Implications of Gamification in Learning Environments on Computer Science Students: A Comprehensive Study

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Background and related work

Computer science has one of the most considerable gender disparities in science, technology, and engineering. The number of female students choosing computer science as their major remains underrepresented regardless of recent efforts. Some noted reasons behind this statistic are challenges in the curriculum that lessen students' motivation in CS majors (Ibáñez et al., 2014; Carbonaro et al., 2010), for example, programming courses are often identified as being negatively viewed by students and cited as requiring more practice (Azmi et al., 2015). Yet, about 500,000 computing positions remain vacant in the US ("The state of K -12 computer science", 2016), and many nations need more computer scientists. Therefore, the underrepresentation of women in computer science is an important topic that has begun to garner university program's attention. This shortage of computer scientists has prompted the computing community and education researchers to be more reflective about current practices in order to try to attract and retain more students, especially women, to keep pace with industry demands. As such, researchers have explored various engagement strategies in the field of computer science. One of the strategies with increased attention in the last two decades is the idea of *gamification*.

Gamification usually refers to the use of video game mechanics in existing processes and activities (Deterding, Khaled, Nack, & Dixon, 2011), which are not related to video games. The purpose of using game elements is to increase the participants' engagement and enjoyment. This notion has been growing in popularity over the years, especially among education researchers, since game elements provide a challenge to players and motivate them to set goals in the learning environment. According to Kim (2015), using gamification can provide an optimal context to change the behavior and improve the users' engagement and performance. However, designing gamification requires determining the target group and understanding their needs and factors such as gender, age, and cultural orientations since they can change gamification reception (Kim, 2015). Also, Gamification is in its initial steps regarding behavior change which is one of the most challenging fields of human science. One reason is that change of behavior is not enjoyable and free-willed (Schoech et al., 2013). There are many applications that use game elements to enhance students' participation and enjoyment.

Although there is a strong body of literature around the implications of gamification in education, there are inconsistent results in the literature with regards to the interests or performance of women. This review aims to summarize the use of gamification in existing literature on 1) gamification in education 2) gamification in other domains 3) gamification in computer science and 4) women in computer science to provide a basis for more targeted learning engagement strategies to motivate and retain more women in computing fields and build on the literature on gamification and gender. The paper discusses a review of each paper in different fields, the main findings, and suggestions for future work. This review focuses on the results of gamification aspect (in application) of studies on participants. at the end of each section, a table with the results taken from research analysis is summarized.

Gamification in education

Gamification is a many-sided tool used in different domains to improve participants' behavior and engagement. However, we should note that in education the terms "gamification" and "video-game learning" are different and are dependent on the primary role of the application. While both can be used in regard to academic content, video-game learning has the pivot role of entertaining and being a game while educating is its secondary effect. Meanwhile, gamification has the primary role of educating in a non-game product with the secondary role of being game (Goehle, 2013). Gamification does not necessarily require developers to create complex systems nor require users to play games or use devices, however, they could. Since video games have proven their impact on gamers' motivation, game elements have the potential to make products without game elements more enjoyable (Zichermann et al., 2011; Flatla et al., 2011). As mentioned before, gamification can be present without computer applications but are often incorporated in computer applications, which is the main focus of this review. The most common gamification elements include points, badges, levels, progress bars, quests, avatars, narratives and leaderboards (Malone, 1981; Lee at al., 2011; Squire, 2011; Gee, 2003; McGonigal, 2011). These elements have been investigated in different studies to explore how they could be used to motivate students.

Different empirical works have investigated how gamification can be used in different contexts and the ways it impacts participants' behaviors (Morford et al, .2014). An educational application of gamification uses gamified elements in formal or informal contexts, for academic developments. (Seaborn et al., 2015); however, more care is required when applying these elements to different contexts, since not all related studies in education show that gamification has definite positive impacts on participants' behavior. In this section, we will review gamification literature in education beginning with the perceived negative or inconsistent implications of gamification and close with the positive resultant studies.

Gasland (2011) who developed an e-learning system using game mechanics called StudyAid, which helps students learn the material and study for their exam, produced results that showed not all aspects of gamification application were positive. The primary purpose of creating this system was to make the work more intriguing, engaging and exciting, focusing on the primary research achievement, which was to evaluate the perception of the students of the system. In general, survey results indicated that the students considered the system useful and simplistic. However, careful analysis of user feedback showed that the gamified mechanics did not have much impact on students' experience of fun and engagement. Although, it was probably due to the circumstances in which students had to study (studying for the final exam and not for fun).

Dominguez et al. (2013), built a gamification plugin on the Blackboard e-learning platform to test on a university course. The plugin provided the same Blackboard exercises in a gamified way to increase students' motivation toward learning. In this experience, students were asked to complete the activities to receive achievements, which in this research were considered as the reward, as well as the leaderboard. The course was randomly given to different groups: control and experimental. The experimental group used the gamified version of the course with 36 challenge achievements and seven achievements. Findings from the mixed-methods study showed that students who had the gamification experience performed better in practical assignments. However,

their performance in class activities and final grades for the written homework were low. Moreover, for many of the students, the system was not appealing enough for participation.

In another study by McDaniel, Lindgren, and Friskics (2012), an online course management system allowed students to choose their module to learn content. A video-game-style achievement system was developed to increase engagement of students toward behaviors, such as taking an exam early or receiving helpful feedback from the students' peers. Students were encouraged to use the badge system in the achievement section on the leaderboard, where they could also view and compare their badges with their peers. Conducting a focus group, students reported that seeing peer badges encouraged competition and motivated them to outperform their peer's scores. A survey asked students about the course features such as points, badges, narrative, and multi-path selections of the course. Research results showed that the leaderboard positively affected students' engagement, and achievement had the desired motivational effect (especially on women). Likewise, half of the students were motivated to earn more badges comparing themselves to their peers. However, just a few number of students reported positive responses toward using the achievements. Mixed response to the use of badges was likely due to the impact badges had on the students' grade.

Although we can see mixed or inconsistent results in the above-mentioned studies, the following research studies demonstrate evidence that gamification also has a positive impact on users' participation and engagement. Using a reverse software engineering activity, Foster et al. (2012) researched the effects of gamification on students. The purpose of the study was to challenge students in an electromechanical class to learn tasks in a more nuanced way with a deeper understanding of the tasks. Providing students with developed achievements before the activity and instructors' encouragement during the activity which motivated students to complete the tasks. The authors investigated the teacher's experience, the student's experience, their interaction, and student's outputs based on their presentation. The objective was to provide first-year students with a gamified version of activity to investigate the incentive of games in order to promote more engagement. To determine the efficacy of this tutorial a simple scoring method was used. The results then were compared to the previous year, which showed a significant increase in the use of design engineer thinking. In general, the gamified system helped students fill in the gaps in their understanding of the concepts and increased their engagement in the activities.

GamiCAD was also a gamified tutorial system developed by Li, Grossman, and Fitzmaurice, (2012) which targeted first time AutoCAD users. Real-time audio and visual feedback, challenging levels, timing, repetitive tasks through score improvements, are the gamified features that have not been explored in previous tutorials. The research focused on software learnability or initial learnability which is defined as the initial performance with a system. Research results indicated that participants using gamified elements reported higher speed and engagement when using GamiCAD. This system was developed using factors such as perceptions of clear goals, real-time feedback, matched skills, and challenges to have the user's optimal experience. Evaluating and comparing this gamified system with an equivalent non-gamified system called TutorialCAD - by imploring mixed-methods - showed that gamified systems improved the participant engagement, enjoyment and learning process.

Another study which showed positive results was done by, Denny (2013) who investigated the impact of a badge-based learning system, PeerWise, on students' participation. Results showed that without a corresponding reduction in response quality, the tool positively affected the participants' engagement and time in which students were working with the tool. Students reported that they enjoyed and preferred using this tool and earning badges. PeerWise is a platform in which students create the course related questions and share it with other students. Denny (2013) conducted a large-scale experiment on more than one thousand students, among which half of them were randomly assigned to use the badge-based system as well as the other half who had access to the system but no badges. The results showed that the badges positively affected the number of answered questions and the days' students worked with the tool. However, it did not affect the number of questions that students were required to author. Students also reported that using badges were enjoyable and they preferred to have badges in the system.

By integrating leveling, achievements, points, progress bar and rewards systems into the online WeBWork homework framework, Goehle (2013) investigated the implications of gamification elements on students' engagement. The system with developed gamification mechanics was used in a 16-week course. Results showed that half of the students who completed the homework put in extra effort to obtain achievements. A post-course survey also showed that most of the students tracked their progress and they were eager to gain achievements. However, the impact of gamification on students' performance was still not determined. Another study with the goal of facilitating time-restricted medical residents developed an online quiz system utilizing favorite concepts of gamification. Online activities in this regard were for gaining medical-related certificates. Results indicate that correct response rate and the participation rate was 70% and 80%, respectively. Overall, this gamified setup increased the engagement of participants, but more research is required to investigate the effect it has on student performance (Snyder and Hartig, 2013).

Table 1

Results from the implementation papers in Education

Researchers	Results
Gasland (2011)	Mixed
Dominguez et al. (2013)	Mixed
Mcdaniel et al. (2012)	Mixed
Foster et al. (2012)	Positive
Li et al. (2012)	Positive
Denny (2013)	Positive
Goehle (2013)	Positive
Snyder and Hartig, (2013)	Positive

Gamification in other domains

As well as the educational application of gamification, there are a variety of other domains that use gamified applications to improve the engagement and awareness of participants. Gamification has been widely applied in different fields including marketing, research, health, work, social

networks, crowdsourcing and so on. In this section, we provide some of the studies which applied gamification in different fields. To better understand the role of gamification in various domains, we review the literature on social networks, health, crowdsourcing and close with some studies in other fields.

Social applications: Using Foursquare (a location sharing application) Cramer et al. (2011) employed the effects of gamification mechanics on users' motivation. Mayorship, a gamification element, are customers' status in the application, which is publicly visible on their profiles, and users who check in a venue the most in a specific duration of time would be mayor of that venue. The results showed mixed motivation through gamification mechanics. For instance, when mayorships were challenging to obtain, motivation decreased. However, the gamified elements had a positive impact on motivating identity and ownership behaviors. Another study which investigated users' behavior on the same application (Foursquare) was done by Frith (2012) who detailed how gamified mechanics used in the Foursquare application can encourage specific behaviors of users. Research results show that doing specific tasks and obtaining badges increased participants' enjoyment. However, some users exploited the system with fake location changes to obtain more badges. Frith found that mayorships could lead to negative results including cheating. Generally, the point system had a positive impact on the surprise factor, but the leaderboard seemed to be demotivating for power users.

Another study by Bista et al. (2012) outlined the design of a model with gamification dynamics analyzing an online community to enhance participants' engagement which leads to social cooperation. To tackle some challenges such as bootstrapping, monitoring and sustainability, gamification strategies are deployed focused on participants' contributions and rewarding participants with badges. To monitor community behavior, gamification data were used. The authors showed that gamification could have positive impacts such as using them to track and monitor user interactions. Similarly, Bista et al. (2012) outlined a game theoretic model to investigate how appropriate point rewards can promote the engagement of participants for their honest activities in environments similar to social networks. In this study, the cooperation of participants was measured as a metric of honesty in an online forum. Participants can publish their articles and comments on the forum and others can rate the posts. Both writers and raters receive points based on their activities. Results showed that rewarded interactions were beneficial, enhancing cooperation and engagement factors.

Another line of thought on gamification in some studies is to explore the impacts of removing gamified elements in applications. One study, done by Thom et al. (2012) investigated the impacts of removing gamification features on user activity in a social networking system. Results showed that removing the gamified elements decreased the participation rate and removal of the incentive scheme, such as the extrinsic rewards negatively impacted activity of distant users. The incentive scheme with the goal of encouraging content contribution awarded users different points based on their activities. The analysis of the contributors before and after the removal of the points for the same users showed that contributions of photos, lists and comments decreased significantly and had harmful effects on users' participation.

Another study which aimed to improve the communication skills was done by Hori et al. (2013) who designed a system to quantify communications through a gamified method. In this method,

the frequency of smiles was measured and used as a communication parameter and automated feedback advice was given to participants. In this research, two prototypes were developed, one measuring the frequency participants can make their conversation friends smile, and the other prototype measured the frequency that participants themselves smile. Results showed users' motivation to make their partners smile and frequency of their own smiles in comparison with the no-feedback type of the application. However, this effect did not translate to the partner involved in the conversation. The authors also found out that high frequency of smiles improves users' listening skills even if they have low scores in social skills.

Another study in this field was done by Fit-Walter et al. (2012) who explored the impacts of a designed gamified mobile app to familiarize new students with the campus and its facilities to motivate them to remain at the university. Game elements (with the purpose of improving the students' exploration and social participation) used in this app include leaderboards, rewards, and challenges with various levels of difficulty and time limits. Qualitative results showed that the majority of the students found the app enjoyable, engaging and easy to use. Quantitative results indicated that the majority of the students completed one to four challenges. Moreover, the survey showed that most students were eager to learn more about the university, obtain rewards and complete the challenges.

Table 2
Results from the implementation papers in Social application

Researchers	Results
Cramer et al. (2011)	Mixed
Frith (2012)	Mixed
Bista et al. (2012)	Positive
Thom et al. (2012)	Positive
Fit-Walter et al. (2012)	Positive

Health: Cafazzo et al. (2012) designed and examined a mHealth diabetes application with the use of gamification elements to manage children with type 1 diabetes. Application design principles were derived from the interviews with patients, and their family caregivers and app users were awarded based on specific actions and behaviors, including the number of times they measured their blood glucose, or they entered the app. The pilot evaluations indicated that participants measured their blood glucose increased significantly in comparison to the time they did not use the application (from 2.4 to 3.6 per day), which is promising. Similarly, Rose et al. (2013) highlighted the impacts of a mobile application called mySugr on the compliance behavior of patients with diabetes. In this study, patients were provided with the guideline of how to use the application. Users' progress was monitored within the app and was based on the patients' physical activity and usage patterns. Participants were offered rewards and points for completing challenges or become encouraged to accomplish tasks. Research results showed that by using the application, the number of blood glucose testing increased, and blood sugar level decreased, and the majority of the participants continued to use the app. Likewise, Stinson et al. (2013), designed a gamified iPhone app, called Pain Squad, to assess the pain in children with cancer. Users were supposed to complete surveys related to their pain twice a day, and the answers were transferred to a database to do more analysis. They received points and rewards after completing a specific number of reports. They developed two prototypes to test the usability of the system and to test the feasibility,

they used the results in another prototype. Research results showed that user satisfaction was high, and the app was considered as easy to use.

Table 3
Results from the implementation papers in Health

Researchers	Results
Cafazzo et al. (2012)	Positive
Rose et al. (2013)	Positive
Stinson et al. (2013)	Positive

Crowdsourcing: The word crowdsourcing is the combination of two words crowd and outsourcing which means outsourcing to the crowd (Schenk et al., 2011). According to Howe (2006), "Crowdsourcing is the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call." Therefore, motivational factors have a great influence on participants to take part in crowdsourcing projects, namely, gamification elements. In one study, Liu et al. (2011) designed two applications, UbiAsk and EcoIsland, to investigate the feasibility of applying game elements in human-powered intelligent environments with the aim of improving the overall user engagement. UbiAsk is a crowdsourcing platform for an image to text translation, which uses gamified elements to motivate participants to translate complex scripts or pictures shared by other travelers. Moreover, EcoIsland is an app which motivates users to reduce CO2 emissions. A point system was the game element inserted to both platforms. The evaluation results did not show a statistical significance; one of the reasons could be the small number of participants. The authors argued that the main functionalities of the system are more important than the added gamified elements since gamification provides secondary support and may not provide the user with an enjoyable experience.

In another study, Witt et al. (2011) investigated the effects of gamified elements into the idea management systems to explore if it can be considered as a game-similar experience. In this study, three game elements (social points, game points, and leaderboard) were integrated to engage participants. Users obtained points for certain types of activities and leaderboard made it possible for users to see the feedback regarding their progress and compare themselves with other participants. Research results based on the questionnaire indicated mixed results, and the authors found out that some design factors such as the leaderboard view or unclear placements might be the reason for these results. However, results also indicated that gamification could be a complementary experience for some users since the participants who ranked game elements highly are those who ranked flow, enjoyment and task enjoyment highly as well.

Tiger Nation is another crowdsourcing project created by Mason et al. (2012) with the purpose of promoting the preservation of the last remaining tigers in the world. The application utilizes gaming strategies (image matching game) to enhance participants skills and reliability of collected data. The game was used to verify the results of the stripe recognition software, and improve and confirm the accuracy of the recognition by asking users to vote if different pictures belonged to the same or different tigers. Points and badges were implemented to motivate users and to ensure

their engagement. Research results showed an enhancement in the user's participation and an improved unsupervised algorithm. However, the effect of the gamification is challenging to decide since no control was used.

Similarly, Massung et al. (2013) developed three applications to investigate the effects of various motivational strategies to encourage users to collect data. The first app used the virtual-points strategy, the second app used monetary incentives, and the third app acted as a control without using any motivational strategy. The central goal of the applications was to involve and motivate members of the public in pro-environmental activities who are not as motivated as community members. Public members were given information about the environmental benefits of closed doors and were tasked to collect data on the shops that carry the "Close the Door" logo and follow its policy. Comparing the effectiveness of these three apps showed that virtual point system increased the performance to some degrees, and monetary incentives increased the amount of data collected significantly. Additionally, environmental disposition was not a significant factor. Research results showed that intrinsic motivation to accomplish the environmental activities was not correlated with performance.

Table 4
Results from the implementation papers in Crowdsourcing

Researchers	Results
Witt et al. (2011)	Mixed
Mason et al. (2012)	Mixed
Massung et al. (2013)	Mixed
Liu et al. (2011)	Positive

Other fields' studies: One of the fields which used gamification as a motivator is *environment service*. MIRABEL is a real-time and user-centric energy management system developed by Gnauk et al. (2012), which uses well-known game mechanics, instead of financial incentives, to increase consumer engagement and motivation, tackling the tasks that computers find difficult and hard to plan and predict. Gamified elements in this research were points and leaderboards. Results showed that the test participants found the interface interesting and easy to use. To increase the recycling rates, Berengueres et al. (2013) introduced a recycle emoticon bin which uses gamification elements to motivate participants. Rewarding gamified elements used in this project included: emoticons and sounds; when users dropped PET bottles in the bin, they heard a coin sound and a happy face on the screen for one second. Research results showed that by using the gamification elements, collection rates increased by three times and users preferred to be rewarded with emo-bin rather than the standard bin. The two above mentioned studies are in the field of sustainability which tries to motivate participants with the idea of gamification.

Another field which uses gamification as an incentive is *work* (orientation); Depura and Garg (2012) designed an innovative onboarding program with the use of gamification elements to successfully enhance the new employees' engagement and training at the Fortune 100 organization. Gamification elements used in this project were badges and rewards which were given to users based on their social interactions and their performance rank, respectively. Majority

of the new employees rated the experience as “good” and “awesome.” However, less than 50% of them found the game format interesting, content appealing or learned something new. Quantitative and qualitative analysis showed that applying such interactive techniques can improve the participants' engagement, decreasing additional costs and increasing productivity.

There are also some studies in the field of *banking, health behavior* and *business strategies* (Terry, 2012; Caminal, 2011; Iliev-Piselli, Fadjo, & Lee, 2011) to stimulate the target audience which show that gamification has garnered the attention of many industries in the last decade. Now that we provided the studies with gamification in practice in different fields, we next cover the literature around gamification in computer science (education) in order to provide simulated learning environments and increase motivation in students of computer science.

Table 5
Results from the implementation papers in other domains

Researchers	Results
Gnauk et al. (2012)	Positive
Berengueres et al. (2013)	Positive
Depura and Garg (2012)	Positive

Gamification in computer science

Past successes in the arena of gamification have prompted educators to expand gamification into course design of various majors, especially computer science, in an attempt to increase engagement, interest, and participation. The demand for computer scientists and related engineers has grown and is projected to continue to grow. Therefore, education researchers have designed many studies that apply gamification in order to investigate participants’ engagement. In this section, we will review gamification literature in computing majors which are categorized by courses taught through the application.

Programming courses: Programming courses (especially object-oriented programming) are one of the most demanding subjects of computer science. Participation is an essential factor in learning programming courses in order to obtain the expected skills and overcome barriers in mastering computer science skills. Embedding gamification in programming courses can enhance students’ engagement and develop their process of learning. However, there is a lack of well-organized guidelines (Azmi et al., 2015).

In one study, Ibanez et al. (2014) developed a Q-learning game platform to investigate the effects of gamification on a learning activity targeted at basic concepts of C programming language to undergraduate students. According to the mixed-methods study, gamified learning activities had a significant positive impact on the students’ engagement and improved their academic performance. Game elements such as badges, points, leaderboard, and altruism were inserted into this game platform. Students reported that points were the most motivating element to participate in activities. However, the authors indicated that maybe self-ruling motivation of the students influenced the increased level of engagement.

Similarly, Butler et al. (2016) developed a serious learning game with CS concepts. In this study, students from different majors were asked to play the implemented game in order to measure the level of enjoyment and participation. Authors compared the results (from surveys filled out by volunteers who played the game) to investigate whether a playful strategy to CS programming courses could enhance the students' engagement in such courses. Research results indicated that gamification has a pivotal role in participants' experience and can improve the learning process and retain students in such majors. In another study, Ortiz-Rojas et al. (2017), investigated the effects of gamification on students' LP (learning performance) in the context of computer programming. In this approach, just one gamified component was inserted into a web-based system (Credly) instead of a mix of several gamified elements. The only gamified element in this study were badges. In this study, 100 students were divided into two equal groups: a control group and experiment group. Students were asked to do five arbitrary and mandatory tasks, and programming tests were compared with the results between these two groups. The number of optional tasks accomplished by the students determined the engagement. Research results showed that gamification had a positive impact on the students' engagement but not on the learning performance.

Introductory computer science courses: Using self-determination theory, Behnke (2015) investigated the effects of gamification on students' motivation (intrinsic and extrinsic) and learning process in some introductory courses in computer science courses. Results showed that gamification has the potential to make the learning process more motivating and engaging for the students. However, the authors indicated that learning is a complicated process that an educational context can work for some students and not others. Therefore, designing activities is an essential factor which should be considered in order to motivate and engage students with the material. In another study which aimed to attract more students in the computer science field, Li et al. (2013), inserted some game mechanics into a social based online learning environment, PeerSpace, in order to engage more students in the computer science field and improve their social and learning activities in online environments. Research results showed that using game elements increased students' social activities.

Other computing courses: Buisman et al. (2014) applied game mechanics to an existing project management tool, Redmine, which is used by the case study Educational software Development (ESD) course to examine the implications of gamification. ESD courses in this study include *artificial intelligence, information science*, and *computer science*. Authors researched if this system influences students to use this tool more frequently, and to what extent the game elements used in this project stimulated students' attitudes. Gamification elements in this project include points and leaderboards. Research results showed that students' motivation was not affected significantly by gamification elements used in the app but by the level of enjoyment they had while doing projects. However, the number of points received by the students were raised significantly, and using the point system with the comparison ability increased the use of the system and made a significant difference.

Additionally, Schreuders et al. (2016) presented the design of a gamified *computer security* module and studied different methods to improve students' engagement and motivation to have a better learning experience. The study was done on 32 students over two years. Qualitative and quantitative analysis results were positive. The authors concluded that gamification in an e-

learning system has a positive impact on students' motivation and experience. Also, shifting from conventional methods to gamified environments help students prepare for their future positions and acquire the required skills. Hakulinen et al. (2015), in an experimental study, developed TRAKLA2, an online learning system to investigate the effect of a voluntary badge system on university students' learning behavior, motivation, and encouragement. This study was conducted on 281 university students taking *data structure* and *algorithm* course. Results showed that the majority of students reported that badges had positive effects on them and made them more engaged and motivated toward learning. The authors also indicated that using badges can also become a distraction for a few of the students. With the goal of fostering students' motivation, Souza et al. (2017), developed a software platform to support gamification and game elements inside the classrooms within the background of *software engineering*. Game elements used in this study include badges and leaderboard, and the goal of the study was to investigate the effects of these elements on students' engagement and stimulation. Qualitative and quantitative results extracted from the interviews and surveys indicated that students found the badges more useful; however, the results regarding the leaderboard were mixed. This study focused more on the students' attitude toward the motivational aspect of gamification rather than its effects on the students' academic records.

Similarly, Fu & Clarke (2016), in an experimental study used gamification in a learning environment called WReSTT-CyLe. The purpose of this study was to support gamification and student learning inside *software testing* classrooms at Alabama A&M University (AAMU). Game elements inserted into this system include rewards points, badge, and leader board. Results indicated that if students follow the instructions, they would experience an efficient learning environment and there is a meaningful relationship between gamification and the learning environment.

Comparing a web-based adventure with a conventional web-based game, McLaren et al. (2018) reported that students performed much better while learning *decimal arithmetic* through the game (Decimal Point) rather than the conventional method. The content of the game condition and non-game condition were alike in this study, and 48 problems were implemented for them. The authors also stated that using math educational game enhanced students' enjoyment while learning, and they understood the material better and gained higher scores in comparison with the non-game version.

Table 6
Results from the implementation papers in the field of computer science

Researchers	Results
Buisman et al. (2014)	Mixed
Schreuders et al. (2016)	Positive
Hakulinen et al. (2015)	Positive
Souza et al. (2017)	Mixed
Fu & Clarke (2016)	Positive
McLaren et al. (2018)	Positive

Gamification and women in computer science

The need to produce more computer scientists has drawn even more attention to the underrepresentation of women in computing. Women currently comprise only 15.7% of computing degrees awarded, a proportion that has been declining in the past three decades. Some researchers believe that this is due to the fact that women experience lower perception of self-efficacy and higher perception of computer anxiety (Ahuja & Thatcher, 2005; Venkatesh & Morris, 2000; Whitley, 1997). Many female students believe that traditional approaches of teaching computer science are boring and uninviting (AAUW, 2000; Margolis & Fisher, 2002; Ashcraft et al., 2012). Therefore, gamification can be a potentially promising approach to enhance the engagement and enjoyment of computer science students. There are also some studies which explain that women are more motivated by social factors of games while men are more motivated by achievements (Williams et al., 2008, 2009; Yee, 2006) which aligns to a study done by Gaffney & Dunphy, 2015 that indicated the use of gamification enhanced women's social benefits more than men. While there is a strong body of literature around the implications of gamification on student learning, there are contradictory results in the literature with regards to the interests or attitudes of women, and most of these studies are exploring gaming impacts rather than effects of gamification on women.

Gaffney & Dunphy (2015) provided guidelines for gender inclusivity in dissemination activities related to an energy project. The role of gender in this study assessed how various positions and identities shaped practices. Language, imagery, social media and gamification were mentioned as best practices. The results of this study showed that gamification increases user engagement; however, this is dependent on the context and qualities of the users. Some studies found that females in comparison to males have a perception of lower ability in advancing computer skills, so it makes them less interested in choosing computing tasks due to the fact that they see it as masculine. For the same reason, female students are less likely to choose computing fields as their career, although there are available positions for both genders in such fields (Anderson et al., 2008). However, there are some other studies which found that there is no significant difference regarding gender in computer attitudes when they have equal situations, such as exposure to computers (Wong & Hanafi, 2007; Teo, 2010). In this section, we present the studies related to the use of gamification in the field of computer science and its impact on women computer science students.

To better understand the decline in participation of women in computer science, Wilson (2002), conducted a study to discover different factors that lead to success in computer science courses. Investigating the differences that these factors have on the gender gap was another purpose of this study. Among the twelve factors included in this model, the most important predictors of success were comfort level in computer science class, math background, and attribution to luck, respectively. However, no gender differences were found on these factors except the game playing experience and males were observed to dominate gaming more than women.

In another study, using ScriptEase application (an interactive and module -based programming toolset), Carbonaro et al. (2010) investigated the computer science concepts that students learned by their own games to find ways to measure gender difference and to motivate women to engage with programming. Carbonaro reported that game authoring activities increase the probability of

stimulating children's abstract learning and higher order thinking ability. Authors found that there were no significant gender differences in CS skills, and the activity encouraged both men and women and can potentially solve the problem of underrepresentation of female students in computer science. Authors also reported that females scored much better on higher-order thinking skills in comparison to men.

Similarly, using a mix-method design, Cakir et al. (2017) developed and evaluated a game-design workshop in order to improve young girls' abilities of programming and consequently enhance their views of the CS career. Changing young girls' attitude help them develop their identity as a computer scientist. Analysis of surveys, interviews and game content indicated that the workshop improves the girls' attitude and self-confidence toward computer science. However, the results are short-term impacts of game design on female students. This study suggests that to have a productive learning environment through identity development, providing a supportive setting including activities with the aim of identity exploration can be very beneficial.

Table 7
Results from the implementation papers including gender differences

Researcher	Results
Wilson (2002)	Mixed
Carbonaro et al. (2010)	Mixed
Cakir et al. (2017)	Positive
Gaffney & Dunphy (2015)	Positive

Conclusion and future works

Despite a large collection of literature surrounding the implications of gamification on student learning, there are antithetical results within this body of literature relating to women's attitudes and interest around gamification. Educational research around gamification have, in general, found that gamification can improve student learning depending on a variety of potential factors. These factors include guidelines for the gamification, setting in which the gamification is applied, outcome of interacting with the gamified elements, and even student personality traits. Other studies simply focused on the impacts of gaming with regards to women, not specifically the effects of gamification when applied to computer science women students. Given that the literature surrounding gamification in different fields has mixed results, and that the research completed by Gaffney & Dunphy (2015) suggested that the use of gamification enhanced women's social benefits, further research needs to be completed in order to verify or confirm this phenomenon in relation to women. The critical need for women representation in computer science and the growth of the computer science field behooves us to research gamification and its effect on women computer science students. Specifically, which of the aforementioned factors apply to women. These factors and additionally, the impacts of specific game elements, need to be explored further in order to determine whether the pursuit of gamification in the realm of computer science education directed at women is logical.

Acknowledgements
This material is based upon work supported by the National Science Foundation under Grant Number (NSF Grant 1712116). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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