Serious Games and Preteen girls’ perception of Computer Science careers: A Systematic Review

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Abstract

Underrepresentation of females in computing education and careers is a pre-existing problem in the field of Computer Science. With the recent technological advancements and increase in the need of professionals in Computer Science, it is time for female to stand up and grab these opportunities. Change in classroom environment with the addition of games in learning has made learning an interactive and fun activity. It is possible to access females’ interest in Computer Science with these learning environment and motivate them towards Computer Science careers. This paper intends to summarize the main outcome of a systematic literature review of the use of serious games to increase pre-teen girls’ interest towards Computer Science as a career option. Additionally, this paper presents an overview of how serious games have been used to access girls’ attitudes towards Computer Science. The research was conducted with 26 primary studies selected from 4 different online databases. The results from the review reveals the ongoing research patterns in this field. Another main exhibit from the review is the impact of the research studies on their participants and relevant design factors present or lacking in the serious games. Finally, this review suggests that in future, researchers should consider similar systematic reviews to enable other researchers in the field to compare and contrast their works for validity. Additionally, this review suggests future researchers to consider various design elements for game design and ways to conduct an activity session which brings out the best in the participants.

Keywords: games, serious games, pre-teen girls, middle school girls, computer science, career
Preface

This project thesis is submitted to the Department of Computer Science at Norwegian University of Science and Technology (NTNU) as part of the course TDT4501, Specialization Project.

The work has been done under the supervision of Professor Letizia Jaccheri as the main supervisor and Post Doctoral Fellows Kshitij Sharma and Javier Gomez Escribano as co-supervisors.
Acknowledgement

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Kshitiz Adhikari
# Table of Contents

Abstract i
Preface ii
Acknowledgement iii
Table of Contents vi
List of Tables vii
List of Figures ix
Abbreviations x

## 1 Introduction
1.1 Motivation .................................................. 1
1.2 Research Questions ....................................... 2
1.3 Research Process ........................................... 2
1.4 Outline of the Report ....................................... 3

## 2 Background
2.1 Women and Computer Science .............................. 5
  2.1.1 Women in Computer Science careers .................. 6
2.2 Strategies to increase girls’ interest in Computer Science .. 8
2.3 Serious Games ............................................. 9
  2.3.1 Serious Games in Learning ............................ 10
  2.3.2 Serious Games over the years ........................ 11

## 3 Research Methodology
3.1 Data Collection ............................................ 13
3.2 Inclusion and Exclusion Criteria .......................... 14
3.3 Manual Search .............................................. 15
### 4 Results

1. **Activities performed in the studies**
2. **Context**
3. **Type of Methodology**
4. **Data Analysis**
5. **Technology**
6. **Outcome**
7. **Age Distribution of the Focus Groups**
8. **Sample Size**

### 5 Discussion

1. **RQ1**: What impact can serious games have on preteen girls perception of Computer Science as a career option?
2. **RQ2**: What are the major factors to be considered when developing a serious game?
3. **Future Work**

### 6 Planning of the Research

1. **Systematic Review Findings and Observations**
2. **Research Questions and Problem Areas**
3. **Research Plan and Approach**
   1. **Research Process**
   2. **Participants**
   3. **Research Paradigm**
   4. **Final Deliverables**

### 7 Conclusion

**Bibliography**

**Appendix**
List of Tables

3.1 Search strings used for different Online Libraries ........................................... 13
3.2 Database searches and Number of Retrievals .................................................. 14
3.3 Primary Studies available from Online Libraries after Inclusion and Exclusion Criteria ................................................................. 15

4.1 A mapping of Data Collection strategies discussed in Section 4.3 to their respective Data Analysis approach .......................................................... 23
4.2 Determining the impact of the studies on the participants and their principal design factor ................................................................. 26

7.1 Paper coding of the primary studies ............................................................... 55
List of Figures

2.1 Laamarti et al. (2014): Growth of serious games research within the years 9
3.1 Study Selection Process ................................. 15
3.2 Manual Search using Snowballing Sampling Technique ............................. 16
3.3 Publication trend of primary studies ........................................ 16
4.1 Activities held in the primary studies ........................................ 19
4.2 The context of the primary studies ........................................ 20
4.3 Different data collection methodologies used in the primary studies .......... 21
4.4 Data analysis methods in the primary studies ................................... 23
4.5 Technologies used in the primary studies .................................... 24
4.6 Tools used in game making in the primary studies ............................. 25
4.7 Age distribution of the focus group in the primary studies .................... 29
4.8 Sample size of the focus group in the primary studies ......................... 30
6.1 The Research Process (Oates (2006)). The green boxes represents the Systematic Review, and the blue boxes represents the Master thesis. .......................... 41
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>CS</td>
<td>Computer Science</td>
</tr>
<tr>
<td>NCES</td>
<td>National Centre for Education Statistics</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>ENIAC</td>
<td>Electronic Numerical Integrator and Computer</td>
</tr>
<tr>
<td>NCWIT</td>
<td>National Centre for Women and Information Technology</td>
</tr>
<tr>
<td>WITI</td>
<td>Women In Technology International</td>
</tr>
<tr>
<td>AP</td>
<td>Advanced Placement</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
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<tr>
<td>CS4FN</td>
<td>Computer Science For Fun</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
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<tr>
<td>WTP</td>
<td>WOmen’s Technology Program</td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
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<tr>
<td>MST</td>
<td>Minimum Spanning Tree</td>
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<td>ACM</td>
<td>Association for Computing Machinery</td>
</tr>
<tr>
<td>IDC</td>
<td>Interaction Design and Children</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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</table>
Introduction

Girls’ involvement in Computer Science has seen a drastic change throughout the years. According to National Centre for Education Statistics (NCES (2012)), in the USA, women accounted to 37% of Computer Science graduates in 1985 while the number went down to 17.6% in 2011. Additionally, NCES (2012) also states that in the last 15 years, women in Computer Science careers has dropped from 35% to 25%. It has not been long since women started getting involved in Computer Science fields like programming and software development. When the industry was on the rise, it was mostly occupied by males. Hence the stereotype “Computer Science is a male-dominated domain”. This thesis aims to provide an overview of research studies which encourages preteen girls towards Computer Science through serious games.

The introduction consists of four subsections. In Section 1.1, we will learn about the motivation and objective of this research. This is followed by the problem definition via research questions in Section 1.2. Section 1.3 describes the research process chosen for this study. The outline of the report is stated in Section 1.4.

1.1 Motivation

The last decade has seen a tremendous rise in Computer Science careers all over the world. Computer Science has become an integral part of people’s lives irregardless of everyone’s awareness of this fact. With the advancement of Software Development, Artificial Intelligence and Machine Learning to name a few, Computer Science have become an ever growing industry which yearns to recruit more professionals to achieve more.

Statistically, interest of women in Computer Science has declined over the years (Groover (2009)). Males are still predominant in most of the Computer Science environments. Studies to expose Computer Science as a viable career option for girls began as early as 2000. Various strategies have been postulated in order to increase the interest of women in Computer Science careers (Miliszewska and Moore (2010)). The focus of these strategies is to attract girls towards Computer Science from an early age. One such strategy was the use
Chapter 1. Introduction

of computer games to attract girls. Companies started focusing on activities that girls liked the most and incorporated them into computer games (Gorriz and Medina (2000)).

Introduction of computer games into education yielded games such as Barbie Fashion Designer, Nancy Drew: Secrets Can Kill, Lets Talk About Me, and Carmen Sandiego series to name a few (Gorriz and Medina (2000)). These games had diverse concepts and ambitions for children to achieve. The gaming industry was populated with games like Mortal Kombat and Zelda whose audience were mostly men. However, these games included rare elements like female character protagonist and story line where problem solving and communication were key to progressing in the game (Gorriz and Medina (2000)). Companies aimed to profit from the girls’ game market while encouraging them to explore the technology to achieve computing experiences for technologically advanced future alongside having fun.

Games in education soon evolved from computer/video games to serious games. Games that are built to serve other purposes (mostly, educational) as opposed to only entertainment are Serious Games (Hakulinen (2011)). Serious games contributes to all the aspects of education, namely, teaching, training and informing (Michael and Chen (2005)). Hakulinen (2011) states that a well-designed game has the potential to motivate students to learn as well as collaborate with others.

In more recent studies, workshops have been conducted to teach students basic Computer Science concepts via technologies such as Scratch (Adams (2010)). This suggests a need for an updated overview of the pre-existing research in order to identify their results and impact along with limitations, and to suggest potential future work in this research field.

1.2 Research Questions

The objective of this thesis is to study available research on the use of serious games to encourage preteen girls towards a Computer Science career. The insufficiency of information from previous studies and their inability to address this research problem has led to the formulation of the following research questions:

1. What impact can serious games have on preteen girls perception of Computer Science as a career option?

2. What are the major factors to be considered when developing a serious game?

1.3 Research Process

A systematic review will be undertaken following the guidelines from Kitchenham (2004) to address the research objective and the research questions. The main steps of the review process includes identifying research problems, search and selection strategy, quality assessment, manual search, data extraction and monitoring, and data synthesis. The objective of the systematic review is to provide insight into previous studies performed in this research field followed by their results and its impact on our research study.
A total of 309 articles were retrieved after performing the search using the search string (Section 3.1). 21 articles were achieved after removing redundancies and refining the articles according to the published date, title and abstracts. Following the guidelines presented in Wohlin (2014), a manual search was conducted using snowball sampling technique. Both, forward and backward snowball sampling resulted in 26 articles which was limited to 5 articles after proceeding through inclusion and exclusion criteria.

1.4 Outline of the Report

The report proceeds as discussed in this section. In Section 2, the background of the study and related work is introduced. This section explains the contributions of serious games or similar activities to encourage students (specially, preteen girls) to study and pursue Computer Science. Section 3 presents the research methods undertaken, and reveals the steps and results achieved from them. Section 4 provides and visualizes the results of the study alongside the results of previous studies. In Section 5, we discuss the results in related to the research questions. This section also provides some insight to design-based ideas for future works. Section 6 presents a detailed plan of future work that will be conducted as part of a Master Thesis during Spring 2019. Finally, we conclude by answering the research questions followed by suggestions and future work in Section 7.
Chapter 2

Background

2.1 Women and Computer Science

Computer Science have become the most sought out domain in the recent years with its ability of integration with any diverse field of sciences such as arts, humanities, natural science, social science, engineering, business, medicine and law. Today, Computer Science not only means the design and use of computers but it can be divided into a various theoretical and practical disciplines such as Software Engineering, Data Structure and Algorithms, Programming Language Theory, Computer Architecture Engineering, and Human-Computer Interaction which can further be divided into numerous sub-disciplines. Computer Science was introduced as a domain in the field of academia during the 1950s and 1960s. The Computer Science discipline was in a rather developing phase in the late 1950s (Tedre (2014)).

Computer Science grew from an emerging study to the behemoth it is today with the introduction of the Information Age and the Internet (Constable (2000)). The internet changed the face of the earth and made human’s life easier. With the internet, information was easily accessible and communication was faster regardless of the distance. The digital revolution then integrated Computer Science to every electronic device possible. Additionally, Computer Science, computers in general, were being used from home to offices, education to professions, and every other sector that involved humans. With the rise of Computer Science, there was equally rise in demand of Computer Science professionals.

Women are underrepresented in Science, in general. According to UNESCO Institute for Statistics, as of 2015, only 28.8% of the world’s researchers are female (Institute for Statistics (2018)). From ‘The Women of ENIAC’ as documented in Bailie (2015) to girls in Computer Science today, women have always struggled in Computer Science. While organizations such as Anita Borg Institute, the National Center for Women and Information Technology (NCWIT) and Women in Technology International (WITI) support and encourage women in computer related fields, Martincic and Bhatnagar (2012) informs that, after college, women leave Computer Science field in a rate two times as that of men. Computer Science has been a male-dominated field in the past and still is occupied by a
majority of males. Computer Science is filled with negative stereotypes. Miliszewska and Moore (2010) reports one such negative stereotypes of computing professionals as being anti-social individuals devoid of personality and lack of diversity in interests. Computer Scientists are also referred with terms like ‘geeks’, ‘nerds’, and ‘hackers’ (Fisher and Margolis (2002), Cheryan et al. (2009)). Negative stereotypes make a powerful impact of the behavior of the individuals. One such stereotypes of Computer Scientists is “Sitting in front of a computer screen all day”, and the results in Carbonaro et al. (2010) reported that student were not interested in Computer Science because of their lack of desire to sit in front of a computer screen all day. “Women cannot do Computer Science” is another negative stereotype comment that demoralizes women towards Computer Science. This is illustrated in Black et al. (2011) where female students rated their abilities to be lower as compared to men even though their grades were higher. A study at The Uppsala University (Couderc et al. (2015)) reported that women associated Computer Science with intelligence and hard work, and had fewer negative stereotypes towards Computer Science than men.

Palma (2001) reported that one main reason why more young men are attracted to Computer Science as compared to women is their interest in gadgets and innovation, and in building things. He also showcased that Bill Gates and Paul Allen’s basic interpreter and Steve Wozniak and Jobs’ first machine were build to amaze their colleagues in the Silicon Valley. With the increasing popularity of Mathematics among women, Palma (2001) suggested that incorporating teaching concepts of Mathematics into Computer Science could be able to attract women towards Computer Science. Women should be an integral part of computing domain for various reasons, and Bailie (2015) described one of the reasons as the ability to produce different perspectives and strategies in order to acquire knowledge and solve problems. Rhee and Kim (2012) described that gender differences exist when acquiring analytical thinking and problem solving capabilities. Their study also report that career related activities were taken more seriously by women than men.

2.1.1 Women in Computer Science careers

The trend of low involvement of women in Computer Science occurs before getting involved in the job industry. ComputerScience.org (2017) reported that boys outnumber girls in the ratio 4:1 in Computer Science placement exams. It also reveals that in 2014, not a single girl participated in the Advanced Placement Computer Science examination in Mississippi, Montana and Wyoming in the USA. Stereotypes suggesting “Computer Science is inappropriate for women” is responsible for lowering the confidence and sense of belonging the field (Fisher and Margolis (2002), Cundiff et al. (2013)). These stereotypes can negatively affect the choice of courses in the future and their career alternatives. The supposition that Computer Scientists are not social, conflicts with women’s desire to have a balanced career and social orientation (Rommes et al. (2007)). Women value working together with people (Ramírez et al. (2016)) as compared to men who do not share similar interest in people (Su et al. (2009)). Thuraisingham (2015) stated that while there are lower percentage of women professionals in computing than in the 1980s, the percentage of women in high technology positions in the industry has certainly grown as compared to 1980s. Additionally, a study (Brown (2014)) conducted by the University of California, Berkeley, to close gender gap Computer Science subjects revealed that the approach in
which courses are marketed might not be suitable to attract female students. In 2014, the university changed their course named “Introduction to Symbolic Programming” to “The Beauty and the Joy of Computing” which resulted in women outnumbering men in the class for the first time.

With endless opportunities in computing, involving rapid innovations and developments, women as well as men can be a part of this revolution while reaping the benefits by developing cutting-edge technology (Thuraisingham (2015)). Additionally, Computer Science careers are perceived to be lucrative (Lockard and Wolf (2012)) and the gender pay gap is very low as compared to other professions and perhaps even non-existent (ComputerScience.org (2017)). Miller and Webb (2015) reported the initiatives from tech giants like Apple and Google to reduce gender disparity in their businesses by encouraging women to explore Computer Science and gain success with the learned skills. Positive initiatives from highly-regarded organizations can create ripple effects in the tech industry thus inspiring women to explore Computer Science as a career option. Lockard and Wolf (2012) revealed that, in the USA, Software Engineering is the fastest growing occupation at the rate of 32.4% and has a generous pay rate of more than 100,000 USD per annum. Additionally, the demand of professionals in Computer Science and Mathematics has a planned growth of 22% from 2010 to 2020. With significant rise in the demand, there is no question to the need of involvement of women in this domain. Mota and Adamatti (2015) and Robinson et al. (2015), in their studies, reported that the participants perceived Computer Science as a form of communication media which made an impact on their everyday lives. This correlates with women’s desire to help the society (Seron et al. (2016)), which is a motivational factor towards a Computer Science career.

A number of factors that get girls into Computer Science have been studied in the past. One such study, Tillberg and Cohoon (2005), stated four main factors that influence girls to study Computer Science as supporting and motivating parents, encouraging teachers, exposure to Computer Science at school, and playing games on a computer. Fisher et al. (1997) highlighted that influence of family is a crucial factor on girls’ interest in Computer Science and its studies. They also pointed out the fact that while girls reported parents’ and teachers’ encouragement as their reasons for attachment with Computer Science, these factors were not rated highly as compared to interest, class experiences, and the future of the field. A number of activities are conducted by researchers to expose young girls to Computer Science with an objective to get them to pursue Computing careers in the future. Programs like Girls Who Code 1, SciGirls 2, Girls, Inc. 3, and Girlstart 4 have been working with the aim to reduce gender gap in technology. Numerous research studies have been performed to identify effective ways to expose girls to Computer Science and strengthen their interest in Computer Science in future. In a study conducted by Harvey Mudd College in 2015 (Klawe (2015)), they reworked their programming course curriculum to make it less pure programming by focusing on creative-problem solving and opportunities in the field. The result showed 30% increase in women taking the course in four years. Lack of female role models in Computer Science ceases to enable young girls to relate to if they study Computer Science or pursue a career in the field. Black et al. (2011) described a

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1https://girlswhocode.com/
2https://pbskids.org/scigirls/home
3https://girlsinc.org/
4https://girlstart.org/
project called Computer Science for Fun (CS4FN) that has produced and made freely available (online) a booklet that showcases female role models and their groundbreaking work in Computer Science. The booklet also contains recent trends and technologies in Computing industry and is published twice a year. In Bailie (2015), a website is used to provide information about historical women in Computer Science. The website provides information from the times of Ada Lovelace, a mathematician who programmed Charles Babbage’s Analytical Engine in 1843, to Yoky Matsuoka, the Vice President in a company that focuses on developing technology that enables people to conserve energy.

2.2 Strategies to increase girls’ interest in Computer Science

Google (2014) conducted a study to access the key factors involved in a woman’s decision to pursue Computer Science degree, and found 4 major indicators:

- Social Encouragement: Positive response from family and friends on persuasion of Computer Science.
- Self Perception: The belief that critical thinking and problem solving skills can provide a successful career.
- Academic Exposure: The opportunities to participate in curriculum and/or extracurricular Computer Science courses/activities.
- Career Perception: Positive thinking towards Computer Science as a career with societal impact.

Applying more stress into these factors in the society is a way to get more women into Computer Science. However, an strategy using only, for example, “Career Perception” is rather unlikely to yield the results as the absence other motivating factors could fail to boost the confidence towards Computer Science as a career. The MIT Women’s Technology Program (WTP) is a program running since 2002 with the goal to increase high school girls’ interest to study engineering and Computer Science in the future. The program runs a rigorous 4-week summer workshop where high school female students with hands-on and team-based activities. Summer camps are popular to access participants’ understanding and knowledge on a certain topic and help them develop other skills and interest in a short time. In a summer camp held for a week by Urness and Manley (2013), female participants reported underrepresentation of females (only 17% of the total participants) and they would have wanted to work together with more girls. Urness and Manley (2013) suggests that camps focused only to female students would be more friendly and engaging to them. Sweedyk (2011) integrated a game design project into the participants’ curriculum to evaluate students’ interest in the topic and how it would impact the students’ Computer Science choices in the future. In 2010, Mattel, Inc. announced that the next
2.3 Serious Games

Serious games are the games which are built with a goal to serve educational purpose rather than pure entertainment. The field of serious games has seen a rapid rise from its beginning phase in 1995 (Laamarti et al. (2014)). The first introduction to serious games was provided by Abt (1970) in his book “Serious Games” published originally in 1970, which states the concern for the game’s educational purpose and not to be played primarily for amusement. Laamarti et al. (2014) showed the evolution of serious games’ research in the Figure 2.1.

Prior to serious games, games were described by six main characteristics (Michael and Chen (2005)): Voluntary - a form of freedom, Pretend (non-realistic), Immersive, Limited, Social, and Rule-based. These characteristics lacked fun, and according to a survey conducted by Michael and Chen (2005), 80% participants said that fun is important in a serious game. Serious games often disobey the “Volunteer” characteristic since players are put under a limitation to play a certain game. Much research has been done to incorporate the element of fun into serious games. Esper et al. (2013) stated that many educational games are criticized and called “Chocolate flavored Broccoli” because the educational component of the game interrupts smooth gameplay. Furthermore, Laamarti et al. (2014) stated the link between games and military when the introduction of Odyssey by Magnavox (launched in the USA in 1972) which is considered the first serious video game because of its potential as an educational tool. As of 2012, Laamarti et al. (2014) estimated the number of serious games in the industry to be 400. Though this number is not huge as compared to normal games (consoles and PC), the growth of serious games has increased exponentially. According to Sonawane (2017), the global serious games market
was valued at 2.731 million USD in 2016 and is projected to reach a value of 9.167 million USD by 2017 to 2023.

Michael and Chen (2005) stated that Ben Sawyer, the co-founder of Serious Games Initiative, defined the ‘serious’ in serious games as the purpose of the game and the reason for its creation. The idea of a serious game does not have to be necessarily a computer game. Using traditional board games for with the purpose of educating the players on a certain subject matter could suffice to be recognized as a serious game. In the Serious Play Conference 8 in 2018, traditional tabletop board games were revolutionized with the integration of the “serious” factor from serious games. A winner of the conference, Mission to Mars: An Agile Adventure 9 is a board game with the purpose of teaching Agile and Agile decision-making with the element of fun. With not much difference in the human to computer ratio, computerized serious games soon became popular. While it is supposed that games will have positive impact on education, not much research has been done in this topic. A study conducted to access the impact of games in collaboration among students (Bourgonjon et al. (2010)) showed that the games were helpful in developing collaboration skills. Sweedyk (2011) reported that students liked to play games and while some were more into games as compared to others, almost all of the 208 participants included in this study played games. This might contribute to the success of serious games in education.

### 2.3.1 Serious Games in Learning

With the purpose of learning while having fun, the present generation of students are more likely to play and learn from games (Michael and Chen (2005)). With its immersive nature, games can get students’ attention for long time as compared to classroom lectures. Shikine et al. (2018) discusses the use of a serious game to teach and get students interested in mathematics. Serious games can be integrated with different educational domain. Some serious games are built specifically for the purpose of classroom environment, and they can cover a variety of study areas. Eordanidis et al. (2017) discusses about a serious game that is built to teach the concept of image representation to students. The study was conducted in a after-school program and concluded that the participants (girls) had an increased understanding of Image representation after playing the game. Colobot 10, with a blend of interactivity, storytelling, and programming, has been proved to be capable in teaching basic algorithms and commands similar to Java and C++ to teenagers. Dominguez-Rodriguez et al. (2016) presents two serious games, Pickit! and Cookit!, developed to introduce children from age 9 to 12 to nutrition education. Pickit! provides information related to the composition of food and the food supply chain, while Cookit! supplies the energy/calorie content and information related to healthy and unhealthy food found at home.

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8 https://seriousplayconf.com/
10 https://colobot.info/
2.3 Serious Games

2.3.2 Serious Games over the years

With the evolution in the gaming industry, serious games are not an exception. The history of serious games have changed over time with the introduction of more advanced features in the games. Microsoft’s Flight Simulator 11 is considered one of the most successful serious games of all time (Al-Riyami (2014)). Developed in 1982, newer versions of the game were still being developed till 2018. Flight Simulator was designed to provide detailed simulation to aviation and is one of the non-combat aviation games. Tiltfactor Laboratory 12, a serious game research centre established in 2003, are recognized as a big player in the serious game industry because of their innovative card games to represent three areas: public health, social attitudes and behaviors (Flanagan (2006)), and knowledge generation. Samovi (2018) states that America’s Army is the best example of the use of serious games in military learning. Serious games are used in military training to create real-world environment using virtual simulation. The primary goal is to prepare soldiers to make decisions faster in real-world scenario. As stated by Laamarti et al. (2014), America’s Army was developed by the US Army and distributed free of cost online in 2002. The game simulates military training and missions to fulfill the goal of advertising the US Army and using the game as a recruitment tool for individuals aged 16 to 24.

Much work has been done in incorporating serious games to Computer Science and Software Engineering. The Serious Games for Computer Science project from Software Quality Research Lab 13 aims to improve learning in Computer Science and Software Engineering through game-based approach. RoboBUG (Miljanovic and Bradbury (2017)), an open source serious game, helps players to learn debugging techniques in Software Engineering through an enjoyable and motivating experience. Robot ON! (Michael A. Miljanovic (2016)) is an educational game designed with the focus of increasing the players’ programming comprehension rather than teaching programming concepts. In this game, instead of writing a program, the players’ tasks is to present their knowledge and understanding of the programs. Gee et al. (2016) presents serious games used to teach common Computer Science concepts to middle school children aged 11 to 13. Gee et al. (2016) discusses a digital puzzle game, GrACE, which is used to determine a graph’s Minimum Spanning Tree (MST). The game play consists of animals collecting food while utilizing least effort. In a study conducted at the Brooklyn College and the College of Staten Island, Kletenik et al. (2017) focuses on using a serious game, Point Mouster, to teach advanced C++ programming concepts and to determine the impact of games to recruit and retain females in Computer Science.

11https://www.mobygames.com/game/microsoft-flight-simulator-v10
12https://tiltfactor.org/
13http://www.sqrlab.ca/
Research Methodology

Under the guidelines from Kitchenham (2004), a systematic review of the existing literature was conducted. The entire process of systematic review was performed by formulating a review process that helped us address the research questions along with data collection, search and selection strategy, manual search, inclusion and exclusion criteria, quality assessment and data analysis. Further, we will discuss the method used for each of the stages of the review process.

3.1 Data Collection

We started by selecting a number of online databases for data collection: Association for Computing Machinery Digital Library (ACM), Science Direct, IEEE Xplore, and EBSCO Education Source including ERIC. Moreover, we searched independent conferences including Interaction Design and Children (IDC). The searches were made on the basis of a search query formulated by conjunction of keywords. We used a number of keywords and their synonyms in order to converge the search to the topic of the research problem. Different databases had different methods for searching and therefore, we had to use the keywords in different ways using AND or OR operators to define the search string (Table 3.1).

<table>
<thead>
<tr>
<th>Online Library</th>
<th>Search String</th>
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<tr>
<td>ACM Digital Library</td>
<td>serious games AND girls AND computer science</td>
</tr>
<tr>
<td>EBSCO</td>
<td>games AND girls AND computer science</td>
</tr>
<tr>
<td>IEEE Explore</td>
<td>games AND girls AND “computer science”</td>
</tr>
<tr>
<td>Science Direct</td>
<td>(serious games AND girls) AND “computer science”</td>
</tr>
</tbody>
</table>

Table 3.1: Search strings used for different Online Libraries

The searches resulted in a combined total of 309 articles from the online bibliographic
Chapter 3. Research Methodology

databases (Table 3.2).

<table>
<thead>
<tr>
<th>Online Database</th>
<th>No. of Retrievals</th>
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<td>EBSCO</td>
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<td>IEEE Explore</td>
<td>17</td>
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<tr>
<td>Science Direct</td>
<td>197</td>
</tr>
</tbody>
</table>

Table 3.2: Database searches and Number of Retrievals

3.2 Inclusion and Exclusion Criteria

In this step, we defined a filter criteria to select articles which are more relevant to the research problem. We excluded on-going studies, short papers, posters, and articles published before 2008. We divided the inclusion and exclusion criteria into three categories, as defined below:

1. Published year should be after 2008: This was done with the idea that girls who were preteen in 2008 are now on their course for a professional career.

2. Avoid redundant articles: Removing articles that appeared in the search results for more than one online library.

3. Relevance to the research problem
   
   - Avoid studies that has no result: Studies without result fails to showcase if the research did succeed in its objective or not.
   - Avoid studies that teaches programming to young girls and does nothing to capture their opinion about pursuing Computer Science
   - Avoid studies that fails to provide their methodology: Studies that lack methodology are unable to provide insights to similar research in the future.

This process decreased the number of articles while increased the relevance of the selected articles. We included articles that succeeded to inspire girls towards Computer Science by teaching programming, or through programming or via game design workshops. Additionally, we focused on studies that made a positive impact on girls’ perception of Computer Science. At this stage, we focused on title and abstract of the articles to find out whether they are inside or outside the scope of our research criteria. We dived into the methodology and results of the articles if the title and abstract were not enough to determine the relevance of the study in relation to our research. Finally, we ended up with 21 studies from various online libraries as shown in Figure 3.1 and Table 3.3.
3.3 Manual Search

A manual search was conducted to identify additional studies that the search string failed to find in the online databases. For the manual search, we used the snowballing technique (Wohlin (2014)) whereby we looked through the references of the paper being examined to find other related studies. Additionally, examination of studies that have cited the paper was also conducted. ACM Digital Library was primarily used to examine the citations. This process provided 26 additional papers, among which 5 papers were published after 2008 and thus were included into the primary studies (Figure 3.2). Even though maximum articles achieved through this process were outdated (published before 2008), they provided guidelines and served as milestone work for numerous future research. Therefore, the results and methodology of some of these articles were used to provide a structure to the introduction of the research problem.

After the manual search, we identified 26 studies as our primary studies for the systematic review. A publication trend can be seen in Figure 3.3 to mark the number of primary studies published during a certain year.
3.4 Quality Assessment

For the quality assessment of the 26 studies, we defined a quality criteria which aligned with our review context. The aim of the quality assessment process was to access the findings of the primary studies and get an overview of their representation methods. The integration of the quality criteria in this study was made to secure the use of detailed and high-level studies to answer the research questions. Kitchenham (2004) has presented three important criteria to perform empirical research in software engineering:

1. **Rigorous**: The studies applies an appropriate research method.

2. **Credible**: The presentation and validity of findings in the study.

3. **Relevant**: The assurance that the findings of the study points towards encouraging preteen girls to Computer Science careers.

To access the quality of the studies, we selected additional seven criteria:
1. The aims and objectives of the research were clearly stated.
2. The design appropriately addressed the aims of the research.
3. The studies comprised empirical research.
4. The context of the research subject was descriptive.
5. Data collection methodology addresses the research problem.
6. Rigorous data analysis was present.
7. Clarity in the findings of the research.

In total, 26 studies met the inclusion-exclusion and quality criteria. The studies were then categorized based on their research area of focus for their critical examination. Categorization of these studies helped to represent their content. The categorization consisted of different attributes of the studies which are discussed in Section 3.5.

### 3.5 Data Analysis

The aim of this step was to gather information that can better answer the research questions. To perform an analysis of the selected studies, several attributes of the studies were analyzed and categorized:

- **Activities**: Main activity in the study (for example: game play, game design, case study).
- **Context**: The area of implementation of the research study (for example: class, workshop, after school).
- **Type of Methodology**: Qualitative or Quantitative or Mixed.
- **Data Analysis**: Presents what data were analyzed and how.
- **Technology**: Presents how technology was used in the study (for example: participants played a game, designed a game, learned programming using tools).
- **Outcome**: Whether the objective of the study was met or not.
- **Focus Group**: Age of the group of participants involved in the study.
- **Sample Size**: Total participants, or number of participants via gender.

Frequent meetings with authors were conducted to verify and approve each step of the analysis of all studies. All 26 studies were analyzed in detail. This process helped the authors better understand the existing studies and their results, and the data thus extracted were used as a basis for answering the research questions. In Section 7.1, we can see the details of paper coding of the studies.
Chapter 4

Results

In this chapter, we will discuss the findings from the primary studies. We will visualize the most relevant findings and put an emphasis on the methodologies followed to reach the results.

4.1 Activities performed in the studies

In this section, we will discuss various activities designed and implemented by the researchers in their studies with the objective to positively impact participants towards Computer Science. As seen in Figure 4.1, out of 26 studies, 16 focused on game design sessions, 10 focused on game play activities, 3 focused on teaching programming, and 1 focused on using a magazine as their main activity. Three studies had multiple activities designed for the participants. Robinson et al. (2015) included both game play and game design in their study, AlHumoud et al. (2014) included game play, game design and robotics programming as the main activities in their study, and Ouahbi et al. (2015) focused on game design and programming as their activities.

![Activities in the studies](image)

**Figure 4.1:** Activities held in the primary studies
Chapter 4. Results

Through most of the game design sessions, researchers aimed to assess participants’ perception of Computer Science and expose them to various aspects of Computer Science like game design and development through interactive environments like Scratch and GameMaker, basic concepts of Computer Science and programming, and algorithms and robotics engineering, in order to increase their interest in the domain. The game play sessions aimed to indulge the participants in the activity and trigger their interest in Computer Science through the game itself. Game play sessions provided a fun and immersive environment to the participants. In Ouahbi et al. (2015), the researchers introduced the students to traditional programming method in Pascal and concluded that participants who were involved in traditional programming were less prone to study programming in future. Black et al. (2011) designed and produced a magazine that showcased female engagement in the domain of computing via female role models in Computer Science.

24 studies out of 26 reported that the activities conducted had an overall positive impact on the participants. These studies also suggest that activities should be planned according to the age of the participants as participants of different age groups cannot be influenced by the same activity. AlSulaiman and Horn (2015) reported that girls liked the game that was specifically designed for girls. Only 2 studies reported negative or neutral impact on the participants. Miller and Webb (2015) reports that the participants were interested in Computer Science before the activity, and hence the game design session failed to make an impact on the participants. In Robertson (2013), while the participants had positive regard for the game design session, all the girls chose to write a fantasy story rather than create a game.

4.2 Context

In this section, we will discuss the context of the studies in terms of implementation strategy. The implementation strategy deals with the area in which the research study is carried out. The main purpose of the categorization of the context is to provide detailed information about the existing trends of the implementation areas for relevant studies. Based on the studies, we have categorized the implementation area into 5 categories, namely: Workshop, Class, After School, Camp, and Computer Lab. Figure 4.2 visualizes the categorization of primary studies conducted in various implementation areas.

![Figure 4.2: The context of the primary studies](image-url)
4.3 Type of Methodology

11 studies out of 26 are conducted in classroom, 6 after school session, 5 workshops, 4 camps, and 2 computer laboratory. Among the studies conducted in classrooms, Sweedyk (2011) has conducted the study as part of the curriculum for game design course where students are required to develop a game. Webb et al. (2012) conducted the study for 2 years with its integration in middle school class to increase students’ motivation for Computer Science education in public schools. Miller and Webb (2015) run their study in 3 semester-long classes conducted by the same teacher. The participating teachers had taken a training course to learn how to teach programming via game design. Carbonaro et al. (2010) conducted their study in a non-science course class (English course class) and this did not affect the enjoyment experience of the participants in any way. AlSulaiman and Horn (2015) and Carmichael (2008) used a computer laboratory to perform their study because of the easy accessibility to computers per participants. The trend of most studies being conducted in classrooms might be the result of easy accessibility to sample groups and implementation area.

4.3 Type of Methodology

In this section, we will discuss various data collection strategies used in the primary studies. A research should implemented at least one data collection strategies to move forward to data analysis to answer the research questions. However, to gather data from various activities present in the research study, a single strategy of data collection is not sufficient. This is because an study can provide various types of data such as objective or subjective answers to questions, ratings, audio or video recordings, and many others. A single strategy that is able to collect data from questionnaires fails to collect data from observations and audio recordings. As seen in Figure 4.3, we have recorded 7 different strategies for data collection in the primary studies, namely, Surveys, Observations, Project/Game Analysis, Interviews, Audio/video Recording, Feedback, and Assessment Tests. The primary studies accessed their participants by using these strategies as deemed sufficient, effective, and efficient in the study.

![Figure 4.3: Different data collection methodologies used in the primary studies](image)

23 studies out of 26 used surveys as their data collection strategy. In general, surveys are the most effective and efficient strategy for data collection. 16 studies used both Pre- and Post-surveys for gathering data. Pre- and Post- surveys are used to access participants’
Chapter 4. Results

attitudes, proficiency, competitiveness, and perception before and after the study respectively. Generally, the Pre- and Post- surveys have the same questions to check whether the activity was able to change participants’ perceptions. However, there is a significant difference in the Pre- and Post- surveys which is the inclusion of certain criteria in Post-survey developed after the activity such as game play preferences and enjoyment ratings in AlSulaiman and Horn (2015). Additionally, 3 studies use Post-survey only and 2 studies use Pre-survey only as data collection strategy. In Robinson et al. (2015), the researchers created specific surveys to access participants’ confidence and self-efficacy via Computer Confidence survey and Computational Thinking survey. These surveys were conducted both, at the beginning of the workshop, and at the end of the workshop.

5 studies have used a combination of 3 strategies to gather information from the activity and their participants. 4 use Observations, 3 use Project/Game analysis, 5 use Interviews, 2 use Audio/Video recording, 4 use Feedback, and 2 use Assessment Tests are their data collection strategy. Ioannidou et al. (2009) used assessment observation checklist to document students’ opportunities to engage in activities, and problem solving and design abilities. Jenson and Droumeva (2016) used assessment tests to evaluate participants’ knowledge of Computer Science concepts before and after the activity. 3 studies used instructor/teacher feedback to collect necessary information about the studies’ activities, while one study, Webb et al. (2012), used participants’ written responses (feedback). 3 studies used game/project analysis to document the use of participants’ competencies and the teachings of the activities in the game. Among the 5 studies that performed Interviews, group interviews were used in 3 studies while individual interviews were used in 2 studies. In all the studies that followed an observation strategy, the participants were observed while performing the activities and notes were taken by the observer (the instructors, the researchers or the teachers). Audio/Video recording strategy was used to record group discussions (in Akku akr et al. (2017)) and group interviews (in Esper et al. (2013)).

4.4 Data Analysis

In this section, we will discuss the approaches for data analysis for the primary studies. The data collected through the strategies discussed in Section 4.3 is analyzed by following three main approaches of data analysis: Quantitative, Qualitative, and Mixed. Quantitative Research Analysis is performed to measure the quality (of data). This approach enables the generalization of results from a focus group to the whole community of interest. Additionally, quantitative analysis allows the measurement of the views and opinions of the focus group. Qualitative Research Analysis enables the researchers to gain a detailed understanding of the reflections and motivations. Qualitative Research provides comprehensive analysis to the research and can be used to generate hypotheses for quantitative research in the future. Quantitative and Qualitative approach for data analysis can also be distinguished by the strategies for data collection, as seen in Table 4.1. For studies that included an integration of both Quantitative and Qualitative data analysis approaches, a Mixed approach was accessed.

Data analysis validates the research problem and provides answers to the research questions. As visualized in Figure 4.4, 13 out of 26 primary studies used Quantitative Data Analysis approach. 11 studies used a Mixed approach while only 2 studies used
4.5 Technology

In this section, we will discuss for what purpose was technology incorporated into the activities in the primary studies. In the primary studies, researchers aim to use technologies to provide an interactive environment for conducting the activities. Based on the analysis of the studies, we have categorized the use of technology into 8 categories: Used Games, Made a Game, Learn Programming, Magazine, Robotics Design, Video Animation, Story Writing, and Made Wearables. The categories and the statistical representation of studies can be seen in Figure 4.5. Out of 26 primary studies, a majority of 15 used technology to

<table>
<thead>
<tr>
<th>Data Collection Strategy</th>
<th>Data Analysis Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveys</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Observations</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Project/Game Analysis</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Interviews</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Audio/Video Recording</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Feedback</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Assessment Tests</td>
<td>Quantitative</td>
</tr>
</tbody>
</table>

Table 4.1: A mapping of Data Collection strategies discussed in Section 4.3 to their respective Data Analysis approach

Figure 4.4: Data analysis methods in the primary studies

Qualitative approach. Among the 2 studies which used Qualitative approach, Black et al. (2011) analyzed the teachers’ feedback to assess the impact of the booklet on young girls and Esper et al. (2013) analyzed audio and video recordings of the game play session and group interviews. In research studies, one important factor to assess the impact of the study on the focus group is to derive conclusions based on the data collected in the sessions. Inability to collect key data from the sessions result in the failure to perform efficient data analysis in order to generate outcomes. Black et al. (2011) reports that their inability to get feedback directly from their target audience (young girls) resulted in the lack of suggestions for future work on the booklet.

4.5 Technology
create games. 10 studies used games as a part of their study to indulge students into various activities as discussed in Section 4.1. Various studies used multiple technologies in order to accomplish one or multiple purposes. AlHumoud et al. (2014) used a tool called App Inventor for Android to enable the participants to play and create games. Ouahbi et al. (2015) used Scratch to allow participants to create games and also conducted a traditional programming learning session in Pascal Programming. Webb (2011) used two technologies, Scratch and Lego WeDo which enabled participants to create games based on drag-and-drop approach.

![Figure 4.5: Technologies used in the primary studies](image)

Only 2 studies used technologies to teach students the basic concepts of programming like Loops, Conditional Statements and Arithmetic Operations. One studies each used technologies in their research for a Magazine, Robotics Design, Video Animation, Story Writing, and Creating Wearables. Lau et al. (2009) incorporated technology to teach electronics and programming to middle schools girls with the help of Wearable Computing. Robertson (2013) incorporated the idea of story writing alongside game design via Adventure Author. The participants were given the freedom to choose between creating a game and writing a fantasy story. AlHumoud et al. (2014) introduced the participants to a robot and its sensors, and asked the students to create a robot using at least 3 sensors. Black et al. (2011) presents a magazine including research in Computer Science done by women. The objective is to expose girls to this and increase the visibility of female role models in computing. Adams (2010) introduced the participants to Scratch and demanded it’s use either to build a game or an animated music video.

A number of tools were used to build a game in the primary studies. An overview of the tools can be seen in Figure 4.6. Among the 15 studies whose activity was to design a game, 12 have stated the tools used for the game design session while 3 studies failed to state the technology tools. Among the 12 studies, only Webb (2011) used two different tools for the same session, Scratch integration with Lego WeDo. In total 9 technology tools were used to design games: GameMaker, Scratch, Unity, AgentSheets, StageCast Creator, Lego WeDo, Adventure Author, App Inventor for Android, and ScriptEase. Robertson (2013) reports that Adventure Author is most efficient for working with participants who are 10 years and older. She also suggests that Scratch may be more suitable for working with participants under 10 years of age. 3 studies used Scratch as their primary technology
4.6 Outcome

Figure 4.6: Tools used in game making in the primary studies

tool, 2 used GameMaker tool, 2 used AgentSheets, and all the other tools were used in only one study. Among the tools used, Scratch, GameMaker, AgentSheets, App Inventor for Android, and ScriptEase uses a drag-and-drop approach to develop games. Unity uses writing C# scripts, StageCase Creator uses a programming-by-demonstration approach, Lego WeDo uses the integration of Lego and computers to develop hardware and software for robots, and Adventure Author uses Neverwinter Nights 2 Aurora Toolset to enable users to create 3D role-play games.

4.6 Outcome

In this section, we will discuss the results of the primary studies. Most of the primary studies in this Systematic Review have one common objective and that is to expose young girls to Computer Science and increase their interest into Computer Science education and careers. This section aims to describe the success or failure of the primary studies in terms of their objectives. Table 4.2 shows the summarization of impact of the primary studies along with their principal design factor. Impact Coding, as presented in Table 4.2, represents the result of the activities (as shown in Section 4.1) performed in the primary studies. The design factors extracted from the primary studies are the resources to design an activity that can yield increment in girls’ interest towards Computer Science. Table 4.2 contains three categories of results: impact of the primary studies, design factors to be considered, and not reported, when the primary study fails to document either the impact or the design factor.

The impact of the studies are not presented in objective format (Yes–No) because the objectives of the primary studies vary and so does their results. Among the 26 studies, the analysis of impact shows that participants in 17 studies were interested in either Computer Science education or career. In 2 studies, Miller and Webb (2015) and Robertson (2013), participants’ interest decreased. This was seen via pre- and post-assessment surveys. Al-Sulaiman and Horn (2015) reports no change in girls’ perception. The reason behind it is stated as girls’ perception that “Programming would be enjoyable” even before the activity session. Finally, 6 studies failed to report the impact of the study on young girls’
perception of Computer Science.

**Table 4.2:** Determining the impact of the studies on the participants and their principal design factor

<table>
<thead>
<tr>
<th>Primary Studies</th>
<th>Impact Coding</th>
<th>Design Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stewart-Gardiner et al. (2013)</td>
<td>60% girls said they could study Computer Science in college.</td>
<td>Girls wanted to personalize the game in their own way, and collaborate with friends.</td>
</tr>
<tr>
<td>Black et al. (2011)</td>
<td>Teachers stated that the magazine could inspire girls to take ICT.</td>
<td>Both males and females could derive benefit from cross-gender roles.</td>
</tr>
<tr>
<td>Eordanidis et al. (2017)</td>
<td>Not Reported.</td>
<td>Flow is achieved through participants engagement in the game.</td>
</tr>
<tr>
<td>Bonner and Dorneich (2016)</td>
<td>Girls were more likely to choose Computer Science career.</td>
<td>Participants showed the behavior of sustained engagement, and collaboration with friends.</td>
</tr>
<tr>
<td>Carmichael (2008)</td>
<td>Increased interest in Computer Science courses.</td>
<td>Participants wanted to learn more difficult concepts.</td>
</tr>
<tr>
<td>Akku akr et al. (2017)</td>
<td>Positive change in girls’ attitudes towards computing careers.</td>
<td>Participants appreciated personalization which helped them to express their preferences.</td>
</tr>
<tr>
<td>Sweedyk (2011)</td>
<td>Not reported.</td>
<td>Not reported.</td>
</tr>
<tr>
<td>Adams (2010)</td>
<td>Positive view of computing careers after participants’ experience with learning programming.</td>
<td>Participants were able to create their own character. Research guideline: Create games.</td>
</tr>
<tr>
<td>Webb et al. (2012)</td>
<td>Increased interest in taking computer courses.</td>
<td>Not reported.</td>
</tr>
<tr>
<td>Study</td>
<td>Outcome</td>
<td>Research guideline</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>AlSulaiman and Horn (2015)</td>
<td>No significant change to girls’ perception.</td>
<td>Participants reported preference for girls’ games and collaboration. Game context made more impact that individual differences between players.</td>
</tr>
<tr>
<td>Lau et al. (2009)</td>
<td>All participants reported increase in interest to learn science or computational subjects.</td>
<td>Participants liked experiments as opposed to theory.</td>
</tr>
<tr>
<td>Esper et al. (2013)</td>
<td>Not reported.</td>
<td>Need for alignment of educational components of the game with smooth gameplay (engagement and immersiveness).</td>
</tr>
<tr>
<td>Denner et al. (2012)</td>
<td>Not reported.</td>
<td>Additional training for designing game with high usability.</td>
</tr>
<tr>
<td>Jenson and Droumeva (2016)</td>
<td>Increased interest in computers, pursuing Computer Science further, and a career in programming.</td>
<td>Ability to collaborate and experience-based learning motivated girls towards programming in school.</td>
</tr>
<tr>
<td>Mota and Adamatti (2015)</td>
<td>Not reported.</td>
<td>Ability to be programmed according to users’ needs.</td>
</tr>
<tr>
<td>Robinson et al. (2015)</td>
<td>Interested to learn and indulge in Computer Science career.</td>
<td>Participants liked to work in groups. Research guideline: gender-unbias and empowerment.</td>
</tr>
<tr>
<td>AlHumoud et al. (2014)</td>
<td>Increased interest in studying Computer Science.</td>
<td>Hands-on training activities accompanied by minimal lecture attract participants’ interest.</td>
</tr>
<tr>
<td>Carbonaro et al. (2010)</td>
<td>Not reported.</td>
<td>Research guideline: Given the right pedagogical context, girls can master computational concepts in a gender neutral way.</td>
</tr>
</tbody>
</table>
6 out of 26 studies did not show the presence of any design factors in them. One such study, Sweedyk (2011), describes the integration of game design in a curriculum and talks about the genre and objective of the player when playing the game rather than the principle design factors considered and augmented in game design process. 20 studies provide the design factors ranging from flow theory to complexity of the game to personalization in the game. 4 studies provide research guidelines that can be used in the future when designing games. 2 studies (Robinson et al. (2015), Adams (2010)) produce both, research guidelines and design factors. The design factors noted in Table 4.2 will be analyzed, and a selected list of the factors will be used in developing the serious game in the next term of this thesis.

### 4.7 Age Distribution of the Focus Groups

In this section, we will discuss the distribution of focus groups based on their age groups. The primary studies analyzed in this systematic review has participants ranging from 4 years old to 16 years old. In Figure 4.7, we can see various age groups and number of studies associated with them. In total, 18 age groups were derived from the primary studies. Among them, only Sweedyk (2011) failed to report the age group of participants. A maximum of 4 studies among 26 worked with focus groups aged 11 to 13. One challenge with the validity of research studies is that not every studies had the same age group for the participants. The result thus indicated variations regarding when should young children be exposed to Computer Science to increase their interest in the domain.

We found out that four studies (Black et al. (2011), Mota and Adamatti (2015), AlHumoud et al. (2014), and Carbonaro et al. (2010)) included participants from high school aged 14 to 18, and only French and Crouse (2018) had participants from Kindergarten aged 4 to 6. Additional analysis of the focus groups used in the primary studies reported that 10 studies had the involvement of participants aged 10 to 12, 8 addressed participants aged 12 to 14, and 7 addressed participants aged 14 to 16. French and Crouse (2018) faced mathematical challenges and limitation of language skills because the participants were very young. In the study, some participants could not count backwards in the Recursion drill, and majority of participants found it difficult to draw the traversal path for the Ozobot. Among the 20 studies that conducted their research with participants from age 10 to 16, only two studies yielded negative results. Miller and Webb (2015) reported in their studies that the female participants, aged 11 to 13, were already interested in Computer
Robertson (2013) revealed that while the participants had best regards for the project, none of the female participants, aged 11 to 14, were interested in creating a game.

## 4.8 Sample Size

In this section, we will discuss the sample size used by the researchers in the primary studies. Sample size is the number of participants in the research study. The data collected from the sample size is analyzed to present results for a research study. Based on the 26 primary studies in our systematic review, our classification of the sample size obtained from the primary studies can be seen in Figure 4.8. We can see that 5 studies had a sample size between 5 to 15 participants, 4 studies each had a sample size of 15 to 25 participants, 35 to 45 participants, and 45 to 55 participants. 3 studies had the sample size of 65 to 75 participants and 2 studies had 55 to 65 participants. Sweedyk (2011) conducted the study on 208 participants, Webb et al. (2012) had 425 participants, and Robertson (2013) had 992 participants. Black et al. (2011) failed to get any participants for focus groups study and hence did not report the involvement the sample size in their study. In her study on sample size in a research, Sandelowski (1995) emphasized that both too few and too many participants in the sample size can cause the quality of the research to degrade. This situation has been observed in multiple primary studies. Eordanidis et al. (2017), Bonner and Dorneich (2016), Carmichael (2008), Akku akr et al. (2017), Webb (2011), Mota and Adamatti (2015), AlHumoud et al. (2014), and Ouahbi et al. (2015) reported that because of small sample size their results lack the statistics to make strong generalizations with regard to larger demographics.

In the pie-chart in Figure 4.8, we have distinguished the studies in which girls contribute to more percentage of the sample size than boys. Among the 25 studies, in 16 studies the majority of sample size is girls. While boys contribute to majority of sample size in only 7 studies. From the 7 studies, Carbonaro et al. (2010), Webb et al. (2012), Spangenberger et al. (2018) and Bonner and Dorneich (2016) do not show significant difference between the number of boys and girls in their sample size. While there is significantly higher involvement number of boys than girls in Miller and Webb (2015), Adams (2010),
and Lau et al. (2009). Only 2 of the primary studies have not stated the sample size in terms of gender. As our research study is based on the objective to expose preteen girls to Computer Science careers, the majority of involvement of girls in the primary studies provides a positive direction.
In this section, we will discuss and analyze the research questions. The basis for the analysis is the data visualized and discussed in Section 4.

5.1 RQ1: What impact can serious games have on pre-teen girls perception of Computer Science as a career option?

In order to address this research question, we will access the attributes in which the primary studies are categorized as defined in Section 3.5 and discussed in detail in Section 4. This will present the research and their findings in this domain after 2008. To evaluate the impact of the studies on pre-teen girls, we need to merge our understanding of serious games, the focus group, and Computer Science careers. In this section, we will discuss the suggestions for future work from the primary studies thus providing a detailed understanding of research conducted after 2008. Additionally, we plan to provide suggestions for future studies in this domain to effectively access the research problem.

Looking at the publication distribution of the primary studies by year in Figure 3.3 in Section 3.3, we can agree on the fact that not much work has been done in terms of research in order to identify the use of serious games to attract girls towards Computer Science. In general, to access the impact of serious games on girls’ interest in Computer Science, serious games play a critical role and they are to be involved in the study one way or the other. Hence, majority of the primary studies focus on:

• participating in game play sessions to create a bridge between the game and Computer Science (Stewart-Gardiner et al. (2013), Eordanidis et al. (2017), Groover (2009), Spangenberger et al. (2018), Bonner and Dorneich (2016), French and Crouse (2018), AlSulaiman and Horn (2015), Esper et al. (2013), AlHumoud et al. (2014)).

The activities conducted by the researchers as discussed in Section 4.1 act as a platform for influencing the participants. Through the activities, researchers planned and executed the tasks designed specially for the participants. The summary from the selected studies have shown that students (particularly girls) became more interested in Computer Science. Students began thinking of Computer Science as a potential career option for them (Bonner and Dorneich (2016), Akku akr et al. (2017), Jenson and Droumeva (2016), Adams (2010), Webb (2011), Robinson et al. (2015)). Some studies particularly do not reveal students’ further interest in Computer Science careers, but do state the increase in their interest in Computer Science and Programming (Stewart-Gardiner et al. (2013), Groover (2009), Spangenberger et al. (2018), Carmichael (2008), French and Crouse (2018), Webb et al. (2012), Lau et al. (2009), Jenson and Droumeva (2016), AlHumoud et al. (2014), Ouahibi et al. (2015)). However, these activities are equally likely to result a decrease in interest in Computer Science (Miller and Webb (2015), AlSulaiman and Horn (2015), Robertson (2013)). Moreover, lack of simple and straightforward activities (Akku akr et al. (2017)) might be a challenge for the researchers to access their focus groups, for example, if they are very young (French and Crouse (2018)). In a rather amusing case, the activities neither decreased nor increased the participants’ interest in Computer Science. The participants in AlSulaiman and Horn (2015) had the mindset “Programming is enjoyable” even before the activity session, and this pre-assumption prevailed even after they were exposed to programming activity with no change. Therefore, the impact of an activity heavily relies on its purpose, design and implementation.

From the analysis of the primary studies, it can be noted that the implementation area is a criteria that makes an impact on participants’ learning and interest. Even though 11 studies among the primary studies were conducted in a classroom, only four studies were conducted as part of the participants’ study curriculum (Sweedyk (2011), Webb et al. (2012), Miller and Webb (2015), Robertson (2013)). As students’ view of learning has changed in the recent years with the increased use of technology in the classroom, primitive and redundant ways of interaction such as long lectures and writing assignments might not provide a better learning environment in the classroom. Even though teachers were trained to use the tool to create games, students were then taught in old-fashioned way in classrooms and were given a game design assignment (Robertson (2013)). Some teachers reported that girls lost their interest after a few weeks into the course, and took the task to write a fantasy story rather than designing a game.

When it comes to the sample size, Sandelowski (1995) reported that both small and very large sample sizes can cause the quality of the result to degrade. Martinez-Mesa et al. (2014) further reports that a small sample size might not be able to demonstrate the precise desired results, and a very large sample size might increase the complexity of the research study. From the primary studies, we found out that 9 studies have small sample size between 5 and 25, which questions the generalizations of results made in relation to the target population. 5 studies (Bonner and Dorneich (2016), Carmichael (2008), French and Crouse (2018), Mota and Adamatti (2015), AlHumoud et al. (2014)) had sample size
5.1 RQ1: What impact can serious games have on preteen girls perception of Computer Science as a career option?

between 5 to 15. Akku akr et al. (2017) states that the sample size was very small to make strong generalization of the result, regardless of its positivity on the participants. 3 studies (Sweedyk (2011), Webb et al. (2012), Robertson (2013)) had rather large participation of 208, 425 and 992 participants respectively. In Robertson (2013), teachers failed to get post-survey responses from all the participants. This resulted a level of inconsistency in the pre-survey and post-survey result. With a rather controllable sample size, this obstruction might not be faced. Sandelowski (1995) suggests that both, having a small and a very large sample size, is “ethically unacceptable” in a research study and researchers should try and avoid it.

The complexity of the activities are acutely related to the age of the target groups. Researchers aim to design activities for a particular target group, with their level of complexity, after the target group is decided for the research. An example is French and Crouse (2018), where the researchers designed 4 basic computing concepts for children aged 4 to 6. The results reported that the researchers had mathematical challenges and limitation of language as the participants were very young. Careful consideration of the age is to be taken when designing tasks for a certain group of participants. AlHumoud et al. (2014) developed 3 committees among which the Scientific committee, which consisted of a team of PhDs, was responsible for designing the content for the camp, and deciding the activities. The committee designed two activities, Robotics programming and Mobile Application design, both of which were effective to increase participants’ interest in Computer Science studies. Researchers should keep in mind when designing the activities (Pavelin et al. (2014)) that very easy activities can be boring while lacking challenges. Carmichael (2008) stated that topics such as Computer Graphics and Artificial Intelligence (AI) were highly rated by the participants, which showed their interest in learning more difficult concepts. Likewise, very difficult activities could lead to demoralization and reduce interest in Computer Science. The results in Denner et al. (2012) revealed that participants struggled with learning some concepts and required help from the instructor. This might be one reason why the girls were reluctant to revisit and revise their games once they were done with it. Pavelin et al. (2014) states that explaining the aim of the activities and the methodology to problem solving increases the probability for positive engagement. Additionally, Rhizome (2012) discusses the ways to introduce an activity to a group.

Due to the abundance of participants’ data from surveys as seen in Figure 4.3 in Section 4.3, quantitative analysis outweigh both, mixed methods and qualitative analysis. 13 studies collect data through quantitative studies, 11 do so from mixed methods, and only 2 studies collect data via qualitative studies. The most practiced data collection methodologies were Surveys, followed by Interviews, Observations, Feedback and so on. As stated by Denscombe (2014), surveys are designed to provide an overview of the problem at a specific time. Surveys do not allow participants to control any variables, and also do not provide special treatment to any participants (Kelley et al. (2003)). From the studies, we can note that sample size also interferes with the use of a data collection methodology. For instance, it is suitable to use Observations to gather data for a small sample size as in French and Crouse (2018), while Observations might not be feasible in studies with large sample size as in Robertson (2013). Additionally, group interviews would be a good choice to gather data from a large number of sample size where a number of participants from the sample are selected randomly for the group interviews as in Robinson et al. (2015) and E-
Chapter 5. Discussion

While studies with small sample size could conduct individual interviews to get detailed insights from the participants as in AlSulaiman and Horn (2015) and Webb (2011). Using only one method as the source of data, for example, say Surveys, focuses only on numeric data and fails to present a holistic overview of the research study and its result. Bryman (2006) argues that in addition to quantitative and qualitative research methods, mixed method, mixture of both qualitative and quantitative, has become an important research paradigm. Recent practice includes the use of more than one quantitative method and the mix of different qualitative methods. Akku akr et al. (2017), Esper et al. (2013) and AlSulaiman and Horn (2015) have used a mixture of multiple qualitative methods such as observations, audio/video recordings, and interviews, in their studies. Likewise, Jenson and Droumeva (2016) have used a mixture of pre- and post-questionnaires and tests as the source for data collection.

Throughout the reviewed papers, we can observe the use of various technologies to introduce the activities to the participants and get them involved. As can be seen in Figures 4.5 and 4.6 in Section 4.5, for 15 studies the task was to create a game and among them 12 of them mention the use of an environment. The results obtained from these studies reveal the effect of using technology as a learning tool, as compared to traditional classroom teaching methodologies. Carmichael (2008) designed the lectures slides to be appealing with less texts and more images, and still stated that this change alone cannot keep the students interested for 2 to 3 hours. Dewan (2015) presents how people use lot of texts in a presentation and fail to engage learners. Dewan (2015) suggests turning words into graphics by representing them into maps or charts. The question of the capability of traditional teaching methodology to engage students has existed for really long. And Milman (2012) reports the idea of “The Flipped Classroom” where the teachers provide video lectures which contains the concepts that were to be taught to the class, and instead, use the classroom time for other collaborative and engaging activities. If we further dive into the interactive learning environments, we get online environments such as Scratch ¹, Alice ², GameMaker ³, Lego WeDo, and so on. These environments provide interactive tools that can be easily understood and accessed by children in order to show their creativity. Additionally, these environments provide the ability to design whatever they want via the tools. Adams (2010), Webb (2011) and Ouahbi et al. (2015) used Scratch as a tool for creating a game or an animated music video, and the results were positive. Not only the participants liked Scratch, 60% students in Ouahbi et al. (2015) considered continuing programming studies in the future, participants in Webb (2011) reported that they could consider Computer Science as a career option for them, and participants in Adams (2010) reported an increase in positivity on Computer Science careers. In a study with 107 students who used Scratch for a duration of 2 years, Saez-Lopez et al. (2016) noted the environment’s ability to motivate and commit the students to work on their projects while having fun. Also, data analysis made using t-tests showed that students were able to learn programming concepts, logic and computational practices. Adams (2010) also showed that from 2003 to 2008, the campers used Alice 2.0 to create animation videos and learn object-oriented programming, and revealed this to be successful because of Alice’s integrated development environment.

¹https://scratch.mit.edu/
²https://www.alice.org/
³https://www.yoyogames.com/gamemaker
5.2 RQ2: What are the major factors to be considered when developing a serious game?

The answer to this research question will be based upon the design factors presented in the primary studies. We define design factor as the attributes that contribute to game design as well as game play. Game Design factors are incorporated into the games (Wolf and Perron (2016)) by the developers, and game play factors are related to the feelings and experience felt by the players when playing the game. Salen and Zimmerman (2004) presents three main items on which game designers should focus on: context, participants, and meaning. In the perspective of game design, context could be the story, spaces, behaviors and objects that players can face, participants are the players, and meaning makes the player feel the presence of the game (Nacke (2014)). Nacke (2014) states several game design elements such as, rules, objectives, players, procedures, resources, conflict (obstacles, opponents, dilemmas), boundaries, and outcome, which put together can be used to develop games. We shall merge these elements with the design factors generated from the findings of the primary studies.

Among the 26 primary studies, 20 studies provided at least one design factor to be considered when designing a game, 2 studies (Carbonaro et al. (2010) and French and Crouse (2018)) suggested research guidelines for future work, and 6 studies reported neither any design factors nor any research guidelines. 2 studies (Adams (2010) and Robinson et al. (2015)) provided both, design factor and research guidelines. A brief overview of design factors from the studies can be seen in Table 4.2 in Section 4.6. From the primary studies, we concluded seven principal design factors: Personalization, Engagement, Challenge/Complexity, Strong Female Presence, Collaboration, Flow, and Educational Components. These are the factors that participants from the primary studies wanted in games during their game play or game design session. An integration of these 7 factors into a game development project is unlikely to yield better product as other key components of game design are missing. However, with the presence of the key game design components in collaboration with these 7 design factors could produce a serious game suitable for generating interest in Computer Science for the participants. Further, we will discuss these 7 design factors alongside their relation with game play and/or game design.

As presented in the results, personalization is the most anticipated design factor in the games. The participants enjoyed the ability to change the characters in the game to make it look like themselves (Alserri et al. (2017)). Alserri et al. (2017) also discussed that this personalization made the girls look upon themselves as role models. In Akku akr et al. (2017), the girls appreciated the functionality to customize the components in the environment, and this helped the girls to express themselves and their preferences. Ioannidou et al. (2009) states that the participants were able to add themselves as a character in the game and were fully engaged in the activity. This shows young children’s curiosity in the games and their eagerness to indulge themselves into it. Nov and Arazy (2013) states that to identify the user’s personality, personalization is required, and even though personalized content in user interface has now become common practice, only few work has been done.
to provide users with personalized interface. According to the primary studies, personalization is more inclined towards game play as the ability or inability to personalize the characters/avatars have immense impact on player’s desire to continue. Stewart-Gardiner et al. (2013), Akku akr et al. (2017), Adams (2010), Mota and Adamatti (2015), and Ioannidou et al. (2009) stressed the functionality of personalization of characters/avatar according to the needs and preferences of the player.

Another important design factors, that are also considered to be the principal factors in a game, are active engagement (Bouvier et al. (2014)) and flow (Hull et al. (2013)). In a state of flow, the player is engaged in the game, the player’s skills match the level of complexity present in the game, and the player’s immersiveness in the game environment distorts the sense of time (Csikszentmihalyi (1992)). Only Eordanidis et al. (2017) reported the presence of flow in the game used in the study. However, games used in other studies also had flow; for example, Spangenberger et al. (2018) reported the limitation of time during the session which did not allow participants to continue playing the games. However, regardless of the limitation of time, participants wanted to play the game to its conclusion. Additionally, Bonner and Dorneich (2016) states that the participants wanted to play longer and along with their friends. In Esper et al. (2013), even though the girls failed to create some new features due to the limitation of the API, the girls were empowered and they kept working. This shows their interest, along with engagement and flow elements. When designing a game, designers should be able to create an interactive game which matches player’s skills as it keeps the player immersed and engaged in the game.

Along with the design factors discussed above, availability to collaborate in a game is an emerging trend and factor that keeps players interested in the game. This is demonstrated by a study conducted by Sung and Hwang (2013) where the participants were divided into 3 groups: an experimental group that learned using collaborative serious game, a control group (say A) that learned using traditional game-based learning methodology, and another control group (say B) that learned using a serious game individually. The results suggested that learning achievements and motivation of the experimental group were significantly higher than that of the control groups. In the primary studies, we found out that the participants were more positively inclined towards the game if the game provided them the functionality to collaborate and play with their friends (Groover (2009), AlSulaiman and Horn (2015), Jenson and Droumeva (2016), Robinson et al. (2015)). Participants in some studies also stressed the addition of collaboration functionality as a recommendation for the future (Stewart-Gardiner et al. (2013), Bonner and Dorneich (2016)). Some examples of collaboration described by the participants in the primary studies are the functionality to play the game with multiple players, availability to play online with other members of the community, and share the games they created with family and friends. Bean (1996) states mutual relationship between participants and problem-solving within themselves, as significant benefit of collaboration. In order to achieve these benefits, with less involvement of instructors and researchers during the game play or game design sessions with participants, it is important to include collaboration as a principal design factor during the game design, and later, during game play.

Lastly, two other design factors, namely, strong female presence and educational components, stood out in the primary studies as we feel that both of them should not be excluded in a game. Spangenberger et al. (2018) and AlSulaiman and Horn (2015) present
the presence of female character as a design factor for games used in these studies. Al-Sulaiman and Horn (2015) developed a game “Rosie the Fashionista” with an intentional gender orientation showcasing that the game was specifically built for girls. After the game play, many students stated the gender orientation in the game. In AlSulaiman and Horn (2015), both, girls and boys, preferred the game with gender orientation, and said the sex of the main character played a role in determining the gender orientation of the game. In Spangenberger et al. (2018), the protagonist of the game was female and this seemed to stand out to the female participants, and as a result, after the game play, female participants’ interest in technical subjects increased. Schimpf et al. (2015) and Bailie (2015) discusses the underrepresentation of women in Computer Science studies and careers, and presents the idea of involving female role models to increase girls’ interest in this domain. We believe in order to increase female students’ interest in Computer Science through the use of serious games, adding female characters and female role models in the games could be an effective approach. Today, numerous games have female protagonist among which The Scythian from the game “Sword and Sorcery” shows that women can fill the role of a mythical hero just as effectively as their counterpart (Beres (2017)). For the use of games as educational tools, the games should contain various educational components that enable the players to learn while playing (Amory et al. (1999)). Without the educational components, the game cannot be categorized as a serious game. However, as Esper et al. (2013) stated that the educational components of the game disrupts smooth game play, ways of integrating educational components alongside retaining smooth game play should be prioritized.

5.3 Future Work

Based on the reviewed papers, we conclude that the research on this domain is better now than in the past, but still much work is to be done to identify key components in serious games that can increase preteen girls’ interest in Computer Science. Additionally, the game play or game design sessions, activities included in the sessions, and the implementation areas of the sessions are also to be studied in order to present an effective experience to the focus group. It is very important for research such as this to be designed and implemented with the correct focus groups to access their interests. Future work should focus on designing games specifically for a certain focus group. For example, a survey showed that girls did not play games with violent behaviors (Yee (2017)) but rather liked puzzle, exploration, science fiction games. The results of the primary studies suggest that future work should focus on early exposure of focus groups towards Computer Science to get them interested into Computer Science careers. Researchers also emphasize the use of game creation sessions to show gender-unbias in the comprehension level of girls and boys and empower them. Serious games in the future should try to add interesting educational components alongside game play to provide an engaged and immersed feeling of gaming and learning. Also, research studies stress that game play and fun should be showcased as the main component as this allows players to learn while playing without realizing it. Some studies have worked to determine long term effects of their intervention on girls, but their results are not yet available or in some cases, the research studies have been halted. Few studies that track the effects of using games to increase interest and motivation in the
Chapter 5. Discussion

long run could be a path to numerous research in this area. With the presence of highly intellectual researchers in this field, we expect more breakthrough research in the future.

As the next step of this research, we seek to evaluate the research questions through a more direct approach with a plan to conduct a game play sessions and evaluate the focus group’s interest towards Computer Science. Studies suggested that mothers are one of the most powerful factors in empowering their daughters. But not much work is done to address women in order to inspire younger women. Only a few primary studies were able to present this scenario to the female participants, mostly via female lead character in the games. With this in mind, we plan to prototype a game where the characters, inspirational women in Computer Science (Bailie (2015)), tell their tale of success in Computer Science. Through this idea we aim to develop a feeling of pride and accomplishment in the minds of preteen girls. Through game play sessions, observations, and surveys, we will try to discover the impact of the game upon preteen girls’ perception on Computer Science and its careers.
Chapter 6

Planning of the Research

This research aims to provide a Systematic Review of pre-existing studies related to the use of serious games to promote Computer Science among pre-teen girls. The research also addresses the issue of under-representation of women in Computer Science careers and with the help of previous studies, present strategies to increase the interest of women in Computer Science. Literature from 2008 and onwards was selected for the investigation and analysis. The authors will select an strategy and conduct a study during Spring 2019 to determine the results of using serious games to promote Computer Science careers to pre-teen girls. The results of the study will be presented as a Master thesis at the Department of Computer Science, NTNU.

The plan for this research is provided in detail in the following sections. First, Section 6.1 brief summary of findings from the literature. Then, Section 6.2 presents the area of the study and the research questions. Lastly, in Section 6.3, we will discuss the research plan, along with the process, participants, research paradigm and final deliverables of this study.

6.1 Systematic Review Findings and Observations

The Systematic Review presents several limitations and shortcomings in the literature studies on which the future work will be based. We noticed that not much work was done to expose pre-teen girls to Computer Science using serious games. Studies either were planned to mitigate the issues with a strategy, or were planned to develop a strategy to address the issue. Additionally, several studies used different approaches and it was difficult to compare studies using different approaches. The purpose of the Master thesis will be to show the impact of using serious games on pre-teen girls’ perception of Computer Science as a career.
6.2 Research Questions and Problem Areas

Womens participation in Computer Science (in areas such as education and careers) has had drastic changes over the years. After the dot-com revolution, the way people use computers have changed dramatically. According to Internet World (2018), a recent data presented in June states that there are 4.2 billion internet users in the world. Computer Science became a developing field which soon reached unimaginable height. With this, Computer Science field required more professionals and manpower. As men claimed the opportunities, women were not able to reap the opportunities which led to under-representation of women in this field. Since long ago, Computer Science has been considered a male dominated field due to heavy presence of males in both, education and careers.

Efforts have been made to expose women to Computer Science to get them interested towards the field. Despite the efforts, stereotypes about the culture in Computer Science impact womens judgment towards the field which has resulted in lack of interest and involvement (Bach (2015)). Eckart (2017) claims that exposing girls to Computer Science at an early age can be an aspiring factor to get them interested towards Computer Science education and careers. Over time, several approaches such as storytelling, game play, game design, and programming courses, have been used by researchers in order to address this issue via workshops, after-school programs, and courses.

The results from several studies (Stewart-Gardiner et al. (2013), Eordanidis et al. (2017), Groover (2009)) suggests that these activities have had a positive impact on their focus group and they are likely to pursue a career in Computer Science. Then again, some studies (Miller and Webb (2015), Robertson (2013)) reported no change in their perception towards Computer Science or decline of interest.

The aim of this research is to use a serious game to increase pre-teen girls perception of Computer Science and make a positive impact about Computer Science careers. There are previous studies that have used serious games in Computer Science for various educational activities such as to teach programming, to teach game design, and to teach basic Computer Science concepts. The demand of professionals in Computer Science is more than ever, still most of the research studies has failed to address the need for involvement in Computer Science careers. The project is driven by the following research questions:

- **RQ1**: What impact can serious games have on pre-teen girls’ perception of Computer Science as a career option?

- **RQ2**: What are the major factors to be considered when developing a serious game?

6.3 Research Plan and Approach

The research plan is developed from the guidelines for conducting a research as suggested by Oates (2006). The guidelines can be seen in Figure 6.1. This section presents the research plan for the analysis of the research questions and delivery the results. Additionally, we will also discuss the plan for the spring project in this section.
6.3 Research Plan and Approach

6.3.1 Research Process

For the Master thesis, a design and creation strategy is planned where a prototype of a serious game will be created and evaluated. The research requires a sample of data from the focus group to evaluate the effectiveness of the product. With technologies such as Google Forms and Kahoot, interactive online questionnaires will be formed, and distributed and conducted via the internet. A questionnaire and game play observations are planned to collect data for further analysis of the project results. Questionnaires are considered the best approach for its capability to generalize large number of data. The collected data is analyzed through both, quantitative (via questionnaire) and qualitative (via observations) data analysis approaches.

6.3.2 Participants

The research will be conducted by the author under the supervision of Professor Letizia Jaccheri along with co-supervisors Kshitij Sharma and Javier Gomez Escribano, who are both Postdoctoral Researchers at the Department of Computer Science at NTNU. Letizia is the main supervisor who will monitor the progress of the thesis continuously. Kshitij and Javier will help the author throughout the thesis and provide feedback and advice on the project process and outcomes based on their expertise and involvement in the project.

For the Master thesis, the plan is to collect data from two types of sample groups: (a) from the focus group (pre-teen girls) who play the serious game, and (b) volunteers who are willing to participate in the online survey. For the first part of data collection, the researchers will request the Norwegian Centre for Research Data (NSD) for approval. Additionally, a colleague of the author who is a teacher in an international school in Stjrdal has agreed to participate in the data collection. For the second part of data collection, an online survey along with the gameplay and feedback will be conducted. The objective of the research and the legal and ethical perspectives of the questionnaire will be clearly stated in the questionnaire. The responses from all the respondents will be handled legally.
Chapter 6. Planning of the Research

and ethically. The responses will be anonymous and will not be used outside the context of this research.

6.3.3 Research Paradigm

This research involves researchers coming together to address an issue in Computer Science careers and resolve the issue via a serious game. Additionally, a survey is planned to be used in this research to find relationships and patterns that exist in between serious games, pre-teen girls and Computer Science careers. This approach is related to the positivism paradigm. This study desires to generate an outcome, either positive or negative, by analyzing and discussing the collected data. The research is based on the objective and relies on the results rather than on the author’s personal beliefs on the subject.

6.3.4 Final Deliverables

The Systematic Review and the design and development of a prototype will be presented in two documents: Project thesis and Master thesis. The Systematic Review is planned to be submitted to the 2019 ACM Interaction Design and Children (IDC) conference in collaboration to the supervisor and co-supervisors.
Conclusion

In this study, we conducted a systematic review to analyze the pre-existing literature related to the use of games to increase preteen girls’ interest in Computer Science. A total of 26 papers as primary studies are presented from 2008 to 2018. The review aimed to explore what kind of games and technologies are used to access girls’ interests, and what are the main design criteria required to design serious games. Furthermore, the author explored the data collection methods, the data analysis techniques, the goals and objectives, and the focus group involved in the studies. This study contributes to provide the results from the primary studies and also the evidence on effectiveness of the primary studies. The systematic review can act as a medium for similar research studies in the future.

The review has shown that most of the studies have carried out sessions in varying areas with varying activities. Most activities are either a game design or a game play session where participants engage in the activity to learn something out of it. All studies have tried to teach Computer Science or Programming concepts through various environments like Scratch, Alice, and so on. The primary studies and other relevant studies show that the use of these technology creates positive impact on learning on young minds. A comparison of the target population ages in the primary studies show inclusion of children from 4 years up to teenagers up to 18 years old. In future, this variety of age could be narrowed down to avoid major inconsistencies between studies.

Most of the studies reviewed in this systematic review provided positive change in participants’ attitudes towards Computer Science education and careers. This concludes that most of the games/technologies used in the sessions were well-designed according to the complexity and skills of the focus group. However, due to small sample size of most studies, more evidence is needed in future to generalize this practices to all the target population i.e. middle school girls. Therefore, future research should be conducted with a decent number of participants from different demographics, because the upbringing of an individual also affects their attitudes and motivational factors.

Factors contributing to a greater experience such as flow, collaboration, and challenge should be taken into consideration when designing a serious game. The studies suggest that designing a game and designing a serious game are not exactly the same because of the
integral educational component in serious games. Designing a serious game is perceived
to be a great challenge as designers have to incorporate educational concepts into the game
without any adverse effects on the game play. Additionally, the element of fun should be
a part of the serious game in order to immerse the players into the game environment.

Unavailability of similar review on this research topic was a challenge faced by the
authors. This prevented the authors to make comparisons on the methods used in that
review, results of the review, and discussions on the results and possibility of future work.
Although, now, this review can be used by researchers in the future to make comparisons
and get an overview on this research topic. Also, for a research topic with so much interest
among researchers, we had a hard time finding the relevant studies from the online sources
and also from manual searching techniques.

Finally, as a summary, we would like to highlight the idea of reviewing intervention
sessions to find the tools and methods used by the participants as well as the researchers to
achieve a result, and to develop tools and methods for the purpose of providing effective
ways to engage and access the researchers and participants. This review would guide
researchers towards improved process to evaluate the activity sessions and achieve high
quality data for data analysis. This would also lead researchers towards informed game
design principles.
Bibliography


URL http://doi.acm.org/10.1145/1734263.1734385


URL http://doi.acm.org/10.1145/2793107.2793127


Cheryan, S., Master, A., Meltzoff, A., 02 2015. Cultural stereotypes as gatekeepers: Increasing girls interest in computer science and engineering by diversifying stereotypes. Frontiers in psychology 6, 49.


URL http://dl.acm.org/citation.cfm?id=3015220.3015226

URL http://doi.acm.org/10.1145/2445196.2445290

URL http://doi.acm.org/10.1145/543812.543836

URL http://doi.acm.org/10.1145/268085.268127

URL https://doi.org/10.1007/s00146-006-0048-3

URL http://dl.acm.org/citation.cfm?id=3282588.3282607


URL http://doi.acm.org/10.1145/323830.323843
URL http://dl.acm.org/citation.cfm?id=1529995.1530022

URL http://doi.acm.org/10.1145/2094131.2094147


URL http://dx.doi.org/10.1016/j.jvlc.2009.04.001


URL http://dx.doi.org/10.1093/intqhc/mzg031


URL http://dx.doi.org/10.1155/2014/358152


Milman, N., 01 2012. The flipped classroom strategy: What is it and how can it best be used? Distance Learning 9, 85–87.


URL http://doi.acm.org/10.1145/376134.376145

URL https://doi.org/10.1371/journal.pcbi.1003485

URL http://doi.acm.org/10.1145/2998626.2998670

URL https://doi.org/10.1007/s12564-012-9228-7


URL https://doi.org/10.1080/08993408.2013.774155

URL https://doi.org/10.1080/13691180701409838


URL https://doi.org/10.1002/nur.4770180211


URL https://doi.org/10.1177/073088415618728


Sonawane, K., November 2017. Serious games market by user type (enterprises and consumers), application (advertising & marketing, simulation training, research & planning, human resources, and others), and industry vertical (healthcare, aerospace & defense, government, education, retail, media & entertainment, and others) - global opportunity analysis and industry forecast, 2016-2023. https://www.alliedmarketresearch.com/serious-games-market, accessed: 2018-12-11.

URL http://genderandset.open.ac.uk/index.php/genderandset/article/view/496


Appendix A

Appendix A presents the paper coding of the primary studies. This includes 26 primary studies used in this research and categorization of available data from the studies into 8 different categories as discussed in Section 3.5.

Table 7.1: Paper coding of the primary studies

<table>
<thead>
<tr>
<th>Primary Studies</th>
<th>Activities</th>
<th>Context</th>
<th>Data Collection Methods</th>
<th>Data Analysis</th>
<th>Technology Used</th>
<th>Outcome</th>
<th>Focus</th>
<th>Group Age</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stewart-Gardiner et al. (2013)</td>
<td>Game play</td>
<td>After School</td>
<td>Surveys</td>
<td>Quantitative</td>
<td>Used Games</td>
<td>Could study CS</td>
<td>11 to 14</td>
<td>57 (41 girls, 16 boys)</td>
<td></td>
</tr>
<tr>
<td>Black et al. (2011)</td>
<td>Magazine</td>
<td>Class</td>
<td>Teachers Feedback</td>
<td>Quantitative</td>
<td>Magazine</td>
<td>Could inspire into CS</td>
<td>14 to 18</td>
<td>Not reported</td>
<td></td>
</tr>
<tr>
<td>Eronlandis et al. (2017)</td>
<td>Game play</td>
<td>After School</td>
<td>Surveys</td>
<td>Quantitative</td>
<td>Used Games</td>
<td>Learned CS concepts</td>
<td>12 to 14</td>
<td>16 girls</td>
<td></td>
</tr>
<tr>
<td>Groover (2008)</td>
<td>Game play</td>
<td>Workshop</td>
<td>Questionnaires</td>
<td>Quantitative</td>
<td>Used Games</td>
<td>Increased interest in CS</td>
<td>11 to 15</td>
<td>48 girls</td>
<td></td>
</tr>
<tr>
<td>Spangenberg et al. (2018)</td>
<td>Game play</td>
<td>Workshop</td>
<td>Questionnaires</td>
<td>Quantitative</td>
<td>Used Games</td>
<td>Increased interest in CS</td>
<td>15 to 15</td>
<td>49 (24 girls, 25 boys)</td>
<td></td>
</tr>
<tr>
<td>Birrer and Dorneich (2016)</td>
<td>Game play</td>
<td>After School</td>
<td>Surveys</td>
<td>Quantitative</td>
<td>Used Games</td>
<td>Likely to choose CS career</td>
<td>10 to 14</td>
<td>15 (8 girls, 8 boys)</td>
<td></td>
</tr>
<tr>
<td>Campagnolli (2008)</td>
<td>Game design</td>
<td>Class and Computer Lab</td>
<td>Surveys</td>
<td>Quantitative</td>
<td>Made a game using GameMaker</td>
<td>Increased interest in CS courses</td>
<td>12 to 14</td>
<td>12 girls</td>
<td></td>
</tr>
<tr>
<td>Aksu akr et al. (2017)</td>
<td>Game design</td>
<td>Workshop</td>
<td>Surveys, Interviews, Discussions</td>
<td>Mixed</td>
<td>Made a game using Unity</td>
<td>Positive change towards CS careers</td>
<td>10 to 13</td>
<td>23 girls</td>
<td></td>
</tr>
<tr>
<td>French and Crouse (2018)</td>
<td>Game play</td>
<td>Class</td>
<td>Surveys, Observations</td>
<td>Mixed</td>
<td>Used Games</td>
<td>Increased interest</td>
<td>4 to 6</td>
<td>9 girls</td>
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<tr>
<td>Sweeley (2011)</td>
<td>Game design</td>
<td>Class</td>
<td>Surveys</td>
<td>Quantitative</td>
<td>Made 2D and 3D games</td>
<td>Women engage with serious games</td>
<td>Not reported</td>
<td>208 (116 girls, 92 boys)</td>
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<tr>
<td>Miller and Webb (2015)</td>
<td>Game design</td>
<td>Class</td>
<td>Survey, Game analysis</td>
<td>Mixed</td>
<td>Made a game using AgentSheets</td>
<td>Decreased interest in CS courses</td>
<td>11 to 13</td>
<td>48 (18 girls, 30 boys)</td>
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</tr>
<tr>
<td>Amanullah et al. (2010)</td>
<td>Game design</td>
<td>Camp</td>
<td>Surveys, Game analysis</td>
<td>Mixed</td>
<td>Made a game using Scratch</td>
<td>Positive view of CS careers</td>
<td>11 to 13</td>
<td>45 (158 girls, 30 boys)</td>
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<tr>
<td>Webb et al. (2012)</td>
<td>Game design</td>
<td>Class</td>
<td>Surveys, Observations, Feedback</td>
<td>Mixed</td>
<td>Made a game</td>
<td>Increased interest in CS courses</td>
<td>11 to 13</td>
<td>425 (212 girls, 213 boys)</td>
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<tr>
<td>Alshullaiman and Horn (2015)</td>
<td>Game play</td>
<td>Computer Lab and Camp</td>
<td>Surveys, Interviews</td>
<td>Mixed</td>
<td>Used Games</td>
<td>No change</td>
<td>6 to 11</td>
<td>50 (68 girls, 10 boys)</td>
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</tr>
<tr>
<td>Lau et al. (2009)</td>
<td>Game design</td>
<td>Workshop</td>
<td>Surveys, Feedback</td>
<td>Mixed</td>
<td>Made wearable computing devices</td>
<td>Increase in CS courses</td>
<td>11 to 16</td>
<td>28 (6 girls, 19 boys)</td>
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<tr>
<td>Roper et al. (2013)</td>
<td>Game play</td>
<td>After School</td>
<td>Audio/Video Recordings, Interviews</td>
<td>Qualitative</td>
<td>Used Games</td>
<td>Interested in game play</td>
<td>10 to 12</td>
<td>48 girls</td>
<td></td>
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<tr>
<td>Deiner et al. (2012)</td>
<td>Game design</td>
<td>After School</td>
<td>Game Analyzer</td>
<td>Quantitative</td>
<td>Made a game using StageCast Creator</td>
<td>Girls were reluctant to revise their games</td>
<td>10 to 11</td>
<td>59 girls</td>
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<tr>
<td>Jenson and Doumas (2016)</td>
<td>Game design</td>
<td>Class</td>
<td>Surveys, Tests, Observations</td>
<td>Mixed</td>
<td>Made a game using GameMaker</td>
<td>Increased interest in higher CS studies</td>
<td>10 to 12</td>
<td>67 students</td>
<td></td>
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<tr>
<td>Webb (2011)</td>
<td>Game design</td>
<td>Workshop</td>
<td>Surveys, Interviews, Observations</td>
<td>Mixed</td>
<td>Made a game using Scratch and Lego WeDo</td>
<td>Could consider CS career</td>
<td>10 to 13</td>
<td>16 girls</td>
<td></td>
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<tr>
<td>Robertson (2013)</td>
<td>Game design</td>
<td>Class</td>
<td>Questionnaires, Survey, Reflections</td>
<td>Mixed</td>
<td>Storytelling or Game design using Adventure Author</td>
<td>Decreased interest in computing</td>
<td>11 to 14</td>
<td>992 participants</td>
<td></td>
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<tr>
<td>Mata and Adamatti (2013)</td>
<td>Programming</td>
<td>Class</td>
<td>Questionnaire</td>
<td>Quantitative</td>
<td>Learned Programming</td>
<td>Increased knowledge in CS</td>
<td>15 to 16</td>
<td>7 (6 girls, 1 boy)</td>
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<tr>
<td>Study</td>
<td>Methodology</td>
<td>Activity</td>
<td>Tools Used</td>
<td>Findings</td>
<td>Participants</td>
<td></td>
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<tr>
<td>Robinson et al. (2015)</td>
<td>Game and Game design</td>
<td>Camp, Surveys, Interviews, Mixed</td>
<td>Used Games and Made games, Interested in learning and CS career</td>
<td>11 to 13, 37 girls</td>
<td></td>
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<tr>
<td>AlHumoud et al. (2014)</td>
<td>Game, Game design, and Programming</td>
<td>Camp, Surveys, Quantitative</td>
<td>Used App Inventor for Android tool, Increased interest in studying CS</td>
<td>14 to 17, 15 girls</td>
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<tr>
<td>Carbonaro et al. (2010)</td>
<td>Game design</td>
<td>Class, Survey, Quantitative</td>
<td>Made game using ScriptEase, Students enjoyed the activity</td>
<td>14 to 16, 50 (24 girls, 26 boys)</td>
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<tr>
<td>Ioannidou et al. (2009)</td>
<td>Game design and Programming</td>
<td>After School, Surveys, Quantitative</td>
<td>Made 3D game using AgentSheets, Established IT fluency by broadening CS participation</td>
<td>11 to 12, 40 (21 girls, 19 boys)</td>
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<tr>
<td>Ouahbi et al. (2015)</td>
<td>Game design and Programming</td>
<td>Class, Surveys, Quantitative</td>
<td>Made games using Scratch, and Pascal programming, Interest in continuing programming studies</td>
<td>13 to 15, 69 (38 girls, 31 boys)</td>
<td></td>
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</table>