



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

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A final year project submitted in partial fulfilment for the degree of  
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# Development of an Educational Game to Teach Conditional and Iterative Control Structures

Submitted by: Amarnath Kakkar

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Department of Computer Science  
University of Bath

Supervisor: Dr. Alan Hayes

**April, 2019**



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# Abstract

To be written.

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# Outline of Project

To be written.

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# Acknowledgements

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 playable 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



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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).

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### 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

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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

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(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 "Digital 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 a fun and pleasurable activity (Prensky, 2001), and research has shown that fun and enjoyment are important part to the learning process, as learners can be more motivated and willing to learn (Bisson and Luckner, 1996; Cordova and Lepper, 1996). Games can also be very motivating and engaging (Prensky, 2001). They can leave players in an optimal balance of challenge and frustration, which can be a very motivating state for players (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**

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

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## 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.

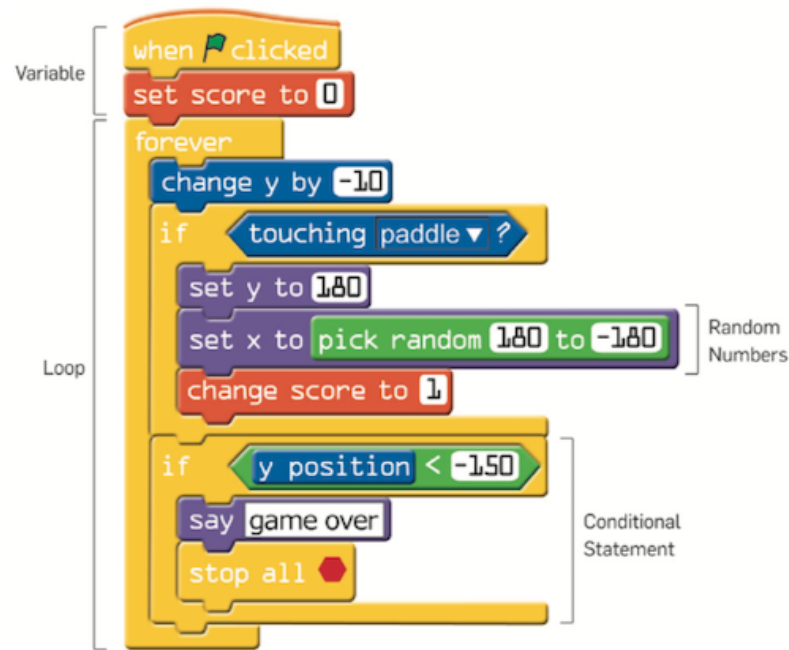


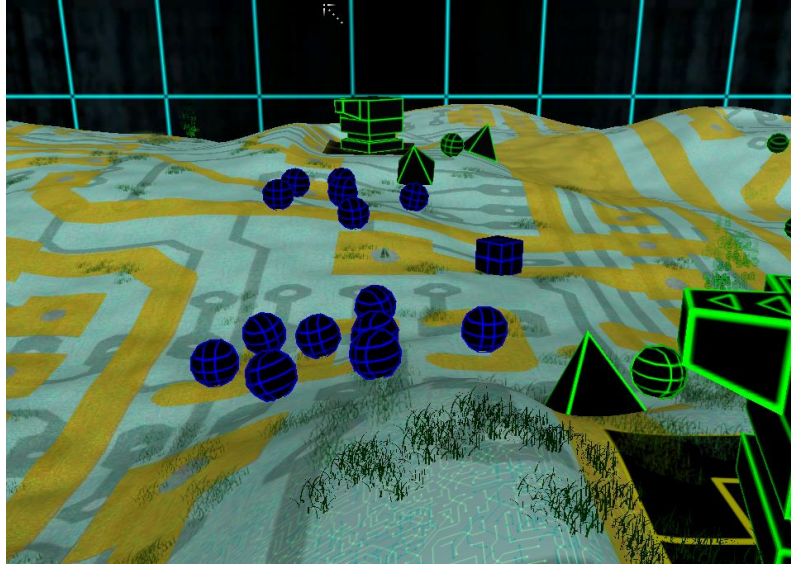
Figure 2.2.1: An example of a Scratch script (Resnick et al., 2009)

### 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 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 to work with a damaged robot, also named Gidget, to help clean up a city and protect its 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 authoritative 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).



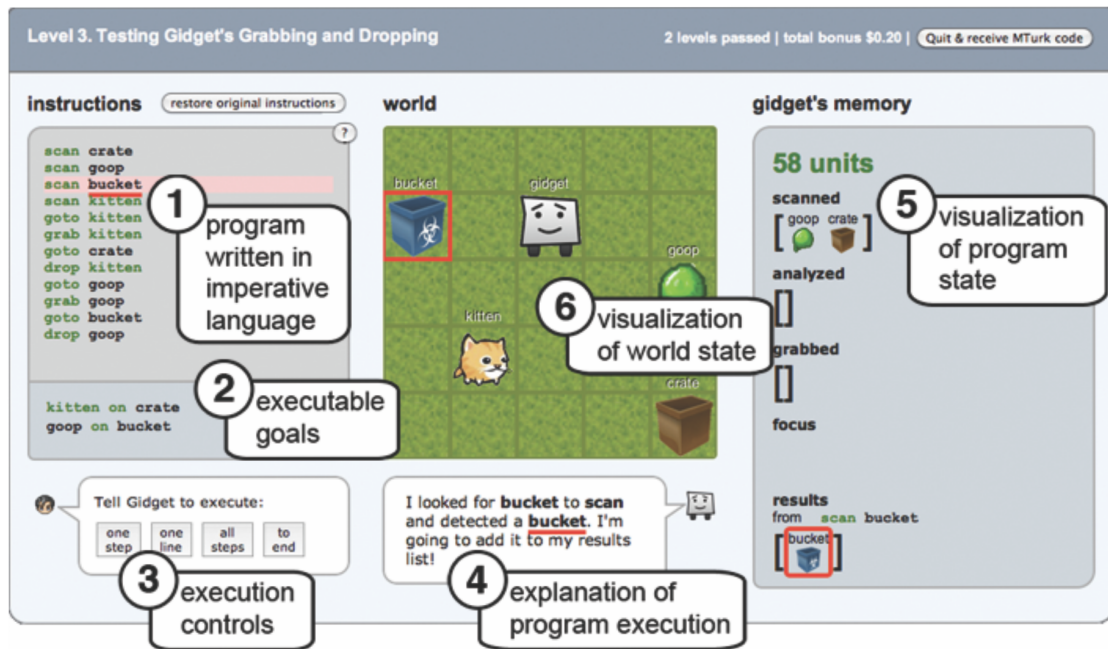


Figure 2.2.3: A screenshot of the game Gidget (Lee and Ko, 2011)

## 2.3 Teaching 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

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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 Codecademy 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**

Teaching introductory programming topics to novice programmers is regarded as a complex issue (Koulouri, Lauria and Macredie, 2014). For learners, 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).

For University students, there is a concern for high failure rates in introductory units, which is potentially leading to high drop out rates in computer science courses (Koulouri, Lauria and Macredie, 2014). (Koulouri, Lauria and Macredie, 2014) carried out a 4-year longitudinal study.

(?)

Researchers have proposed guidelines as to what makes good introductory programming units. For example, Stevenson and Wagner (2006) 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.

## **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).

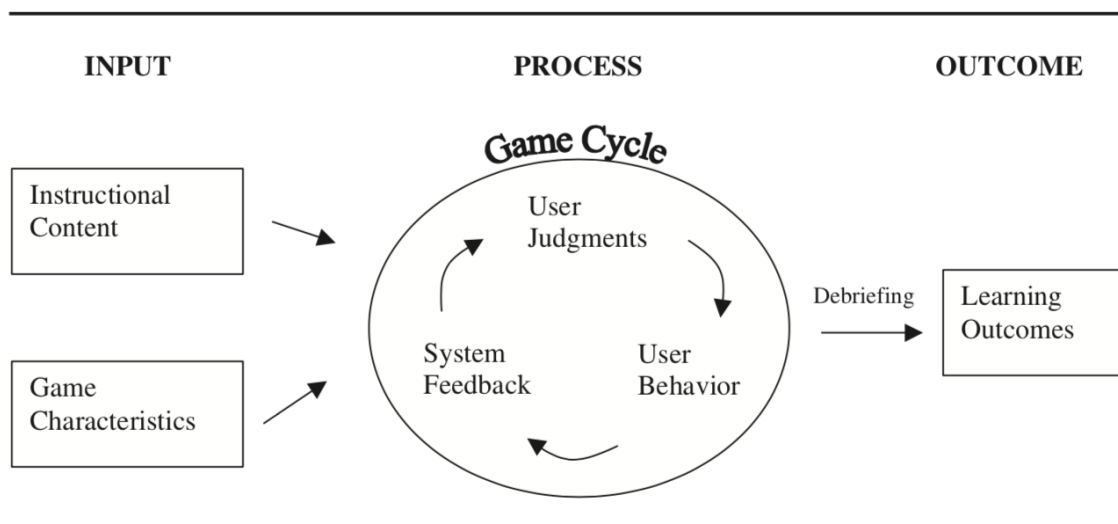
Despite the similarities between games and learning, it is not sufficient to just assume that all forms of games are equally suitable for learning and that simply presenting material in a game-like setting will increase the quantity and quality of learning Breuer and Bente (2010).

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 enter-

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tainment 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](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

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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).



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# Appendices

# Appendix A

## Uncertainty Analysis

# Appendix B

## Screenshots

# Appendix C

## Ethics Checklist