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Review

Improving girls' perception of computer science as a viable career option through game playing and design: Lessons from a systematic literature review

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ABSTRACT

The objective of exposing girls to Computer Science as a career option has led to research directed towards gaming activities for girls. These activities include both game play and game design. Research about gaming activities for increasing girls' interest in computer science has gained much attention over the past few years and has resulted in a number of contributions. We follow up with an overview of the status of research through a Systematic Literature Review. We investigate the relation between the various game playing or designing activities and their impact on girls' perception of Computer Science as a career choice. We further present the design consideration for the games and related activities to potentially improve the perception of girls towards a Computer Science career. The applied method is a Systematic Literature Review through which we investigate which contributions were made, which knowledge areas were most explored, and which research facets have been used. We identify 25 papers to distill a common understanding of the state-of-the-art. Specifically, we investigate the effects that the game play/design activities had on girls' perception about Computer Science; and what are the key design factors to be kept in mind while designing a serious game to improve girls' perception about Computer Science. The results of this systematic literature review show that game playing or designing could indeed improve how girls perceive having a career in CS. The key aspects that such activities require are personalizing, opportunity for collaboration and the presence of a female lead character.

1. Introduction

Recent years have witnessed an unprecedented increase in the Computer Science (CS) jobs across the globe. With the recent advents in hardware capabilities, Software Engineering and Artificial Intelligence, IT industry has shown a groundbreaking growth in the demand of professionals [1]. In spite of this high demand in the IT industry, interest of girls in CS has shown a concerning decrease over past few years [2]. National Centre for Education Statistics (NCES, [3]) has reported a 20% decrease in the population of women among Computer Science (CS) graduates over last 25 years. It decreased to 17% in 2011 from 37% in 1985 across universities in the USA. Around the world, there has been a 10% decrease in the population of women CS graduates in the same period of time [3].

The trend of low involvement of women in CS occurs before getting involved in the IT industry. In the USA, boys outnumber girls in the ratio of four to one in Computer Science placement exams [4]. Moreover, in 2014, not a single girl participated in the Advanced Placement Computer Science examination in Mississippi, Montana and Wyoming [4]. Despite of these pessimistic scenarios, some other approaches have successfully increased the proportion of girls in the last 20 years through different activities, such as technology camps and networks (CITATION ANONYMISED).

The situation in Europe is well explained in [5] and in the She Figures of the European Commission (2008). At Bachelor level, in Austria, Belgium, Denmark, Finland, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Poland, Spain, Switzerland, and the UK, 80% or more of the students enrolling or graduating in Informatics Bachelor programs are male. In Bulgaria, Greece, Romania and Estonia a slightly narrower gap exists. However, women do not represent more

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than 30% of the Bachelor students. At Master's level female participation increases in some countries, over 35% of the Master graduates in Bulgaria, Romania and Greece, and around 30% in the UK, Estonia, Ireland, and Latvia, but decreases in others, not surpassing 20% of the Master graduates in Austria, Belgium, Czech Republic, Germany, Italy, Lithuania, the Netherlands, Poland, Portugal, Spain and Switzerland [5]. At Ph.D. level, except for Bulgaria, Romania, Estonia, Turkey, all other countries have less than 25% of women graduating from Informatics Ph. D. programs, corresponding in some cases to less than a handful of women, as the total number of Ph.D. graduates in many countries is quite smaller [5].

These decreasing numbers of women professionals in IT industry, alarmed educational researchers in the early 2000s and various strategies were proposed to increase interest of women in CS careers [6]. Most of these strategies aimed to attract girls towards CS from early ages. One of these strategies was to employ computer games, by incorporating girls' favorite activities into computer games [7]. Most of the games were designed for a "male-dominated" audience, while the games to attract girls included elements such as female protagonist and problem solving based story lines [7].

With the evolution of serious games (games built to serve mostly educational purposes as opposed to pure entertainment [8]), the researchers could have a tool with the potential to motivate students not only to learn but also to inform them about the CS careers [9]. Organizing workshops to teach CS concepts to students via technologies such as Scratch has also attracted attention over recent periods [10].

Therefore, the importance of the topic and the variety in approaches and methods suggest a need for an updated overview of the existing research in order to identify their results and impact along with limitations, and to suggest potential future work in this research field.

Recent work has shown that it is possible to increase the motivation and interest of girls in CS studies and careers using several instruments: a few initiatives (see 2.2.1), role-models (see 2.2.2), early-interventions (see 2.2.3), and games (see 2.2.4), However, the "know-how" of related research is scattered and there is no structured set of recommendations and guidelines to move forward on the front of improving girls' perception about CS. In this work, we choose to concentrate on the games that have been developed using the design factors aiming to increase the perception of girls about CS in a positive manner so that they start looking at CS studies as a viable career option.

In this paper, we provide an overview of research to encourage girls towards Computer Science through games. To accomplish this, we decide to conduct a Systematic Literature Review (SLR). In particular, through this SLR, we focus on the following research questions:

1. What is the impact of serious games (playing/designing) on girls' perception of Computer Science as a career option?
2. What are the major factors to be considered when developing a serious game?

The rest of the paper is structured as following. In the second section, we provide the theoretical background about why there is a lack of women's interest in CS studies and careers; we also provide a brief overview of strategies to increase women's interest in CS studies/careers and about serious games. In the third section, we provide the basic definitions and the methodology followed in this SLR. In the fourth section, we present the results of the SLR. Fifth section provides the interpretations of the findings based on the two research questions, and implications for game design, study design and practical implications. Finally, the sixth section concludes the paper.

2. Related work

2.1. Theoretical background: Reasons for the lack of Women in CS

There is a counter-intuitive trend for number of women in CS related careers. In her contribution article, Bailie cites that Women have always faced unique challenges in CS [11]. These challenges include, lack of self-confidence; little to none computer experience at home and school; negative perceptions (seen as boring, anti-social and isolating) of computer science; and the absence of female role models at home, school and the workplace [11]. In the same vein, to find out the reasons why after college, women are twice likely to leave CS as compared to their male counterparts, Martincic and Bhatnagar found that most women leaving the CS careers cite "cultural" issues (also called as "geek mythology" by Ficher and Margolis [12]) as the main reasons to change the career choice [13].

One of the most plausible reasons for such trends (lack of women in CS to begin with and the higher dropout rates than males) might be the stereotype that "women cannot do CS" [14]. This stereotype is heavily reflected in a survey conducted by Black and colleagues, where girls themselves rated their computer self-efficacy to be lower then male students [14]. As is shown in the terms of the secondary and higher education that self-efficacy is one of the most common predictor of student dropout [15–17]. The fact that girls have lower self-efficacy than their male classmates could be detrimental for the morale of the girls to continue, as was reported by Black and colleagues [14].

Another set of stereotypes that affect the confidence and hence the interest in CS found by Fisher and Margolis as a result of a survey in Carnegie Mellon University include: lack of hands-on experience before college and the "geek mythology" (i.e., continuously questioning the female's ability in CS) [12]. Similar results were reported about the gender-stereotypes in a survey by Cundiff and colleagues at the Pennsylvania State University with 1700 students [18]. As it is generally shown that the gender stereotypes can affect the career options in many other related fields such as, engineering, maths, ICT [19–21]. Having such gender-bases stereotypes in CS can also negatively affect the women's choice of courses in the future and career alternatives [12,18].

Palma points another stereotype-based reason for CS to deter women from CS education and hence careers [22]. The author speculates that the aversion in women towards tinkering and building gadgets and tools [22]. Palma further suggests to teach CS to girls not as a science to "build gadgets" but to "solve logical problems" [22]. Other reasons for fewer women in CS include the supposition that Computer Scientists are not social, conflicts with women's desire to have a balanced career and social orientation [23]. In another study to compare the gender-based differences, Su and colleagues [24] reported that men prefer working with tools and have realistic and investigative, while women prefer working with people and women have stronger artistic, social, and conventional interests. Su and colleagues further report that men were also found more interested in engineering, science and mathematics interests [24]. One specific part of the quantitative results from Su and colleagues [24] were confirmed qualitatively by Ramírez and colleagues [25]. Interviewing 26 female CS students from two Colombian University, Ramírez and colleagues found that women value working together with people [25].

A number of factors that motivate young girls into CS have been studied in the past [26,27]. Tillberg and Cohoon conducted a survey with 182 undergraduate students seeking for the most influential factors for girls to choose CS as a viable career option [26]. The results showed four main factors that influences girls to study CS: (1) supporting and motivating parents, (2) encouraging teachers, (3) exposure to CS at school, and (4) playing games on a computer [26].

One of the most important factors in the study by Tillberg and Cohoon was the influence of family [26]. These results were also found by an Ethnographic study by Fisher and colleagues [27]. Influence of family was found to be a crucial factor on girls' interest in Computer Science and its studies [27]. However, while girls reported parents' and teachers' encouragement as their reasons for attachment with CS, these factors were not rated highly as compared to interest, class experiences, and the future of the field [27].

Most of the prior work in the direction of finding the different reasons behind the lack of participation in and motivation towards CS studies and thus CS careers lay down the foundation of the knowledge [12,23,25–27] and provide certain guidelines about solving the problem at hand [11,18,22]. However, all these contributions lack on the practical front, i.e., these guidelines are theoretical. Therefore, further research was required to solve the issues raised by aforementioned researchers. In the next set of studies, we present the efforts to practically solve the problem of lacking motivation and participation of women in CS.

2.2. Strategies to motivate girls towards CS studies and careers

2.2.1. Initiatives from the Tech-Giants

There have been several practical efforts to increase the interest in women towards CS courses and careers. For example, a study conducted by the University of California, Berkeley, to close gender gap in CS subjects revealed that the approach in which courses are marketed might not be suitable to attract girls [28]. 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 [28]. Programs like Girls Who Code [29], SciGirls [30], Girls, Inc. [31], and Girlstart [32] have been working with the aim to reduce gender gap in CS related careers. Furthermore, one of the biggest motivating factor in current times about CS careers for women could be the fact that CS careers are increasingly perceived to be lucrative [33] and the gender pay gap is very low as compared to other professions [4].

Positive initiatives from highly-regarded organizations can create ripple effects in the tech industry thus inspiring women to explore CS as a career option. A number of activities were conducted by researchers to expose young girls to CS with an objective to get them to pursue Computing careers in the future. Miller and webb cited the diversity reports from Apple[1] and Google[2] to state that there is a requirement for increasing the diversity (both women and minorities) [34]. Miller and Webb further propose that 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 [34]. Furthermore, in a study by Google, to access the indicators involved in a woman’s decision to pursue CS degree, four key factors were revealed [35]:

- Social Encouragement: positive response from family and friends.
- Self Perception: belief that critical thinking and problem solving skills can provide a successful career.
- Academic Exposure: opportunities to participate in curriculum and/or extra-curricular CS courses/activities.
- Career Perception: positive thinking towards CS as a career with societal impact.

Emphasizing these factors in the society is a way to get more women into CS. However, a 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 CS as a career [36].

2.2.2. Role-models

Another strategy is to introduce female role-models in CS to girls [14,37], or to introduce them to stories and event [13,38,39] that can influence their professional choice at an early age. Black and colleagues [14] cited Güre and Camp [37] to state that the lack of female role models in Computer Science was found to be one most detrimental factors for young girls to stop relating CS; and hence they require a female role model to be motivated to study Computer Science or pursue a career in the field [14]. More specifically, a project called Computer Science for Fun (CS4FN [40]) that has produced and made freely available (online) a booklet that showcases female role models and their groundbreaking work in Computer Science. CS4FN [40] was aimed to address one of the biggest hurdles for women to consider CS as a viable field of study, that is the lack of female role models [14].

Concerning the toys that girls relate to, in 2010, Mattel, Inc. announced that the next Barbie will be a computer engineer, as this profession got the most votes (out of five options, i.e., architect, news anchor, environmentalist, surgeon, and computer engineer) from the public [38]. In another contribution Cheryan and colleagues argue that efforts to increase female participation in computer science one might benefit from changing masculine cultures and providing students with early experiences that signal equally to both girls and boys that they belong and can succeed in these fields [39]. Cheryan and colleagues argue that it might be difficult for women and girls to pursue fields with masculine cultures (beliefs and values encouraging and rewarding masculine characteristics in men) [39]. Similarly, in a survey conducted to study the attitudes of women towards the Computer Engineer Barbie by Martincic and Bhatnagar, 75% of the participants agreed that the doll could influence a girl’s decision to enter the field of Computer Science [13]. Martincic and Bhatnagar argue in favour of such toys that could be viewed as the experimental tool for future occupational choices for the children [13].

2.2.3. Early-interventions

One of the suggestions from Palma was to start exposing the girls to the intricacies of CS at an early age [22]. French and Course emphasize on this key strategy of “early interventions”. They mentioned that it is important to start the exposure of CS to the young girls is important [36]. French and Course cite the “lack of exposure to girls” as the main hurdle and argue that the earlier this hurdle is crossed the more could be the chances of keeping the interest in CS and hence the access and exposure to computing is necessary at a young age to foster interest and comfort in the field [36]. The importance of early interventions was also supported by the findings of Wang and Degol, who argue in favour of early interventions by stating that during the developmental process it becomes easier to “imprint” a long-lasting impression of the intervention [41]. Taking the argument for the early interventions further, Maltese and Tai conducted an analysis of factors influencing the completion of the given degree [42]. Out of the most influencing factors were the early achievement in the educational domain and the early career decisions (if they were in the same educational domain) [42].

We can observe that previous research has tackled the problem of improving and maintaining women’s interest in CS studies and/or careers using a multitude of strategies. However, this has resulted in a scattered field of knowledge about the state-of-the-art in the field of serious games for this purpose. Therefore, we present a systematic literature review on the current status of research about the effect of the serious games on the girl’s attitudes towards CS studies and careers.

2.2.4. Games and dedicated efforts

There is a common consensus about creating special programs and putting special efforts to encourage more girls to pursue CS studies. There have been several successful efforts such as the MIT Women’s Technology Program[3] (WTP), which is a program running since 2002 with the goal to increase high school girls’ interest to study engineering and Computer Science in the future. In a summer camp held for a week, girls reported under representation of females (only 17% of the total participants) and they would have wanted to work together with more girls [43]. Camps focused only to girls would be more friendly and engaging to them [43]. Previous results also suggest that camps focused

[1] https://www.apple.com/diversity/.

[2] http://www.google.com/diversity/at-google.html.

[3] http://wtp.mit.edu/.

only for girls to be more friendly and engaging to them [43].

Research also suggests that the focus of game-based interventions should be on interest enhancement alongside ability enhancement as individuals with high-skill and low motivation are less likely to opt for a CS career then those with high-skill high-motivation [44]. Further, Wang and colleagues suggest that girls may get more out of science and maths lessons if they are taught through the lens of a storytelling and gamified lessons since stories make the lessons more relatable [41]. Their suggestions are backed up by the findings from Sadik and colleagues [45]. Finally, integrating a game design project into the participants' curriculum to evaluate girls' interest in the topic and might also impact their CS choices in the future [46].

In this paper, we decided to review the state-of-the-art in one of these efforts, that is, serious games. We extract systematically the knowledge that is scattered in the area and make an attempt to present it in a useful structure of what has been done, and the guidelines and recommendations from the previous work to the future research ventures.

2.3. Games for educational purposes

Serious games are built with a goal to serve educational (mostly) purpose rather than pure entertainment. The field of serious games has seen a rapid rise from its beginning phase in 1995 [47]. The concern for the game's educational purpose and not to be played primarily for amusement [48].

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 [9]. 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. While it is supposed that serious 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, showed that the games were helpful in developing collaboration skills [49]. Students liked to play games and while some were more into games as compared to others, almost all of the participants included in a study played games [46]. This might contribute to the success of serious games in education. 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 [50].

Alongside the proposal of playful learning, the present generation of students are more likely to play and learn from games [9]. With its immersive nature, games can get students' attention for long time as compared to classroom lectures [51]. Serious games can be integrated with different educational domains. Some serious games are built specifically for the purpose of classroom environment, and they can cover a variety of study areas [52]. In a study conducted in a after-school program Eordanidis and Carmichael measured girl's engagement and mastery levels during the game play and concluded that the participants (girls) had an increased understanding of Image representation after playing the game [52]. Pickit! and Cookit!, developed to introduce children from age 9 to 12 to nutrition education [53].

Incorporating serious games to CS has also attracted attention. The Serious Games for CS project from Software Quality Research Lab[4] aims to improve education in CS through game-based approach. RoboBUG, an open source serious game, helps players to learn debugging techniques in Software Engineering through an enjoyable and motivating experience [54]. Robot ON! is an educational game designed with the focus of increasing the players' programming comprehension rather than teaching programming concepts [55].

GrACE, which is used to determine a graph's Minimum Spanning Tree (MST) s was used to teach common CS concepts to middle school children aged 11 to 13 [56]. The game play consists of animals collecting food while utilizing least effort [56]. In a study conducted at the Brooklyn College and the College of Staten Island, 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 CS [57].

3. Methods

For the present contribution, we followed the guidelines provided by Kitchenham [58]. In the following we give the details about the data collection, inclusion and exclusion criterion, quality assessment and data analysis (see Fig. 1). We first collected the articles from automatically searching the main online archives (see Section 3.2). Second we apply the exclusion criteria on the collected articles (see Section 3.2.1). This step resulted in **twenty-one** articles. Once we had the selected articles from the automatic search, we applied snowballing [59] to the references of the selected articles and applied the exclusion criteria once again (see Section 3.2.2). This step resulted in **four** additional articles that we included in this systematic literature review (SLR). Finally, we analysed the **twenty-five** selected articles using the coding scheme presented in the section.

However, before presenting the details about the main methodology employed in this contribution, we list the basic definitions used in this Systematic Literature Review (SLR).

3.1. Basic definitions

Serious games: Serious games are designed with the primary purpose of education and/or training, rather than the entertainment. The "fun" aspect of the games in general takes the secondary priority in serious games.

Simulation: In simulations, the students take the active role in learning in a way where they can learn by their own mistakes in a safe environment. Simulations are known to provide more open ended and exploratory problems to solve to students, while games are designed to be close-ended and more goal-oriented.

Game play: In this SLR, we will use the term "game play" when a study uses one or more already developed serious games to motivate the female students to pursue CS studies and/or CS careers.

Game design: In this SLR, we will use the term "game design" when a study involves the target audience into designing and/or developing a game. The output of such an activity could range from a wireframe representation of the game interface to a completely developed games. Moreover, the output game (or the idea) does not have to be serious game.

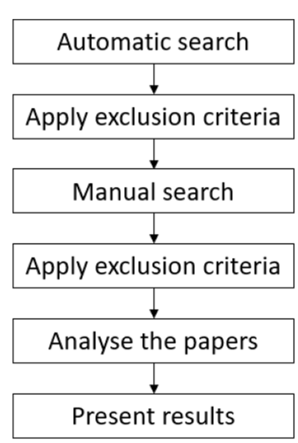

Fig. 1. Overall process of the systematic literature review.

[4] http://www.sqrlab.ca/projects/cs-games/.

3.2. Data collection

We started the data collection by selecting the main online archives such as 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 keywords and the logical conjunctions to form the search strings for the different databases are listed in Table 1 (Second column).

3.2.1. Exclusion criteria

Once we had the initial search results, the next step was to select the most relevant research articles to include in this contribution. Fig. 2 shows the output of each major step. The basic aim was to keep the articles with the current state-of-art in terms of technology and also to keep the ones that are closely related to our research questions. Initially, we focused on title and abstract of the articles to find out whether they reside within the scope of our research criteria. If the title and abstract were not enough to determine the relevance of the study for this contribution, we considered the methodology and results of the articles. Finally, we selected 21 studies from various online libraries. We used the following criteria (C) to **exclude** the papers:

- **[C1:]** articles before year 2008: This was done with the idea that girls who were pre-teen in 2008 are now on their course for a professional career.
- **[C2:]** redundant articles that appeared in the search results for more than one online library.
- **[C3:]** studies that have no results: Studies without result fail to showcase if the research did succeed in its reported objective or not.
- **[C4:]** studies that teach programming to young girls without capturing their opinion about pursuing Computer Science.
- **[C5:]** studies that fails to provide their methodology: Studies that lack methodology are unable to provide insights to conduct similar or replicate the research in the future.

3.2.2. Manual search

After the automatic search, we conducted a manual search to identify additional studies that the search string failed to find in the online databases. We used the snowballing technique that looks through the references of the papers selected from the automatic search to find other related studies [59]. Fig. 3 shows the output of each major step. These new papers go through the same exclusion criterion as the papers from the automatic search results. The manual search provided 26 additional papers, among which four papers were included into the primary studies.

3.3. Data analysis

All the 25 articles included for in-depth analyses met the quality assessment criteria [58]. These criteria include three basic factors. First, that the study applies an appropriate research method (Rigour). Second, the findings presented have a validity aspect (Credibility). Third, the findings of the study points towards encouraging girls to choose CS careers (Relevance).

To focus on our research questions in a systematic manner, we analyzed the selected articles according to the scheme shown in Table 2.

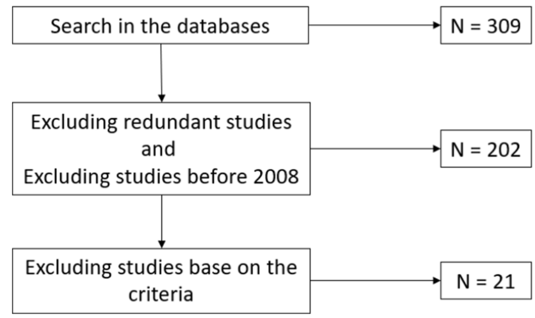

Fig. 2. Automatic search and filtering process and the number of articles remaining after each phase.

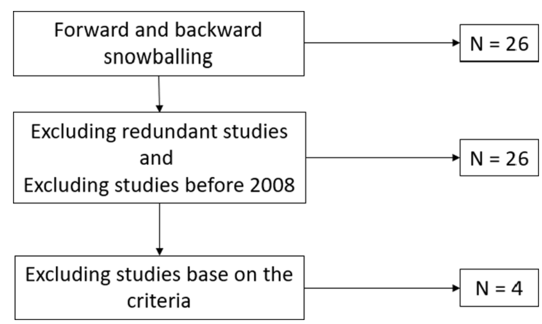

Fig. 3. Manual search and filtering process and the number of articles remaining after each phase.

4. Results

We first present the detailed descriptions of the studies in the terms of target population (age, sample size), technology involved, the activities carried out and the context of the selected studies. Then, we answer the first research question i.e., "What is the impact of serious games (playing/designing) on girls' perception of Computer Science as a career option?", by coding the outcome of the research objectives. Finally, we code the most important design factor from the selected studies to answer our second research question, i.e., "What are the major factors to be considered when developing a serious game?"

Table 1
Search strings used for different Online Libraries.

Online Library	Search String	Retrievals	Selected automatic search
ACM Digital Library	games AND girls AND computer science	75	11
EBSCO	games AND girls AND computer science	20	4
IEEE Explore	games AND girls AND "computer science"	17	3
Science Direct	(games AND girls) AND "computer science"	197	3

Table 2
Analysis schema for the present systematic literature review.

Area of Focus	Description	Example
Activity	Main activity of the study	game play, game design, programming
Context	Physical space where the activity took place	class, workshop, after-school
Technology Purpose	How technology was used in the study	game creation, robot design
Outcome	Whether objective was met	increased motivation, increased interest in CS courses
Age Group	Age group of participants	11–14, 13–15, 11–16
Sample Size	Number of participants	57, 18, 48
Intervention duration and span	Total duration and span of intervention	span = 5 days (1 h per day, so the duration is 5 h)

4.1. Age group

The included papers had participants aged 4–16 years old. One study did not report the age group of participants. Ten out of 26 studies had focus group in the range 10–13 years old [46]. We observed that three studies had participants from high school aged 14–18 [60–62], and only one had participants from kindergarten aged 4–6 [36]. Additional analysis of the focus groups revealed that 10 studies had the involvement of participants aged 10–12, eight included participants aged 12–14, and seven had participants aged 14–16.

4.2. Sample size

Based on the 25 studies included into this contribution, we observe various sample sizes used in the different studies. The sample size varies from small groups of 5–15 participants to large classes of about 1000 participants. We observed that nine studies had a sample size below 25 participants; 13 studies each had a sample size of 25–100 and three studies had big groups of more than 100 participants.

We also distinguish the studies in which girls contribute to more percentage of the sample size than boys. Among the 25 studies (where the sample size and gender information is reported), 16 studies had the majority of sample size as girls; while boys contribute to majority of sample size in only seven studies. Only two of the primary studies have not stated the sample size in terms of gender.

4.3. Activities performed in the studies

We categorized various activities designed and implemented by the researchers in their studies with an objective to positively impact participants towards CS, such as game design, game play or teaching programming. During the game design sessions, researchers aimed to assess participants' perception of Computer Science and expose them to various aspects of CS like game design and development through interactive environments like Scratch and GameMaker. Game design sessions introduced basic CS concepts, programming, algorithms and robotics engineering, to children 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 CS through the game itself. Game play sessions provided a fun and immersive environment to the participants.

Out of 25 studies, 15 focused on game design sessions and 13 focused on game play activities. Three studies had multiple activities designed for the participants. Robinson and colleagues included both game play and game design in their study [63]; AlHumoud and colleagues included game play, game design and robotics programming as the main activities in their study [61]; and Ouahbi and colleagues focused on game design and programming as their activities, where they 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 [64].

4.4. Context

The context is the social setup where the research study is carried out (Fig. 4). The main purpose of the categorization of the context is to provide detailed information about the existing trends for relevant studies. Based on the studies, we categorized the context into 5 categories: **Workshop, Class, After School, Camp, and Computer Lab.**

Out of 25 selected studies, 10 were conducted in classroom [14,34,36,46,60,62,64–68], six were designed as after school sessions [52,69–73], five were designed as workshops [2,74–77], four were designed as camps [10,61,63,78], and two in a computer laboratory [68,78]. Among the studies conducted in classrooms, a few were (e.g., [46]) conducted as part of the curriculum for game design course where students were required to develop a game. Others (e.g., [34,65]) conducted longitudinal studies integrated within school class to increase students' motivation for CS education. On the other hand, two studies used a computer laboratory for their investigation because of easy accessibility to computers per participants [68,78].

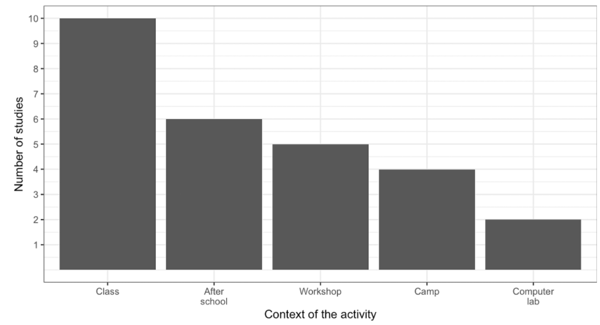

Fig. 4. Distribution of the different places where the activities used in the included papers took place. The class context was used the most, while the computer lab was utilised only two times.

4.5. Purpose of technology

We analyzed purposes for which technology was incorporated into the activities (Fig. 5). The primary aim to use technologies was to provide an interactive environment for conducting the activities(Fig. 6). Based on the analysis of the studies, we have categorized the use of technology into 8 categories: **Used Games, Made a Game, Learn Programming, Robotics Design, Video Animation and Made Wearables.**

Out of 25 studies, a majority of 15 used technology to create games; 10 studies used games as a part of their study to indulge students into various activities. Some studies used multiple technologies in order to accomplish their purposes. AlHumoud and colleagues used a tool called App Inventor for Android to enable the participants to create and play games [61]. Ouahbi and colleagues used Scratch to create games and also conducted a traditional programming learning session in Pascal [64]. Webb used two technologies, Scratch and Lego WeDo to create games based on drag-and-drop approach [77].

Two studies used technologies to teach students the basic concepts of programming like loops, conditional statements and arithmetic operations. One study used wearable technology to teach electronics and programming to middle schools girls [76]. Another study utilized the idea of story writing and/or game design via Adventure Author [67]. One other study asked the participants to create a robot using sensor technology [61]; while another study engaged the participants to either to build a game or an animated music video using Scratch [10].

Concerning the tools used by the 15 studies whose activity was to design a game, three studies did not report the technology tools. Among the 12 remaining studies, only one used two different tools for the same session: Scratch integration with Lego WeDo [77]. In total nine technology tools were used to design games by others: GameMaker (2), Scratch (3), Unity, AgentSheets (2), StageCast Creator (1), Lego WeDo (1), Adventure Author (1), App Inventor for Android (1), and ScriptEase (1).

4.6. Intervention duration and span

The overall time span of the studies included in this review varied from a few hours to one semester. Fig. 7 shows the distribution in terms of the span of the intervention. We observe that majority of the studies lasted only for a day (nine studies) or a few hours only (three studies). Four studies lasted less than two weeks, where the daily participation was close to an hour only [10,66,68,76]. Moreover, four studies lasted more than two weeks, however, the exposure to the game design/

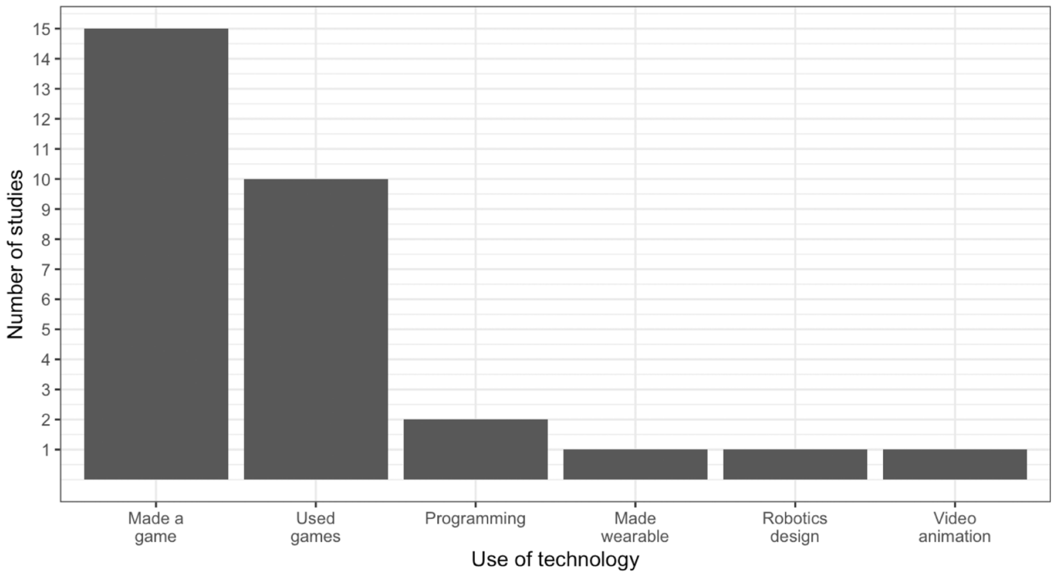

Fig. 5. Use of technology in the selected studies. Most of the studies required the girls to either to play the games to design them.

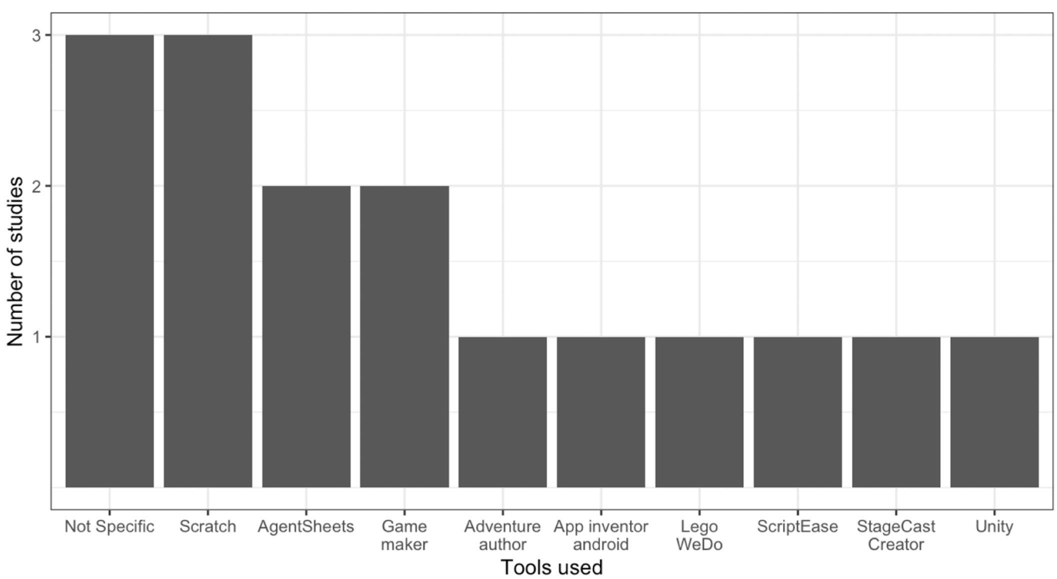

Fig. 6. Tools used to design the games in the selected studies. There is almost a uniform distribution of tools used in the studies. This shows that the researchers use the tools that are readily available to them.

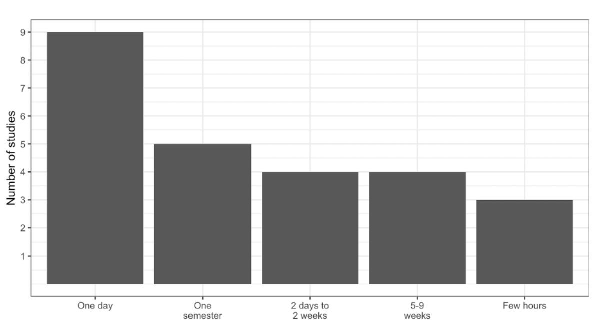

Fig. 7. Time span for the interventions used in the studies. Most of the studies lasted less than two weeks. The "longer" studies were also limited in the terms of exposure time per week (not more than 2 h per week).

playing was limited to less than two hours per session [52,61,67,69]. There were only five studies that lasted for about a full semester with continuous exposure to game designing/playing activities, as these activities were planned as a part of the curriculum for those semesters.

4.7. Outcome

To answer our first research question i.e., *"What is the impact of serious games (playing/designing) on girls' perception of Computer Science as a career option?"*, we coded the outcome of the research objectives in the selected studies. The included studies in this Systematic Review had one common objective and that is to expose young girls to CS and increase their interest into CS education and careers. Table 4 shows the summary of the impact of these studies according to their principal design factor. Impact on girls' perception about CS careers, as presented in Table 4, represents the result of the activities performed with/by the children in the studies. The design factors extracted from the primary studies might serve as the resources to design an activity that can yield increment in girls' interest towards Computer Science.

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. Table 3 shows the main categories of outcomes and their respective explanations.[5] Among the 25 studies, the analysis of impact shows that participants in 17 studies were interested in either CS education or career. In two studies, participants' interest decreased. This was seen via pre- and post-assessment surveys [34,67]. Al Sulaiman and Horn report no change in girls' perception [78]. The reason behind it is stated as girls' perception that "Programming would be enjoyable" even before the activity session. Finally, six studies failed to report the impact of the study on young girls' perception of Computer Science.

Six out of 25 studies did not show the presence of any design factors in them. One such study, [46], 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. Twenty studies provide the design factors ranging from flow theory to complexity of the game to personalization in the game. Four studies provide research guidelines that can be used in the future when designing games. Two studies produce both, research guidelines and design factors [10,63].

4.8. Major factors considered for design

To answer our second research question i.e., *"What are the major factors to be considered when developing a serious game?"*, we coded the most important design factor considered in the study. Among the 25 studies included in this contribution, most of the studies (20) provided at least one design factor to be considered when designing a game, two studies suggested research guidelines for future work, and six studies reported neither any design factors nor any research guidelines [36,62]. Table 5 summarises the design factors considered in various studies.

5. Discussion

We conducted a systematic literature review concerning two questions based on girls' perception about CS as a potential career option. First, what impact has been shown in the previous studies; and second, what are the major design factors?.

5.1. What impact can games have on girls' perception of Computer Science as a career option?

The first research question considers the assessment of the impact of the activities (game design, game play, programming) on girls' interest in CS. To this end, the studies engage the participants in two different ways:

- Utilizing various tools to design and develop games and interact with Computer Science [10,34,46,61–68,70,71,75,77].
- Participating in game play sessions to create a bridge between the game and Computer Science [2,36,52,61,69,72–74,78].

Table 3
Outcome categories.

Outcome Category	Explanation
CS Career	Increased interest in CS as a career choice
CS Courses	Motivated to take a few CS courses
Interested in CS	Increased interest in CS
Decreased	Decreased interest in CS
No Change	No significant change in girls' perception
NR (not reported)	Study does not report the effect on girls' perception

[5] Some of the studies might be counted for two categories.

From the studies included in this contribution, we observed two main trends in the reported results. First, the studies reported that the students became more interested in CS as a potential career option [10,63,66,72,75,77]; and second, even if there was no such indication, studies have reported increased interest in CS and programming, suggesting that the continued efforts are required for a sustainable increase in the motivation to choose CS as a potential career option [2,36,61,64–66,68,69,74,76]. However there were some studies which reported inconclusive results regarding the girls' interest in CS [34,67,78]. There are several reasons cited for such results, for example, lack of well-defined activities [75], already motivated group of participants [78], or a non-suitable (very young) group of participants [36].

One of the most influential factors affecting participants' learning and interest is the implementation context (workshop, class, after school, camp, computer lab), specifically for "in-the-clss" type of activity contexts. Four out of 11 studies, included the activities as a part of the participants' study curriculum [34,46,65,67]; and three out of them reported negative impact on the girls' perception about CS [34,65,67]. Such results are indeed counter-intuitive, however the root cause for this is within the fact that the students were given game design assignments [67]. Teachers reported this being the major reason for the participants to loose interest midway.

Second key observation is the acute relation between the type of activities and the age distribution of the target group. Too complicated tasks designed for young children might lead to their disengagement from the activity [36]. Difficult activities could also lead to demoralization and reduce interest in CS [70]. On the other hand, easy activities for "older" children might lead to boredom and hence reduced interest in CS topics [79], these children are often interested in learning more (relatively) difficult concepts [68].

Finally the third influential factor is the use of interactive/online learning environments, such as Scratch, Alice, GameMaker, and Lego WeDo. These environments provide interactive tools that can be easily understood and used by children in order to show their creativity. Additionally, tools in such environments provide a wide range of design capabilities. High levels of usability, intelligibility and having a wide range of design capability usually leads to positive results [10,64,77]. Likability of such environments positively affect the perception of CS at a very early age [10,64,77]. Moreover, the environment's ability to motivate and commit the students to work on their projects while having fun, over long periods of time can also influence their perception in a positive manner [80].

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

Game Design factors are incorporated into the games by the developers, and game play factors are related to the feelings and experience felt by the players when playing the game [81]. Among the 25 studies included in this contribution, 20 studies provided at least one design factor to be considered when designing a game, 2 studies [36,62] suggested research guidelines for future work, and 6 studies reported neither any design factors nor any research guidelines. From the reviewed studies, we can find following basic design factors:

5.2.1. Personalization

Personalization is one of 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 [82]. Personalization could also motivate the girls to look upon themselves as role models [82]. Girls were reported to have appreciated the functionality to customize the components in the environment which helped the girls to express themselves and their preferences [75] and were reported to be fully

Table 4
Summary of main areas of focus for data analysis. NR= "not reported".

Study	Context	Activitiy	Sample Size	% of girls	Technology used	Intervention total hours	Intervention span	Effect on girls' perception
Stewart-Gardiner et al. (2013) [69]	After school	Game play	57	65	Gram's Grocery Shop	5	5 weeks	CS career
Eordanidis et al. (2017) [52]	After school	Game play	18	100	Hidden Image	NR	8 weeks	NR.
Groover (2009) [2]	Workshop	Game play	48	100	Towers of Hanoi	NR	1 day	Interest in CS
Spangenberger et al. (2018) [74]	Workshop	Game play	49	50	Adventure game	1	1 day	Interest in CS
Bonner and Dorneich (2016) [72]	After school	Game play	15	50	NR	1	1 day	CS career
Carmichael (2008) [68]	Class & Lab	Game design	12	100	GameMaker	NR	1 day	CS courses
Akku et al. (2017) [75]	Workshop	Game design	21	100	Unity	NR	1 day	CS careers
French and Course (2018) [36]	Class	Game play	9	100	Robot Turtles	few hours	NR	Interest in CS
Sweedyk (2011) [46]	Class	Game design	208	56	Globe Trotter	NR	1 semester	NR
Miller and Webb(2015) [34]	Class	Game design	48	33	AgentSheets	NR	1 semester	Decreased
Adams (2010) [10]	Camp	Game design	45	33	Scratch	NR	1 week	CS career
Webb et al. (2012) [65]	Class	Game design	425	50		NR	1 semester	CS courses
AlSulaiman and Horn (2015) [78]	Class & Lab	Game play	70	88	Virtual Family	2	1 day	No change
Lau et al. (2009) [76]	Workshop	Game design	25	25	Arduino	NR	5 days	CS Courses
Esper et al. (2013) [73]	After school	Game play	40	100	CodeSpells	1	1 day	NR
Denner et al. (2012) [70]	After school	Game design	59	100	StageCast	12	6 weeks	NR
Jenson and Droumeva (2016) [66]	Class	Game design	67	NR	GameMaker	1.5	1 day	CS career
Webb (2011) [77]	Workshop	Game design	16	100	Lego WeDo	3	1 day	CS career
Robertson (2013) [67]	Class	Game design	992	NR	Adventure Author	18	9 weeks	Decreased
Mota and Adamatti (2015) [60]	Class	Game design	7	95	Scratch	NR	1 semester	NR
Robinson et al. (2015) [63]	Camp	both	37	100	NR	5	5 days	CS career
AlHumoud et al. (2014) [61]	Camp	both	15	100	AppInventor	NR	2 weeks	CS courses
Carbonaro et al. (2010) [62]	Class	Game design	50	48	ScriptEase	12 h	NR	NR.
Ioannidou et al. (2009) [71]	After school	Game design	40	52	AgentSheets	10	NR	CS courses
Ouahbi et al. (2015) [64]	Class	both	69	70	Scratch	NR	1 semester	CS courses

Table 5
Design factors mentioned in the studies.

Design Factor	List of Studies
Personalization	Stewart-Gardiner et al. (2013); Akku et al. (2017); Adams (2010); AlSulaiman and Horn (2015); Mota and Adamatti (2015); Ioannidou et al. (2009)
Engagement & Flow	Eordanidis et al. (2017); Bonner & Dorneich (2016); Carmichael (2008); French & Course (2018); Esper et al. (2013); AlHumoud et al. (2014)
Collaboration	Groover (2009); Bonner & Dorneich (2016); Jenson & Droumeva (2016); Robinson et al. (2015)
Strong Female Presence	Spangenberger et al. (2018); AlSulaiman & Horn (2015)
Educational factor	Carmichael (2008); Lau et al. (2009); Esper et al. (2013); Denner et al. (2012); Carbonaro et al. (2010)

engaged in the activity [71]. Personalization is mostly seen, in terms of game play as the ability to create the characters/avatars and is reported to have significant impact on player's desire to continue [10,60,69,71,75].

There are a variety of ways through which one can achieve personalization in a serious game [83]. First, where a certain central character is involved, using avatars for personalization could be used [82]. Second, for the games where there is no playing character, the personalization could be achieved through utilizing personality traits (big-five traits: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) to design the content presentation Nov and Arazy [84]. Moreover one could also benefit from the user types as defined by Tondello and colleagues [85]. These gamification user types (e.g., philanthropists, Socialisers, free spirits, achievers, players and disruptors) are based on the motivation for playing the games [85]. One can design for the specific needs for each user type, for example, philantropists are willing to give without expecting rewards, for such girls one could create knowledge sharing opportunities in the games. On the other hand, free spirits seek autonomy in the game, for such girls once could design exploratory tasks and a non-linear game play [85].

5.2.2. *Engagement and flow*

Other important design factors are active engagement [86] and flow [87]. 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 [88].

Only one study reported the presence of flow in the game used in the study [52]. In other studies, games used in other studies reported high levels of engagement; for example, regardless of the limitation of time, participants wanted to play the game to its conclusion [74]; or participants wanted to play longer and along with their friends [72]. Especially, in one case, even though the girls failed to create some new features due to the limitation of the API, the girls felt engaged and they kept working [73]. A student experiencing enjoyment and flow while engaged in learning, for example, focuses attention on the activity of learning, not on outcomes [89].

One of the primary ways of maintaining the engagement and flow is to keep adapting the content based on the real-time behaviour and performance of the girls. There is a vast amount of research done in the area of intelligent tutoring systems (ITS) [90–92] and adaptive assessment tests (AAT) [93–95] about how to adapt the content based on the capabilities of learners. One could take inspiration from the gamified versions of ITS [96,97] and AAT [98–100] to design games that can support long term engagement by maintaining the flow of the game up to the level of the individual players.

5.2.3. Collaboration

The ability to collaborate in a game is an emerging trend and factor that keeps players interested in the game. In a between subject design, learning achievements and motivation of the collaborative group were reported to be significantly higher than that of the control (no collaboration) groups [101]. Various studies reported that the participants were more engaged the game if the game provided them the functionality to collaborate and play with their friends [2,63,66,78]. Participants in some studies also stressed the addition of collaboration functionality as a recommendation for the future [69,72]. Mutual relationship between participants and problem-solving within themselves has been seen as significant benefit of collaboration [102–105]. 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 one of principal design factors during the game design, and later, during game play.

Introducing collaboration in the CS based serious games is one of the factors that has the least hurdles in the process. One of the methods to implement collaboration is to promote knowledge sharing among the members of the same class in the form of “help” boards with gamified elements [106]. Challco and colleagues have provided a detailed framework of gamifying the collaborative learning scenarios [107], which could be easily adapted to the needs of games for the young girls. Further, gamification could be used in the ideation phase of the game design (in cases where the girls are designing the games themselves) [108].

5.2.4. Strong female presence

Girls were reported to prefer the game with gender orientation, and said the gender of the main character played a role in determining the gender orientation of the game [78]. The female protagonist of the game seemed to stand out to the girls, and as a result, after the game play, girls’ interest in technical subjects increased [74]. To increase girls’ 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 [11,109]. Today, numerous games have female protagonist which show that women can fill the role of a mythical hero just as effectively as their male counterparts [110].

5.2.5. Educational factor

For the use of games as educational tools, the games should contain various educational components that enable the players to learn while playing [111]. Without the educational components, the game cannot be categorized as a serious game. However, the educational components of the game might disrupt smooth game play, ways of integrating educational components alongside retaining smooth game play should be prioritized [73].

The presence of the educational factor is a key element for the serious games (see definition). The purpose of the serious games is two fold: being entertaining and being educative [112]. Therefore it is necessary is that the gamification process should not overcome the learning processes. One should keep in mind that the end goal is to promote CS education among girls, this makes the educational part of the serious game even more important [69,72,78]. The games should give an honest idea about the basic and primary content of CS field to the young girls. Molnar and Kostkova have provided a basic framework about how to effectively integrate the learning content into serious games mechanics [113].

5.3. Implications for study design

In this subsection, we present our recommendation for a typical study design keeping in mind the findings of our Systematic Literature Review. We provide these recommendations from the point of view of ensuring the internal and external validity of the study design.

Measurement validity: There is a risk of measuring the perception of girls about the game/technology used (during the activity) instead of their perception about CS. One should make sure that the girls are aware that they have to report their perceptions about CS, and not about the activity (game play/design). It is important to assess the impact of the study on the focus group is to derive conclusions based on the data collected in the sessions.

Internal validity: when design of the study involves female role-models, the most important thing to be taken care of is that the relation between the female role model (see 2.2.2) and the learning content should be clearly observable. For example, the game designer should make clear Ada Lovelace’s relation with loops; Grace Hooper’s relation with branching; Betty Holberton’s relation with breakpoints. These links would ensure that the girls are not only learning about CS but they are also relating with the fact that what they were learning is because of a female computer scientists.

Coping up with the maturation effect: as we can see that engagement and flow is one of the most sought for design factor in Table 5, this could also be the answer to the maturation effect in a study. With time, the difficulty of the content should increase with the experience of the young girls.

Coping up with the confounding factors: a longitudinal and repeated measurement study might be one of the most suited in such cases, since the first confounding factor would be the novelty effect of the technology on the girls. Girls might find the new technology appealing but with time they would loose interest in it and the intervention would loose the purpose. To counter for the novelty effect, a longitudinal study should be carried out with careful planning with the curriculum of the schools. Inability to collect key data from the sessions result in the failure to perform efficient data analysis in order to generate outcomes.

Coping up with the regression to the mean: as we mention in the previous point that a longitudinal and repeated measurements study seems most suitable in our case, there is a risk for the girls’ perception levels to regress to the whole group’s mean. This could be taken care of by using the previous perception measurement as a co-variate while analysing the current perception measurement.

External validity: this is the most difficult one to achieve with any of the 25 selected studies. All the results are difficult to generalise across a wider female audience than the reported ones in the selected contributions. One of the prime reasons could be the emphasis on and the over-presence of the technology that was used for the intervention. One should be more focused on the actual educational factor and emphasise that. In this manner the findings about the educational factor could be generalized. This would be a higher level of external validity than the effect of technology. Also, it is advisable to conduct a power analysis prior to deciding upon the sample size, so that there is an idea about the effect size of the differences. One challenge with the validity of research studies is that not every study had the same age group for the participants. The results, thus indicated variations regarding when should young children be exposed to Computer Science to increase their interest in the domain.

Sample size: Having either a small or a very large sample is “ethically unacceptable” in a research study, and researchers should try and avoid it [114]. Three studies had rather large participation of 208, 425 and 992 participants respectively [46,65,67]. In the study conducted by Robertson and colleagues, teachers failed to get post-survey responses from all the participants [67]. This resulted in a level of inconsistency in the pre-survey and post-survey results. With a rather controllable sample size, this obstruction might not be faced.

Moreover, both too few and too many participants in the sample size can cause the quality of the research to degrade [114]. This situation has been observed in multiple primary studies. Eight studies reported that because of small sample size their results lack the statistics to make strong generalizations with regard to larger demographics [52,60,61,64,68,72,75,77].

6. Conclusions

We identified 309 studies from searches of the literature, of which 25 were found to be research studies of acceptable rigour, credibility, and relevance. All of the studies identified were primary studies.

We identified a number of activities, context and outcomes related of games (playing/designing) and girls perception of Computer Science Careers. However, the strength of evidence is low as the time span of the interventions and evaluations is limited. This makes it difficult to offer specific advice to game and activity designers and instructors. Consequently, we advise practitioners to use this article as a map of findings according to topic, which they can use to investigate relevant studies further and compare the settings in the studies to their own situation.

A clear finding of the review is that we need to increase both the number and the quality of studies to understand the relation between game play or game design behavior of girls and their perception of Computer Science Careers. In particular, computer games, such as Hidden Image or Robot Turtles, and game making platforms such as Scratch, and Unity, warrant further attention. We see that there is a backlog of research issues to be addressed, like how to sustain the engagement of girls over a long period of time and keep on evaluating the intervention without loosing the interest of the participants. One of the most interesting design guideline of this review is that the girls said that they felt the need and the importance of female protagonists.

In this context, there is a clear need to establish a common research agenda for increasing the positive perception of girls toward Computer Science Careers and for future field studies to pay more attention to the fit between their research methods and the state of prior work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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