UNIVERSITY OF BATH

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

Amarnath Kakkar

A final year project submitted in partial fulfilment for the degree of Bachelor's in Computer Science and Mathematics with Honours
University of Bath

April, 2019

This dissertation may be made available for consultation within the University Library and may be photocopied or lent to other libraries for the purposes of consultation.

Signed:

Development of an Educational Game to Teach Iterative and Conditional Control Structures

Submitted by: Amarnath Kakkar

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.

Department of Computer Science
University of Bath

Supervisor: Dr. Alan Hayes

April, 2019

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; that is 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).

In the same year Michael and Chen defined the term, Zyda provided his own. There is however a contradiction between these two definitions (Susi, Johannesson and Backlund, 2007). Whilst Michael and Chen say that serious games should not have entertainment or fun as their primary objective, Zyda says that the entertainment component of the game should come first, and 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).

For the purpose of this dissertation, I will use the definition 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 an educational game in higher education may not be that alien 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 leaners 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, 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).

According to Prensky (2001), playing games is a fun and pleasurable activity, and research has shown that fun and enjoyment are an important part of the learning process as learners can be more motivated and willing to learn (Bisson and Luckner, 1996; Cordova and Lepper, 1996). Games which also provide an optimal balance of challenge and frustration, leave players in a motivated state to continue to play (Gee, 2003).

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). Though a number of studies agree that serious games support learning, and used alongside other instructional methods, can make learning more effective and can improve the learning experience (Wouters et al., 2013; Concannon, Flynn and Campbell, 2005; Granic, Lobel and Engels, 2014)

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).

The ages of Scratch users extend beyond 16; up until 80 (Scratch, 2019), and Scratch has also been used in higher education (Resnick et al., 2009). In one study, Scratch was used in a course at Harvard's summer school to introduce students to programming fundamentals (Malan and Leitner, 2007). After a total of 5 hours on Scratch, students were then transitioned onto Java. More than 75% of the students reported that Scratch was a positive influence, with some reporting that it was fun and easy to use. From the responses presented in the study, it is clear that Scratch helped students improve their computational thinking skills, which seemed to have greatly helped when transitioning into Java (Malan and Leitner, 2007). This suggests that removing the burden of having to learn the syntax, of more so complex syntactical languages like Java (Malan and Leitner, 2007), in introductory courses, can help motivate students to learn programming.

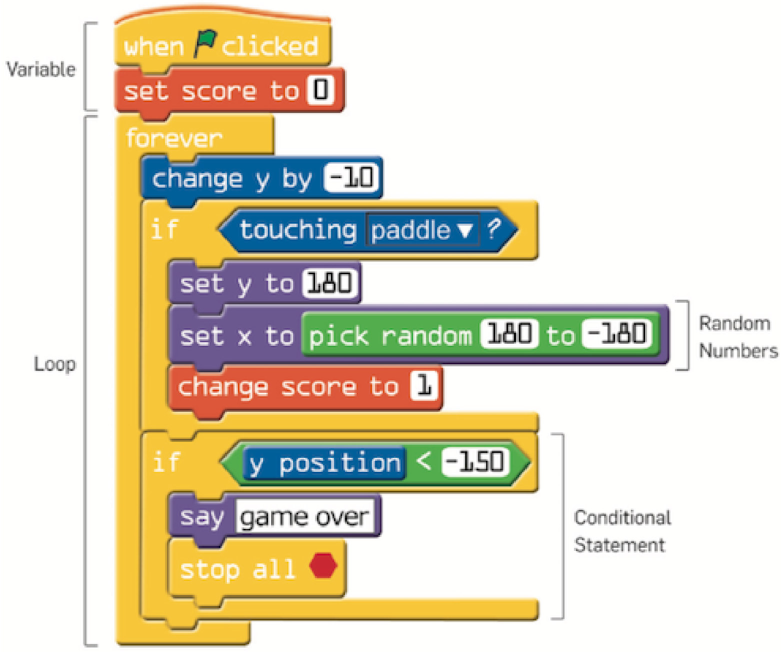

Figure 2.2.1: An example of a Scratch script (Resnick et al., 2009)

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 iterative and conditional 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).

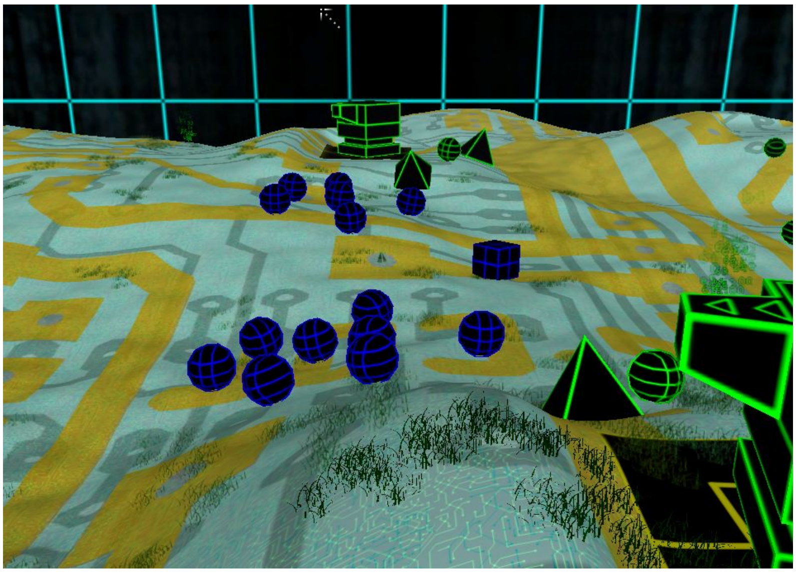

Figure 2.2.2: A screenshot of the game Prog&Play (Muratet, 2012)

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 programatic 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).

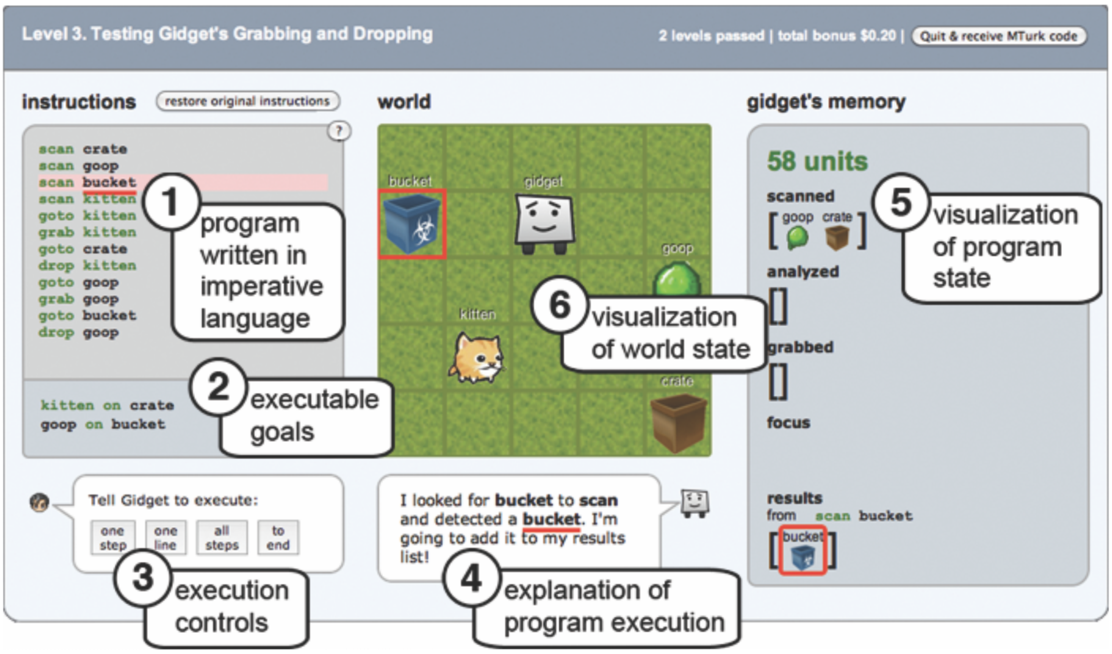

Figure 2.2.3: A screenshot of the game Gidget (Lee and Ko, 2011)

2.3 Teaching Programming Fundamentals

In 1978, ACM Computing Curricula used the terms "CS1" and "CS2" to designate the first two courses in the introductory sequence of a computer science undergraduate course. CS1 described introducing students to programming fundamentals and CS2 to teaching data abstraction/data structures. The general principles of CS1 and CS2 have continued, but through the past years, the concepts covered in these courses have changed. The most recent curriculum by ACM-IEEE was created in 2013 (Hertz, 2010). This curriculum notes that the "vast majority of introductory courses are programming-focused, in which students learn about concepts in computer science (e.g., abstraction, decomposition, etc.) through the explicit tasks of learning a given programming language and building software artifacts". The curriculum considers 'iterative and conditional control structures' as fundamental programming concepts (ACM-IEEE, 2013). Thus these concepts are likely be taught as a part of CS1 or introductory programming units.

2.3.1 Iterative and Conditional Control Structures

2.3.2 Methods

Conventional introductory programming courses at University are structured courses based on lectures and practical laboratory work, and a curriculum focused largely on programming knowledge - particularly relating to the features of the programming language being taught and how to use them (Robins, Rountree and Rountree, 2003). Robins, Rountree and Rountree suggest that this approach is popular, due to the important role of such programming knowledge in programming and the sheer volume and detail of language related features that can be covered (Robins, Rountree and Rountree, 2003).

Another method for learning programming fundamentals which are 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 comparison, traditional methods such as face-to-face or pencil-and-paper teaching (Girard, Ecalle and Magnan, 2013), centers on instructors who have control over class content and the learning process, whereas, online learning, offers a learner-centered, self-paced learning environment. Online resources are also time and location flexible and provide unlimited access to learners (Zhang et al., 2004). On the other hand, whilst there are many benefits to online learning, there are doubts over its effectiveness (Zhang et al., 2004). Some argue that online learning should not replace traditional forms of learning (Zhang et al., 2004; Gunasekaran, McNeil and Shaul, 2002; Agal, Devija and Dave, 2010), instead it should be used to complement the learning process (Zhang et al., 2004) and potentially improving the quality of the learners education (Concannon, Flynn and Campbell, 2005). Whilst other researchers highlight the great advantages of games over traditional methods (Girard, Ecalle and Magnan, 2013).

In conclusion, there are advantages and disadvantages to both methods of teaching. However, there is a lot of support that games are effective learning tools (Girard, Ecalle and Magnan, 2013).

2.3.3 Issues

The complexity of teaching introductory programming, which includes; iterative and conditional control structures, is widely acknowledged among educators (Koulouri, Lauria and Macredie, 2014). Novice programmers have difficulty in tracing (a method of mentally simulating the execution of the code before compiling), reading and understanding pieces of code and fail to grasp basic programming principles and routines. The overhead of learning the syntax and semantics of a language at the same time, and difficulties in combining new and previous knowledge and developing their general problem-solving skills, all add to the complexity of learning how to program (Koulouri, Lauria and Macredie, 2014). Therefore careful consideration will be taken to reduce these problems, with efforts to; introducing programming concepts at a reasonable pace, and making the game fun and enjoyable to keep the user motivated.

Researchers have proposed guidelines as to what makes good introductory programming units. For example, Stevenson and Wagner analysed assignments from textbooks and historical usage to look for students problems, and proposed a criteria as to what would make good programming assignments: (1) be based on real world problems, (2) allow students to generate realistic solution, (3) allow students to focus on current topic(s) within context of a larger problem, (4) be challenging, (5) be interesting, (6) make use of one or more APIs, (7) have multiple levels of challenge and achievement and finally (8) allow for some creativity and innovation (Stevenson and Wagner, 2006).

2.4 Educational Game Design

When researching the effects and effectiveness of digital games for learning, the importance of enjoyment for/in education needs to be taken into account. This means that when the effectiveness of a serious game is assessed, the question about its entertainment value should always be addressed (Breuer and Bente, 2010).

Despite the similarities between games and learning, 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).

Given this background, 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 (digital) games for prescribed educational aims Breuer and Bente (2010).

The design and production of video games involves aspects of cognitive psychology, computer science, environmental design, and storytelling, to name a few (Koster and Wright, 2004).

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).

Garris, Ahlers and Driskell describes a "tacit model that is inherent in most studies of instructional games". The model is as follows. Initially, we define a set of learning outcomes and objectives that we wish to achieve. We then design an instructional program which incorporates certain characteristics of games, that delivers the desired learning objectives. Subsequently, the program triggers a cycle that includes user judgments, user behaviours and system feedback. If the pairing of the instructional content with the appropriate game features is successful and effective, the cycle achieves recurring and self-motivated game play. Finally, this engagement in the game leads to the achievement of the learning outcomes (Garris, Ahlers and Driskell, 2002). This model is illustrated in Figure 2.4.1.

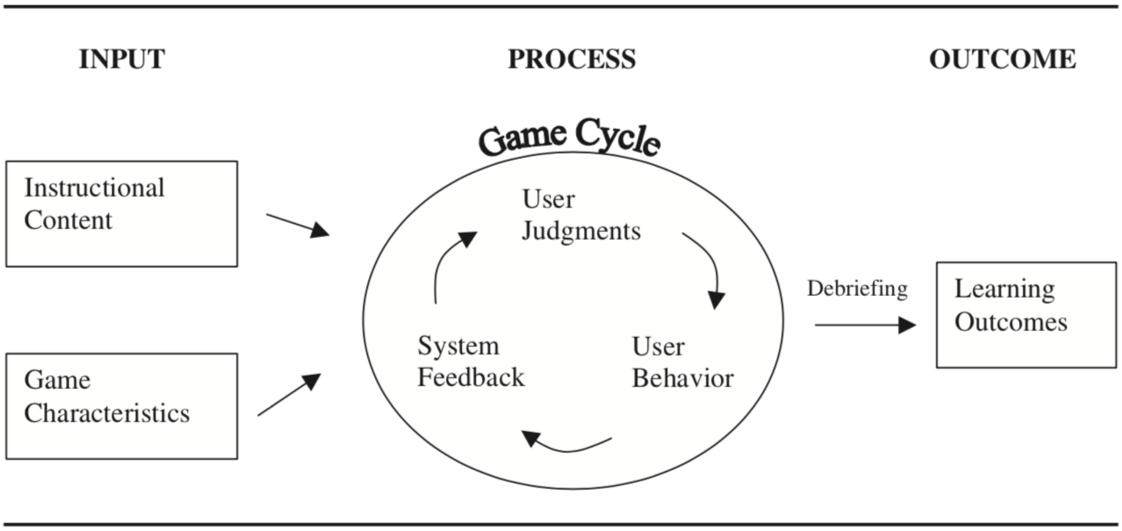

Figure 2.4.1: Input-Process-Outcome Instructional Game Model (Garris, Ahlers and Driskell, 2002)

Pleasure/fun and challenge have been found as some of the key reasons for people playing entertainment games (Connolly et al., 2012).

2.4.1 History

In 1980, Thomas W. Malone had begun researching the natural motivational properties of video games. With this work Malone created a set of heuristics based on motivational principles of games to create fun instructional game designs (Malone and Lepper, 1987). In 1996, Lloyd Rieber Z

2.4.2 Frameworks

2.4.2.1 Motivational

2.4.2.2 Learning

To be written.

EFM: A Model for Educational Game Design

Game object model version II: a theoretical framework for educational game development (318)

Game, motivation, and effective learning: An integrated model for educational game design (230)

Serious Games: A New Paradigm for Education?

2.4.3 Game Genre

Connolly et al. finds that simulation games are one of the most common game genres in serious games, possibly because their use in education is already established (Connolly et al., 2012). Simulation games have the ability to represent real-life situations (Braghirolli et al., 2016).

https://www.researchgate.net/publication/272166351_A_taxonomy_of_educational_games

To encourage the use of games in learning beyond simulations and puzzles, it is essential to develop a better understanding of the tasks, activities, skills and operations that different kinds of game can offer and examine how these might match desired learning outcomes (Connolly et al., 2012).

2.4.4 Game Elements

(CHANGE IT UP) Barnes et al. ran a project that made University Students create games that would teach basic programming. They carried out evaluations to test participant learning from the game, and made some interesting observations as follows: Clear instructions and game goals must be provided and accessible throughout the game, Learning goals must be clearly tied to in-game feedback that motivates the player (through, e.g. experience points, health), and penalizes guessing, Humor can be a motivation for in-game interaction (Barnes et al., 2007).

rewards remain controversial in education due to their possible negative side effects on individuals motivation, Despite the controversy concerning the use of external rewards in education (Cameron, Pierce, Banko, & Gear, 2005). badges in the context of a technology-based innovation in an elementary school can enhance learning without undermining motivation (Filsecker and Hickey, 2014).

Chapter 3

Requirements Specification

Chapter 4

Design

Chapter 5

Implementation

Chapter 6

Testing

Chapter 7

Results

Chapter 8

Conclusions

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).

Bibliography

AAStocks, 2016. Number of active video gamers worldwide from 2014 to 2021 (in millions) [Online]. Accessed: 2019-04-12. Available from: `https://www.statista.com/statistics/748044/number-video-gamers-world`.

Abt, C.C., 1970. *Serious games: The art and science of games that simulate life in industry, government and education*. New York, NY: Viking.

ACM-IEEE, 2013. Computer science curricula 2013 [Online]. Accessed: 2019-04-02. Available from: `https://www.acm.org/binaries/content/assets/education/cs2013_web_final.pdf`.

Agal, S., Devija, P. and Dave, P.D.K., 2010. Can e-learning replace the traditional classroom? a case study at a private college in udaipur. *AISHWARYA RESEARCH COMMUNICATION*, 2, pp.173–178.

AlliedMarketResearch, 2017. Serious games market [Online]. Accessed: 2019-04-04. Available from: `https://www.alliedmarketresearch.com/serious-games-market`.

Arkorful, V. and Abaidoo, N., 2015. The role of e-learning, advantages and disadvantages of its adoption in higher education. *International Journal of Instructional Technology and Distance Learning*, 12(1), pp.29–42.

Barnes, T., Richter, H., Powell, E., Chaffin, A. and Godwin, A., 2007. Game2learn: Building cs1 learning games for retention. *SIGCSE Bull.*, 39(3), pp.121–125.

Bisson, C. and Luckner, J., 1996. Fun in learning: The pedagogical role of fun in adventure education. *Journal of Experiential Education*, 19(2), pp.108–112.

Botturi, L. and Loh, C.S., 2009. *Once upon a game*, Boston, MA: Springer US, pp.1–22.

Braghirolli, L.F., Ribeiro, J.L.D., Weise, A.D. and Pizzolato, M., 2016. Benefits of educational games as an introductory activity in industrial engineering education. *Computers in Human Behavior*, 58, pp.315–324.

Breuer, J. and Bente, G., 2010. Why so serious? on the relation of serious games and learning. *Journal for Computer Game Culture*, 4, pp.7–24.

Concannon, F., Flynn, A. and Campbell, M., 2005. What campus-based students think about the quality and benefits of e-learning. *British Journal of Educational Technology*, 36(3), pp.501–512.

Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T. and Boyle, J.M., 2012. A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59(2), pp.661–686.

Cordova, D.I. and Lepper, M.R., 1996. Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of educational psychology.*, 88(4), pp.715–730.

Djaouti, D., Alvarez, J., Jessel, J.P. and Rampnoux, O., 2011. *Origins of serious games*, Springer London, pp.25–43.

Ferguson, C.J., 2007. The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *Psychiatric Quarterly*, 78(4), pp.309–316.

Feurzeig, W. et al., 1969. Programming-languages as a conceptual framework for teaching mathematics. final report on the first fifteen months of the logo project.

Filsecker, M. and Hickey, D.T., 2014. A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement and learning in an educational game. *Computers & Education*, 75, pp.136–148.

The first video game?, n.d. [Online]. Accessed: 2018-12-06. Available from: `https://www.bnl.gov/about/history/firstvideo.php`.

Garris, R., Ahlers, R. and Driskell, J.E., 2002. Games, motivation, and learning: A research and practice model. *Simulation & Gaming*, 33(4), pp.441–467.

Gee, J.P., 2003. What video games have to teach us about learning and literacy. *Comput. Entertain.*, 1(1), pp.20–20.

Girard, C., Ecalle, J. and Magnan, A., 2013. Serious games as new educational tools: how effective are they? a meta-analysis of recent studies. *Journal of Computer Assisted Learning*, 29(3), pp.207–219.

Granic, I., Lobel, A. and Engels, R.C.M.E., 2014. The benefits of playing video games. *American psychologist.*, 69(1), pp.66–78.

Gunasekaran, A., McNeil, R.D. and Shaul, D., 2002. E-learning: research and applications. *Industrial and commercial training.*, 34(2), pp.44–53.

Hayes, E.R. and Games, I.A., 2008. Making computer games and design thinking: A review of current software and strategies. *Games and Culture*, 3(3-4).

Hertz, M., 2010. What do "cs1" and "cs2" mean? investigating differences in the early courses. *Proceedings of the 41st acm technical symposium on computer science education.* pp.199–203.

Koster, R. and Wright, W., 2004. *A theory of fun for game design*. Paraglyph Press.

Koulouri, T., Lauria, S. and Macredie, R.D., 2014. Teaching introductory programming: A quantitative evaluation of different approaches. *Trans. Comput. Educ.*, 14(4), pp.26:1–26:28.

Lee, M.J. and Ko, A.J., 2011. Personifying programming tool feedback improves novice programmers' learning. *Proceedings of the seventh international workshop on computing education research*. pp.109–116.

Lee, M.J. and Ko, A.J., 2015. Comparing the effectiveness of online learning approaches on cs1 learning outcomes. *Proceedings of the eleventh annual international conference on international computing education research*. ACM, pp.237–246.

Lehrer, R., 1986. Logo as a strategy for developing thinking? *Educational Psychologist*, 21(1-2), pp.121–137.

Lowood, H., 2009. Videogames in computer space: The complex history of pong. *IEEE annals of the history of computing*, 31(3), pp.5–19.

Malan, D.J. and Leitner, H.H., 2007. Scratch for budding computer scientists. *ACM Sigcse Bulletin*, 39(1), pp.223–227.

Malone, T. and Lepper, M., 1987. Making learning fun : a taxonomic model of intrinsic motivations for learning. *Conative and Affective Process Analysis*.

Michael, D.R. and Chen, S.L., 2005. *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade.

Muratet, M., 2012. Prog&play [Online]. Accessed: 2019-04-17. Available from: `http://progandplay.lip6.fr/index_en.php`.

Muratet, M., Torguet, P., Viallet, F. and Jessel, J.P., 2011. Experimental feedback on prog&play: a serious game for programming practice. *Computer graphics forum*. vol. 30, pp.61–73.

Newzoo, 2017. Distribution of video gamers worldwide in 2017, by age group and gender. [Online]. Accessed: 2019-04-12. Available from: `https://www.statista.com/statistics/722259/world-gamers-by-age-and-gender/`.

Newzoo, 2018. *2018 global games market report* [Online]. Available from: `https://resources.newzoo.com/hubfs/Reports/Newzoo_2018_Global_Games_Market_Report_Light.pdf?`

Prensky, M., 2001. Digital natives, digital immigrants part 1. *On the Horizon*, 9, pp.1–6.

Prensky, M., 2003. Digital game-based learning. *Computers in Entertainment (CIE)*, 1(1), pp.21–21.

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J.S., Silverman, B. et al., 2009. Scratch: Programming for all. *Commun. Acm*, 52(11), pp.60–67.

Ritterfeld, U. and Weber, R., 2006. Video games for entertainment and education. *Playing Video Games: Motives, Responses, and Consequences*, pp.399–413.

Robins, A., Rountree, J. and Rountree, N., 2003. Learning and teaching programming: A review and discussion. *Computer science education.*, 13(2), pp.137–172.

Sangrà, A., Vlachopoulos, D. and Cabrera, N., 2012. Building an inclusive definition of e-learning: An approach to the conceptual framework. *The International Review of Research in Open and Distributed Learning*, 13(2), pp.145–159.

Scratch, 2019. Scratch statistics [Online]. Accessed: 2019-04-16. Available from: `https://scratch.mit.edu/statistics/`.

Sherry, J., Greenberg, B., Lucas, K. and Lachlan, K., 2006. Video game uses and gratifications as predictors of use and game preference. *International Journal of Sports Marketing and Sponsorship*, 8, pp.213–224.

Stevenson, D.E. and Wagner, P.J., 2006. Developing real-world programming assignments for cs1. *Proceedings of the 11th annual sigcse conference on innovation and technology in computer science education*. ACM, pp.158–162.

Susi, T., Johannesson, M. and Backlund, P., 2007. *Serious games : An overview*. University of Skövde, School of Humanities and Informatics.

Tennis for two, n.d. [Online]. Accessed: 2019-03-21. Available from: `https://www.sunysb.edu/libspecial/videogames/tennis.html`.

Vygotsky, L.S., 1978. *Mind in society: The development of higher psychological processes*. Harvard university press.

Wilkinson, P., 2016. *A brief history of serious games*, Springer, pp.17–41.

Williams, D., 2003. The video game lightning rod. *Information, communication and society.*, 6(4), pp.523–550.

Wouters, P., Nimwegen, C. van, Oostendorp, H. van and Spek, E.D. van der, 2013. A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, 105(2), pp.249–265.

Zhang, D., Zhao, J.L., Zhou, L. and Nunamaker, Jr., J.F., 2004. Can e-learning replace classroom learning? *Commun. ACM*, 47(5), pp.75–79.

Zyda, M., 2005. From visual simulation to virtual reality to games. *Computer*, 38(9), pp.25–32.

Appendices

Appendix A

Uncertainty Analysis

Appendix B

Screenshots

Appendix C

Ethics Checklist