills, the game then introduces a new problem, which requires players to integrate their old skills with new ones. These new problems are practised until a problem requiring a different solution comes along. This cycle is repeated throughout the game (Gee, 2003).

However, repetition needs to be managed, as it could lead to boredom. To avoid this, Roungas and Dalpiaz (2015) suggest modifying the content of the task after each repetition. This can be achieved in games by slowly introducing new rules or controls that build upon previous game knowledge, or, by framing the task in different scenarios. Roungas and Dalpiaz (2015) also suggested managing how frequent the task is presented. A task repeated too often could lead to boredom, or a task repeated at very long time intervals, could reduce the learning benefits from repetition.

2.4.1.3 Rewards

The use of rewards and punishments in learning have a few different impacts. Firstly, rewards allow a learner to link learning with something pleasant. Secondly, rewards are form of extrinsic motivation, that is, learners are motivated by factors external to themselves. For example, achieving high grades, winning trophies or recognition by peers are all forms of extrinsic motivation (Roungas and Dalpiaz, 2015). Thus attempting to seek such rewards gives learners, motivation. However on the other hand, Filsecker and Hickey (2014) found that the use of external rewards; badges, in an educational game for primary education, led to increased learning, but had no significant impact on student motivation or engagement.

Wang and Sun (2011) goes as far as to say, rewards can foster intrinsic motivations, specifically, fun that arises from achieving rewards. An increase in intrinsic motivation in learners, has shown that learners are more deeply involved in activities and are more confident (Cordova and Lepper, 1996).

There are a variety of ways rewards can be expressed in video games, the following are some examples: score system, experience point system, item granting, resources, achievements, instant feedback, plot animations and unlocking mechanisms (Wang and Sun, 2011). However, the relevancy and frequency of rewards needs to be managed, otherwise they can lead to diminishing returns; rewards should be suitable to the target audience, and like repetition, the frequency of rewarding is important. Rewarding too often can cause players to lose interest, or rewarding very little can lead players to lose motivation to play (Roungas and Dalpiaz, 2015).

2.4.2 Game Elements

Games have several characteristics. Roungas and Dalpiaz (2015) argue the following characteristics are important for serious game design. These characteristics are aimed keeping games engaging, exciting and educational.

1. **Rules**. Rules are essential to a game. They describe how the game works and limit the players actions (Roungas and Dalpiaz, 2015). Whilst surveying players of introductory programming games, Barnes et al. (2007) gathered that rules should be provided and accessible throughout the game. This would allow players to refer back to the rules during the game in case they needed reminding or help.

2. **Goals**. Goals allow players to judge their performance. They also act as a motivation for players (Roungas and Dalpiaz, 2015). (Barnes et al., 2007) found that goals should also be provided and accessible throughout the game. They must be clearly tied to in-game feedback, such as avatar health or score, that either motivates or penalises players (Barnes et al., 2007).

3. **Challenge**. Challenge leads to engagement, if, tasks are optimally balanced between challenge and skill (Whitton, 2011; Csikszentmihalyi, Abuhamdeh and Nakamura, 2014). Challenges need to be carefully designed in order to not be too boring or too difficult (Roungas and Dalpiaz, 2015).

4. **Feedback**. Feedback allows players to assess their performance (Roungas and Dalpiaz, 2015). It leads players towards correct answers if their assumptions are wrong, and thus creates learning opportunities. However in programming, feedback in the form of errors can be quite discouraging to novice programmers (Lee and Ko, 2011). Thus care should be taken when designing feedback in a beginner programming game. Feedback should be presented clear and on time (Roungas and Dalpiaz, 2015).

Chapter 3

Requirements Specification

The literature review highlights several key areas of study that were used to inform the requirements specification. The following parts of the literature review will be considered; benefits of educational games; issues of teaching iterative and conditional control structures; the elements from the example of educational games that had a positive impact, and finally educational game design.

The requirements are split into functional and non-functional sections, and each requirement is given an importance rating of: high, medium or low, which refer to being essential, conditional and optional for the system respectively.

The aim of the current study is to develop an educational game to teach iterative and conditional control structures. This will be achieved through the following requirements:

3.1 Non-Functional Requirements

3.1.1 **Game must be easily accessible from home, work or school.** A key benefit of e-learning over traditional forms is being able to access learning material at any time, given an internet connection, browser, etc (Girard, Ecalle and Magnan, 2013).
Priority: High

3.1.2 **Game must improve player's knowledge on iterative and conditional control structures.** A key requirement of a serious game is to educate the player.
Priority: High

3.1.3 **Game must not assume player has any existing programming knowledge.** Iterative and conditional constructs are fundamental programming concepts, and the target audience is assumed to have little to no programming knowledge.
Priority: High

3.1.4 **Game should have a reasonable difficulty curve.** Players should be able to learn the basic game controls early on in the game. Game should then get progressively harder, keeping the player challenged and engaged.
Priority: Medium

3.1.5 **Game should be fun and enjoyable to play.** Entertainment is not the primary purpose of the game. However experiencing fun and enjoyment whilst playing helps improve players' learning performance (Giannakos, 2013).
Priority: Medium

3.1.6 **Player should be motivated throughout the game.** Motivation is a key aspect that drives learning (Gee, 2003).
Priority: Medium

3.1.7 **Player should feel challenged.** Challenge is described as one of the aspects that leads to player engagement (Whitton, 2011).
Priority: Medium

3.1.8 **Game may foster player motivation to learn more complex programming.** Player motivation, specifically student motivation in computer science courses is a concern, and can be improved.
Priority: Low

3.2 Functional Requirements

3.2.1 **Game rules and goals must be accessible throughout the game.** Players must be able to refer back to the rules and goals throughout the game.
Priority: High

3.2.2 **Game must at least introduce *if* statements and *for* loops.** These constructs can be considered one as one of the basic iterative and conditional control structures.
Priority: High

3.2.3 **Game must define in-game functions to be used with *if* statements and *for* loops.** This will allow to merge the educational goals of the game with its entertainment aspect.
Priority: High

3.2.4 **Game must have levels with clear defined goals, that require increasingly difficult solutions.** Clear accessible goals will tell the player what to do each level. Concepts can be introduced at a reasonable pace, that work to limit player overwhelm.
Priority: High

3.2.5 **Game must give players some control over choice of action.** Learner control is an aspect that is not widely present in most traditional forms of teaching, and control is described to lead to greater engagement (Whitton, 2011).
Priority: High

3.2.6 **Game must give feedback to player solutions.** Feedback is important as it allows players to assess their performance and deal with any mistakes.
Priority: High

3.2.7 **Game must use some form of in-game rewards and punishments, such as score points and hit points.** The use of game rewards and punishments foster extrinsic motivations, encouraging player engagement (Roungas and Dalpiaz, 2015).
Priority: High

3.2.8 **Game must have a general help section.** Players could use this as a reference point throughout the game.
Priority: High

3.2.9 **Game should give feedback in a personal and constructive way.** Impersonal feedback on programming errors can reduce player motivation, whilst constructive feedback can improve motivation.
Priority: Medium

3.2.10 **Game should be web-based, and playable in three most popular web browsers.** These are Chrome, Safari and Firefox (StatCounter, 2019). Allows the game to be widely accessible.
Priority: Medium

3.2.11 **Game should have a tutorial to introduce the game rules, goals and game mechanics.** The tutorial will be able immediately introduce the core concept of the game including the educational aims.
Priority: Medium

3.2.12 **Game may provide tips to the player about individual level.** In case player is ever stuck on a level, tips would help the player progress.
Priority: Low

3.2.13 **Game may save players progress.** Saving game state would allow players to leave the game for any reason, and return any time they wish.
Priority: Low

3.2.14 **Game may educate the player about functions and parameters.** In-game functions of the form of actual programming functions, may familiarise players about the use of functions and passing in parameters.
Priority: Low

Chapter 4

Design

4.1 Web-based

4.2 Game Mechanics

4.3 Game Aesthetics

4.4 Game Dynamics

4.5 Level Design

4.5.1 Tutorial

Chapter 5

Implementation

5.1 Technologies Used

5.2 System Architecture

5.3 Player Command Functions

Chapter 6

Testing

6.1 System Testing

6.2 User Testing

6.2.1 Observed Playthroughs

6.2.2 Questionnaires

Useful literature: Purposeful by design?: a serious game design assessment framework

Chapter 7

Results

7.1 System Improvement

7.2 Usability

7.3 Learning

7.4 Engagement

Chapter 8

Discussion

Chapter 9

Future Work

Here, it is important that not only the final outcomes are assessed, but also that the learning and training process itself is monitored continuously without impairing the playing/learning experiences (e.g. via psycho physiological measurements or automated logs/recordings of player behaviour). This is especially beneficial as it can inform new ways to make learning games more adaptive so that they can always offer help or additional information when the players need it (e.g. when they get stuck at a certain point of a game) (Breuer and Bente, 2010).

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Appendices

Appendix A

Uncertainty Analysis

Appendix B

Screenshots

Appendix C

Ethics Checklist