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Gamification in education: a mixed-methods study of gender on computer science students' academic performance and identity development

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Abstract

Underrepresentation of women in computer science (CS) increasingly demands the necessity to find and enhance current learning engagement approaches to bring more women into computing fields. Some researchers have been exploring the influence of gamification on female students as one of these possible learning engagement strategies. Gamification refers to the introduction of video game elements into non-game activities to enhance engagement and motivation. Previous studies have reported mixed results of the impact of gamification on women. In this study, we introduce SEP-CyLE (Software Engineering and Programming Cyberlearning Environment), an online gamified tool that was designed to provide supplemental computing content to students. This paper presents a convergent mixed-methods study guided by social identity theory and self-efficacy to understand women's experiences with this gamified tool. More specifically, this study explores virtual points' and leaderboards' effects on CS identity development, self-efficacy, and performance. The results show that virtual points and the leaderboard contributed to improved performance for students of all genders, suggesting that gamification is a gender-neutral learning engagement strategy that improves female students' performance as much as male students. Regardless of improved performance, most women did not actively enjoy or were motivated by the virtual points or leaderboard in SEP-CyLE. Additionally, gamification had no significant impact on CS identity development or self-efficacy constructs and had little to no impact on women's interest and engagement in the field of computing.

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Introduction

Gender imbalance in computer science (CS) is a topic that has garnered education researchers' attention, primarily since it is a major that has one of the largest gender disparities in science, technology, and engineering (Cheryan et al. 2011). Underrepresentation of women in CS increasingly demands the necessity to find and enhance current learning engagement approaches to bring more women into computing fields. For this reason, some researchers have been exploring the varying learning engagement strategies (LES) that demonstrate evidence of closing this gap in gender representation. One such learning engagement strategy is gamification. Gamification, the use of video game elements in non-game processes and activities (Deterding et al. 2011), is a learning strategy that has seen heightened interest in the past few decades due to its potential influence on improving users' engagement and enjoyment. Today, students live in an era with interactive social media and video games, suggesting that a gamified environment may also be interesting to them (Glover 2013). Moreover, according to the Engagement Alliance (2020), gamification can provide a unique contextualization that changes users' perceptions and can improve their performance or engagement, possibly improving both simultaneously (Kim 2015).

Since gamification is a relatively nascent engagement strategy, careful consideration is needed when designing gamified platforms to maximize desired beneficial outcomes for learning. Different characteristics such as gender, age, and cultural orientations should be considered in gamified designs, which can lead to changing a user's or group's reception of gamification (Kim 2015) and consideration of the target group and their needs are required for good design practice (Zahedi et al. 2019). Though the reception of gamification on different genders has not been explored in many studies (Buisman et al. 2014; Schreuders et al. 2016; Hakulinen et al. 2015; Souza et al. 2017; Fu and Clarke 2016; McLaren et al. 2018), behaviors of different genders should be taken into account when designing a gamification platform. Some studies show that men are more task-oriented, and other studies show that women are more socially motivated, but it is still important to prevent gender stereotyping when designing gamification platforms (Gaffney and Dunphy 2015) to avoid negative impacts. Likewise, careful consideration should be given to the study of the impact of these strategies on engagement.

Despite recent efforts, the body of literature regarding the impacts of gamification demonstrates that there are inconsistent results regarding the interests or performance of women (Zahedi et al. 2019). Additionally, the limited sample of empirical studies that explicitly explored gender were centered on the impacts of video games and not gamification, and many others suffer from short term treatments (Wilson 2002; Carbonaro et al. 2010; Cakir et al. 2017), often overlooking the participants who may lose interest toward the end of the experiment. Regardless of the popularity or initial effectiveness of gamification, some studies have shown that a gamified environment might be appealing to the users due to the novelty effect, and that

positive impact may decrease over time and go back to the baseline after a while (Farzan et al. 2008; Koivisto and Hamari 2014) when long term outcomes are expected. Further research is necessary to investigate the consequences of gamification not only on performance and engagement, but also its context and impacts on constructs such as self-efficacy and identity development; these constructs are often identified as having an influence on persistence in STEM fields (Godwin et al. 2016; Hazari et al. 2010; Taheri et al. 2018). Rigorous inquiry in this arena will help to identify where gamification is beneficial or deleterious to women's success in CS.

In this study, we investigated gamification's effects on women's CS identity development and self-efficacy and their experiences with gamification. Almost all incentives and rewards offered by gamification have a theoretical basis for stimulating self-efficacy, which can either enhance or impede motivation and performance. We also explored whether there are any gender differences in usage patterns regarding gamification and earning points. These usage patterns are captured through SEP-CyLE, an online gamified tool that rewards adult students' successful activities with virtual points. This gender-focused study was conducted utilizing convergent mixed-methods to investigate behavior and performance (in terms of learning outcomes) of undergraduate computer science students when interacting with SEP-CyLE. The study aims to analyze the use of game elements in educational systems to improve students' performance and self-efficacy during the learning process.

The rest of the paper is organized as follows: in Sect. 2, we first provide an overview of gamification, including some studies on the impacts of specific game elements, studies exploring gamification's impacts on performance, and finally, gender studies. Section 3 covers the theoretical framework, where we explain why and how it guided the research team in answering this study's research questions. Section 4 presents methods and analyzes SEP-CyLE's use of gaming elements in relation to identity, self-efficacy, and performance. Section 5 reports our findings. Lastly, Sect. 6 concludes the paper and provides recommendations to the computing community to provide students of all genders an opportunity to learn skills and tools that create diversity in computing fields. Additionally, it helps them have the best possible academic experience, thus contributing to equity.

Background

Gamification

As mentioned in the introduction, gamification is the use of video game elements in non-game processes and activities (Deterding et al. 2011). Unfortunately, many people misunderstand the difference between gamification and video games, especially with regards to education. Gamification and video games in the field of education play different roles in educating, depending on the primary purpose of the application. The primary role of video games is entertaining and then educating, while for gamification, the order is the other way around (Goehle 2013). The impact of video games has proven to have positive results on gamers' motivation. Therefore, inserting game elements in non-gamified applications has the potential to attract more

users (Flatla et al. 2011; Zichermann and Cunningham 2011). While there is potential for gamification, the literature has been inconsistent with results, likely due to the lack of study surrounding individual game elements.

The contradictions in the literature can be seen depending on the context, topic, and applied game elements. Lots of studies have found that gamification in education has positive results (Foster et al. 2012; Li et al. 2012; Denny 2013; Goehle 2013; Snyder and Hartig 2013; Stott and Neustaedter 2013; de-Marcos, De-Marcos et al. 2014). However, not all research shows the positive effects of gamification; many studies have inconsistent findings (Gasland 2011; McDaniel et al. 2012; Dominguez et al. 2013). Additionally, Zahedi et al. (2019) developed a review of 33 empirical studies in the field of gamification across different contexts, in which more than half of the studies in the field of education showed positive aspects of gamification, such as increased performance, enjoyment, and engagement. However, there were also a fair amount of mixed results. It is important to note that our review resulted in only four studies that considered gender as a factor within their gamified settings, underlining the importance of studying gender more closely within gamification. Given prior findings, it is clear that the context in which gamification is applied (environment, content, chosen game elements, and target group) can affect the results. Therefore, increased attentiveness is required when applying game elements.

Next, we will describe some mechanisms leveraged in gamification and their reported effectiveness, define performance as it is used in this study and in relation to existing gamification literature. Then, we will close with the current state of gamification as it relates to women.

Points, badges, leaderboards

Leaderboards, points, and *badges* are the most common game elements across different fields, respectively, and are regularly used to gamify applications (Hamari et al. 2014). Points are the numerical units (also referred to as scores) that show the progress of users. Leaderboards or rankings are the mechanism to display users' rank mostly for comparison or competition purposes (Camilleri, Busuttil, & Montebello 2011; Seaborn and Fels 2015). Badges (trophies) are visual icons showing participants' achievements. Some game scholars use the term "pointsification" for gamification in those applications which exclusively use these three elements (Bogost 2011; Kapp 2012).

Although there is a strong body of literature around the implications of gamification in education, there has not been a lot of recent research in this realm. There are mixed results regarding the impact of specific game elements on engagement and motivation. Frith (2012) explored the impacts of points, badges, leaderboards, and status in an application to encourage specific behaviors. Their results indicated that doing specific tasks and obtaining badges increased participants' enjoyment and that point systems had a positive effect on users, but the leaderboard seemed to be demotivating for some participants. Liu et al. (2011) also designed two applications with points, badges, leaderboards, and status to encourage the users' participation. They discovered that gamification improved the speed and quality of the responses to the system's questions. Binti Mohd Nor Hisham and Sulaiman (2017) conducted an

experimental study comparing experimental and control groups in an online application with progress bars, points, and badges. The results of this study showed that there was a significant difference between these two groups regarding engagement. Still, the number of users completing the course in the experimental group was higher, which shows that gamification improved the completion rates. Bernik et al. also compared the achievement of control and experiment groups. This study's findings indicated that students' performance in the experiment group was much higher than students in the control group. Huang and Hew (2015) also gamified a Moodle SPSS (Statistical Package for Social Sciences) course. The authors found that leaderboards and badges motivated the majority of the students, and points motivated students to do the challenging tasks while the students in the control group did not perform that same. Aldemir et al. (2018) investigated users' attitude towards gamification elements, including leaderboards, points, badges and found that, in general, users have positive insights about the game elements inserted into a gamified course. Tsay et al. (2018) also opted for some gamification elements, including badges and a leaderboard, and compared the experiment and control groups with results that suggest that students in the treatment group were more engaged and therefore had a better performance compared to the control group.

Gamification has a multitude of aspects to explore. What is missing from these studies is a clear discernment of which game elements provide the users with the highest effectiveness; many studies use a combination of many game elements instead of singling out game elements, specifically. Virtual points and leaderboards, especially points, are among the most common elements used in gamified environments (Gasland 2011; Goehle 2013; Cramer et al. 2011; Bista et al. 2012; Frith 2012; Thom et al. 2012; Cafazzo et al. 2012; Liu et al. 2011; Witt et al. 2011; Massung et al. 2013; Gnauk et al. 2012; Rapp et al. 2012). This study focuses on the effectiveness of an online gamified system (SEP-CyLE), which gives students various tasks to earn virtual points and compete for higher ranks on a leaderboard. Our goal was to examine how these specific elements affect self-efficacy, identity, and performance in women.

Performance

Performance in different contexts may be operationalized differently; however, performance in education usually refers to students' course final grades, graduation rate, cumulative GPA (grade point average), or assignments (Boumi et al. 2019, 2020; De-Marcos et al. 2014; Dominguez et al. 2013; McDaniel et al. 2012). In some studies (Mirzaei et al. 2019, 2020), performance is measured by assessing learning gains evident in students' pre-and post-test grades. However, for the purpose of this study, performance refers to students' final grades since performance is a strong predictor of persistence through college in computing majors (Zahedi et al. 2020).

Like other studies in gamification, impact on performance has reported mixed results within the literature. In a study done by McDaniel et al. (2012), a gamified online system with badges and leaderboards was used to promote targeted behaviors, such as taking an exam within specific timeframes or giving helpful feedback to students' work. Results showed that badges encouraged competition and motivation,

and the leaderboard also affected students' engagement. Gamification modestly improved the students' grades in the course. Findings from another study completed by Dominguez et al. (2013) used a gamified add-on with levels, challenges, badges, and leaderboards which was used by the experiment group; 44% percent of this group used gamification features, and results revealed that gamification improved students' practical assignments and overall final grades. However, their performance regarding the written assignments was low. Previously, studies have shown that the presence of a leaderboard may lead to feelings of competitiveness amongst users and can result in increases in portal activity and score performance (Christy and Fox 2014). However, it should also be noted that the presence of a leaderboard may increase cheating, as students feel compelled to rise higher in the ranks relative to their peers (Orosz et al. 2013).

Studies that explore gender

While there are not many studies demonstrating the differences between men and women regarding the performance impact of gamification, those that exist show mixed results as well. One gender study demonstrated that gamification (points, badges, levels) improved male students' performance, but no improvement was observed for female students (Pedro et al. 2015). Another gender study demonstrated that gamification improved students' engagement, generally. Engagement can be defined as "[a] psychological investment in an effort directed toward learning, understanding, or mastering the knowledge, skills, or crafts that academic work is intended to promote" (Newmann et al. 1992, p. 12). Despite this engagement improvement, it was not equally effective for both genders since female students outperformed male students regarding engagement and final outcomes (Khan et al. 2017).

According to Venkatesh and Morris (2000), when considering the likelihood of adapting and using new technology in a work setting, males and females are equally likely to begin using it. However, gender differences exist in terms of which features are most valued. Males are more concerned with how useless the new technology is, whereas women are more concerned with how easy it is to use the new technology. Claims such as these align with some gamification studies that state that women reported greater social benefits using gamification (Gaffney and Dunphy 2015; Koivisto et al. 2014).

Lack of theoretical frameworks and studies around self-efficacy

Another issue with the existing literature is the lack of theoretical frameworks described in the design of the gamification studies (Seaborn et al. 2015). Additionally, there is a gap in the literature surrounding self-efficacy and gamification. We found just one study surrounding the impacts of self-efficacy and gamification by Ortiz-Rojas et al. (2017) that found there were no significant impacts on learning performance, intrinsic motivation, and self-efficacy in a quasi-experiment using a web-based application called Credly. The study mentioned that further research is needed to understand the lack of connection between the aforementioned variables.

The presented study was guided by the theoretical frameworks of social identity theory and self-efficacy to fill this gap in the literature.

Theoretical framework

Social identity theory is an established theoretical framework founded by Henri Tajfel (1979) in psychology that promotes understanding in participation within sciences and engineering, including CS (Stryker and Burke 2000; Taheri et al. 2018). Exploring role identity within social identity theory enables us to understand better how a role or identity impacts engagement (Pugh et al. 2010), retention (Perez et al. 2014), and persistence (Pierrakos et al. 2009). In this context, identity is defined in three general ways: how someone describes themselves (Brickhouse et al. 2000), how they relate to others in a community (Buffum 2015), and how they talk about how they act or participate in a community (Brickhouse and Potter 2001). Understanding how women identify as it relates to roles in computing could be crucial to improving gender parity within CS and computing-related fields. Previous research demonstrates the importance of identity in students' success and academic performance (Godwin et al. 2016; Hazari et al. 2010). Additionally, other studies have explored the contribution of computing identity to students' academic performance and persistence and how cultural factors or experiences impact female students' decisions to choose CS as their career choice (Kargarmoakhar et al. 2019; Kargarmoakhar et al. 2020). Social identity theory enables us to pinpoint factors that promote or inhibit a CS career choice. Therefore, this framework can distinguish whether gamification as a learning engagement strategy increases or decreases computing identity salience within women in this inquiry. When designing the study, we used identity theory, specifically, role identity, to aid in developing the interview protocol. Leveraging prior work, we designed an interview protocol that helped to unpack how women that used the gamified SEP-CyLE tool perceived their identity was influenced by that experience (Ross 2016). Interview questions for the protocol were drawn from these prior works and include the following sample questions: How would you describe yourself in the context of computer science? Do you consider yourself a computer science person? Do you intend to continue as a computer science major?

The other theoretical framework used to guide this study is self-efficacy. Self-efficacy is defined as someone's personal beliefs that they can perform behaviors necessary to act or perform in a specific role (Bandura 1977). Self-efficacy is a student's belief that they can be successful in computing (for this study). They feel confident in their ability to start and complete their course in computing and/or their degree in computing. Self-efficacy has been identified as one of the many reasons women do not continue in CS and may dismiss it as a potential occupational pursuit when considering career paths (Cheryan et al. 2009; He and Freeman 2010). Therefore, discovering gamification's impact on women's self-efficacy has significant consequences for improving retention, performance, competence, and engagement of women in CS. Prior work demonstrates the importance of self-efficacy to students' success and academic performance (Cribbs et al. 2015).

Almost all incentives and rewards offered by gamification have a theoretical basis for stimulating self-efficacy, which can either enhance or impede motivation. These incentives and rewards include sound effects, progress bars, points, mini-games, challenges, or quests; badges; virtual goods; leaderboards; rewards-choosing colors or power; achievements; and levels (Reiners and Wood 2015). Specifically, in the computing field, Banfield and Wilkerson (2014) conducted a study whereby gamification was assessed as an experiential learning theory on student motivation and self-efficacy in a System Engineering/Information Assurance course. Their analysis demonstrated that increasing gamification increased student intrinsic motivation and self-efficacy in these computing courses. These findings indicate that gamification can have a positive impact on self-efficacy and intrinsic motivation. As such, we also decided to explore self-efficacy through the interview protocol to ensure we adequately explored participants' perceptions of their ability to complete tasks in their computing course with integrated SEP-CyLE in their second interview. Interview questions for the protocol were drawn from these prior works and include the following sample questions: Have you found the course work to be challenging? Describe how. Would you describe yourself as confident about the major/discipline? Why or why not?

In the past few years, there has been increased popularity of gamification in education and industry (McGonigal 2011; Glover 2013; Bernik et al. 2015; Binti Mohd Nor Hisham and Sulaiman, 2017; Aldemir et al. 2018; Tsay et al. 2018). However, there are some potential areas for concern over its benefits in some fields, such as education. Findings from previous research regarding gamification show that most studies did not run statistical analysis, nor were they driven by or grounded in theory (Seaborn et al. 2015). While there is a substantial body of literature surrounding identity theory, self-efficacy, and gamification individually, there are gaps in the literature when discussing gamification's impact on women's self-efficacy and identity. This study addresses some of the limitations of previous empirical research on gamification, such as singular assessments, lack of theoretical framework, and a high number of game elements. To do so, we designed a convergent parallel mixed-methods inquiry to evaluate and understand social identity theory and self-efficacy described by our participants. These frameworks were utilized to understand how SEP-CyLE affected social identity development (more specifically computing identity) and self-efficacy in women students. In addition to these variables, performance was measured in the quantitative analysis. In this study, four research questions were investigated:

1. How do women CS students describe their experiences with gamification?
2. What impact does gamification have on CS identity development and self-efficacy of women?
3. Is there a significant relationship between gamification and the student's performance?
4. Are there any significant gender differences in usage patterns and learning gains with regards to earning points?

Methods

Research design

To answer the study's research questions, we used a mixed-methods design to provide a comprehensive analysis of the research questions and improve the overall strength of the findings. Utilizing this design allowed us to observe the evolution of identity and self-efficacy beliefs, one-on-one descriptions of experiences with gamification, and gamification's impact on student performance.

Mixed-methods is a well-established approach for collecting, analyzing, and mixing qualitative and quantitative data in a single study. By collecting both qualitative and quantitative data, we could better understand research problems using the advantage of using both close-ended quantitative data and open-ended qualitative data. The mixed-methods analysis enabled us to have a general understanding about the population while simultaneously allowing us to develop a nuanced view of specific concepts for individuals with the help of quantitative and qualitative analysis, respectively (Creswell and Creswell 2017). This study used a convergent parallel mixed-methods design, which consists of two distinct phases. In this design, two independent strands of qualitative and quantitative data are collected and analyzed in a single phase. The results are then merged during the overall interpretation to look for convergence, contradictions, or relationships of two sources of data (Creswell and Creswell 2018).

Setting and participants

SEP-CyLE

The Software Engineering and Programming Cyberlearning Environment (SEP-CyLE) is a configurable learning and engagement cyberlearning environment that contains digital learning content in the areas of software engineering and programming (Chang-lau and Clarke 2018). It was created at a metropolitan public research university as a part of a funded research project that sought to find unique ways to deliver supplemental content to students enrolled in computing courses. SEP-CyLE uses embedded learning and engagement strategies (LESs) to get students more engaged in learning activities. These LESs include collaborative learning, gamification, problem-based learning, and social interaction. The learning content includes Digital Learning Objects (DLOs) and tutorials specific to different areas of software engineering and programming, such as software testing and introduction to programming (CS1) (Smith 2004). SEP-CyLE is an instance of STEM-CyLE, a framework that can be used to instantiate an application for any given STEM course. Figure 1 (below) shows the block structure of STEM-CyLE, which is the same structure used in SEP-CyLE. SEP-CyLE consists of 5 major components: Authentication, Embedded Learning and Engagement Strategies (ELESs), Learning Content, Administration, and Course Management.

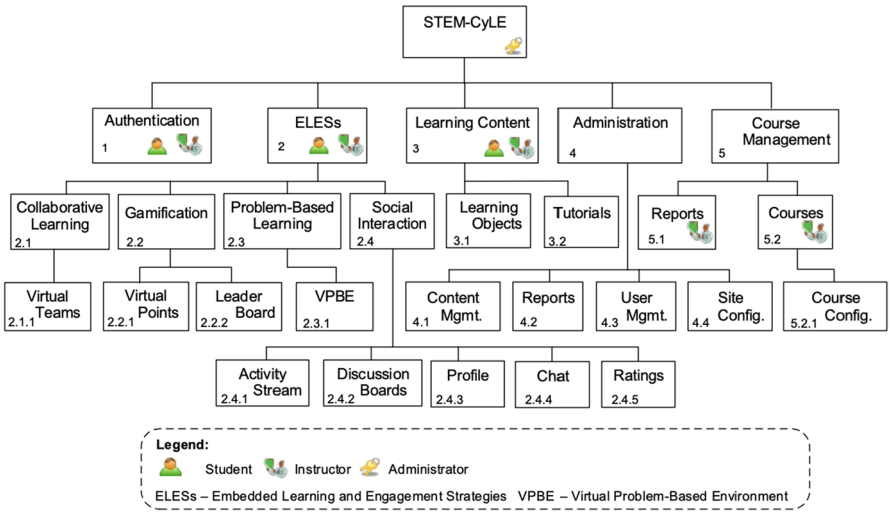

Fig. 1 Clock structure architecture of STEM-CyLE

The gamification LES is shown as the box labeled 2.2 in Fig. 1 and consists of virtual points (Box 2.2.1) and a leaderboard (Box 2.2.2). Virtual points are awarded for completing various tasks in SEP-CyLE. These tasks include completing a DLO and obtaining a percentage above some predefined value, posting to the class forum in SEP-CyLE, and completing the user profile. These points are awarded based on individual activities or as part of a virtual team. The leaderboard shows the five students with the highest virtual total points in the class at any time. The leaderboard can be shown in two modes: anonymized (aliasing) and non-anonymized. Currently, only a web-based version of SEP-CyLE is available to students. Additional details on the structure of SEP-CyLE can be found in (Duke et al. 2019).

SEP-CyLE is accessible outside of the classroom, and the original intent was for students to use SEP-CyLE to supplement the in-class learning activities. The supplementary nature of SEP-CyLE is particularly helpful for classes that use a cross-section of tools and need vetted tutorials on how to use the tools. For example, this is helpful for some courses such as Fundamentals of Software Testing, where students are expected to use at least five tools to test various parts of the software application assigned in their class project. It should be noted that within the content of the tool, no gender-based terms or images were explicitly used. Instructional messages were written based on the topic itself with no specific set style across topics.

Figure 2 shows the instructor's partial screen in SEP-CyLE to allocate the points for a class using SEP-CyLE. In Fig. 2, the instructor has allocated 10 points for a student that completes the DLO assessment quiz with 70% or greater. Collaborative learning was enabled for this class; therefore, the class was divided into virtual teams and was awarded points as follows. If the entire team completed the DLO assessment quiz with 70% or greater, each team member received five bonus points. The first team to complete the DLO assessment with 70% or greater, each team member received 10 bonus points. Second-place team members each received five

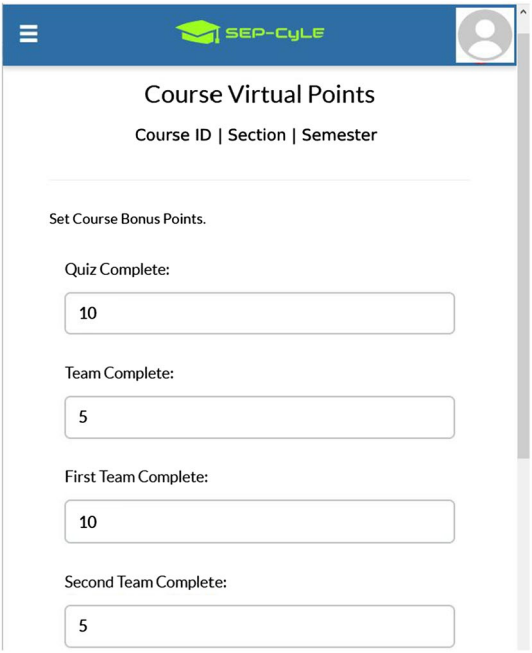

Fig. 2 Instructor's partial screen to set virtual points for the class in SEP-CyLE

points and third place team member three points. Students that uploaded a picture to their profile received one point and if they posted to the course thread, they were awarded two points.

Figure 3 shows the screen in SEP-CyLE used to enable the LESs, all LESs available in SEP-CyLE are enabled for this course. In addition, the aliasing feature is enabled since the virtual points are used as part of the course grade.

Figure 4 shows the student's dashboard for the class. The dashboard of the tool includes buttons for the following:

Assignments—DLOs assigned to the class,

Tutorial Assignments—tutorials assigned to the class (does not contain an assessment component),

Leaderboard—current leaderboard for the class,

Course Forums—post made to the class forum,

My Course Activity—activity of the student, and.

Course Activity—activity for all the students in the class.

Below the quick access buttons (Fig. 4) in green, is the leaderboard showing the top three students in the class using aliasing. Note only the student knows their alias identifier.

Now that we have described the tool and its features, we would like to note that not all LES strategies were activated during our study. Only the virtual points and leaderboard LESs were selected by the instructors that participated in this study.

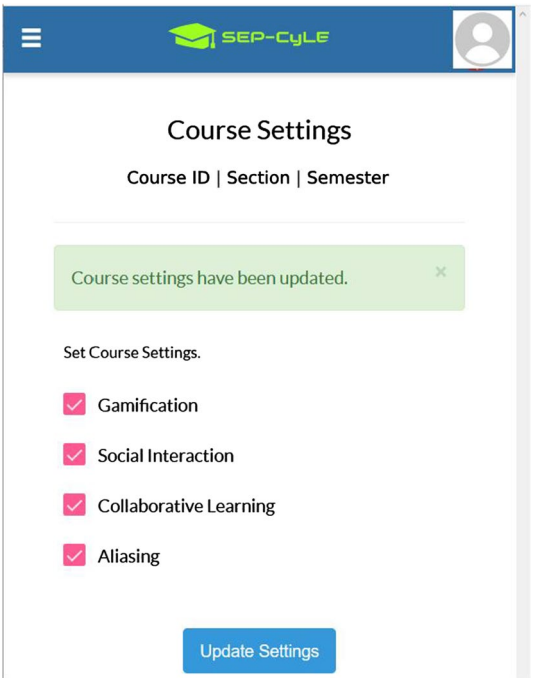

Fig. 3 Instructor's course settings screen in SEP-CyLE

As such, our findings are isolated to these gamification features. Now we will continue describing the research design, namely the participants, data collection, and analysis.

Participants

This study used both purposive and convenience sampling. We used purposive sampling in that we only elicited participation from courses that we knew already had SEP-CyLE integrated into their course. The convenience sampling was leveraged during the qualitative portion of the study, in that we only solicited from the students in that course. Due to the nature of the mixed-methods approach, this study has unequal samples for the qualitative and quantitative parts from different resources: SEP-CyLE and interviews. The research team only interviewed a sub-sample of the overall quantitative sample (Fetters et al. 2015). The quantitative sample consisted of all of the students currently enrolled in the programming course with SEP-CyLE; meanwhile, the qualitative sample consisted of only the women in the class that elected to participate when we solicited participants. As previously stated, we collected qualitative data through two interviews at the beginning and the end of each semester. Quantitative data was collected from SEP-CyLE's already collected usage

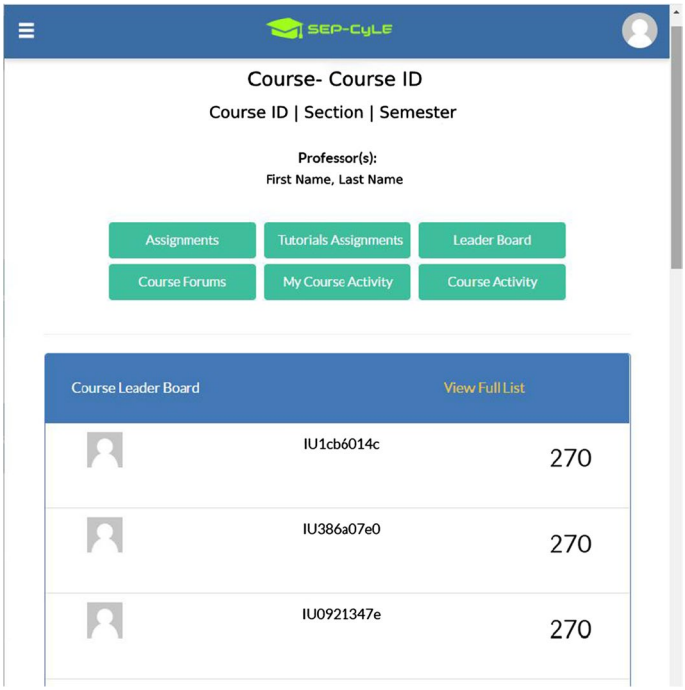

Fig. 4 Student's partial dashboard for a CEN 4072 class in SEP-CyLE

data and was used for analysis at the end of each semester. An institutional review board approved the research design, and investigators obtained online consent from each student before using SEP-CyLE. Moreover, additional written consent from participants was obtained before doing interviews.

The quantitative part of the study consisted of 181 undergraduate CS students registered for a programming I course, collected during three semesters. As is the case in most CS courses, the number of female students was low. There were just 34 of the 181 students that self-identified as females (about 19%). The qualitative portion of the study consisted of a series of interviews with 11 women in the SEP-CyLE-integrated courses.

Qualitative phase

Data collection

Qualitative data were collected through two interviews with the participant. The first interviews were conducted before they encountered SEP-CyLE and once after they had completed the course. We will refer to these as pre-interview and post-interview from here on. Each interview had its own semi-structured interview protocol, described more in-depth below. One research member conducted

a majority of the interviews, but a few were conducted by other members of the research team who had been trained to conduct qualitative interviews. All interviewers used a semi-structured interview protocol operationalized by the main investigator based on the theoretical framework and research questions to guide the interviews. Training of all interviewers consisted of rehearsal of the interview protocol with each other to become familiar with its structure and ensure strong interviewing skills, as suggested by Adams (2015) as a best practice in conducting semi-structured interviews.

The protocol was semi-structured to provide flexibility in probing to understand better, clarify, and obtain meaning from the interviewees' thoughts, observations, and experiences. If a question was asked from the protocol and the interviewer needed to elicit more information for clarification, a probing question could follow that question. Utilizing a semi-structured interview protocol ensures the quality and dependability of interview data by providing main questions that all interviewers must ask while also providing flexibility in asking open-ended questions surrounding those main questions (Adams 2015). The interviews were conducted in private offices to protect interviewee confidentiality and ensure the quality of all audio recordings.

Pre-interviews Every semester, a member of the research team solicited participation from the female students in the class prior to using SEP-CyLE. Females in the course then self-selected and volunteered to participate in the pre-interview. The pre-interview included six general types of questions: demographics, computing pathways,

Table 1 Pre-interview questions included in the semi-structured interview protocol

Variables measured	Sample questions
Demographics	How do you identify in terms of gender, race, and ethnicity? Were you born in the US or abroad? What year of your program are you in?
Computing pathways	Can you walk me through how you decided to go into computer science/IT? Was there a teacher or counselor that encouraged you? Was there a friend that encouraged you?
Computing identity	What computer science courses have you taken so far? Do you consider yourself to be a computer science person? How would you describe computer science to a friend, neighbor, or family member?
Self-efficacy in computing	Would you describe yourself as confident about the major/discipline? Why or why not? How would you describe yourself in the context of computer science (beginner, intermediate, expert)? Have you found the coursework to be challenging?
SEP-CyLE attitudes	Are you familiar with SEP-CyLE? If so, what was your expectation of the tool?
Gaming attitude	Would you describe yourself as competitive? Why or why not? Do you enjoy video or PC games? Why or why not?

computing identity, self-efficacy in computing, current expectations of SEP-CyLE, and gaming attitude (see Table 1).

Post-interviews After using SEP-CyLE and at the end of the semester, we followed up with the students who did the pre-interview. The post-interview included four different types of questions: computing identity, self-efficacy in computing, SEP-CyLE experiences, and gamification feedback. The post-interview included the same questions from the pre-interview from the computing identity and self-efficacy in computing categories to identify any shifts in attitudes regarding these constructs. In addition to these questions, we also added questions regarding SEP-CyLE experiences and gamification feedback to obtain insight into the individual's personal experiences with the tool and gamification (see Table 2).

Qualitative data analysis

All interviews were audio-recorded, and the audio was subsequently sent out to be transcribed verbatim by a third party. After transcription of the audio, three of the researchers started to deductively code the interview data utilizing a provisional list of descriptive codes based on the theoretical framework (social identity theory) and research questions in the initial coding phase. New codes were added as needed, and sub-codes of those new codes were created to further analyze any important sub-concepts. The second phase of coding consisted of another round of detailed line-by-line combing through the interview data to further clarify any new codes created in the initial phase and remove any codes unnecessary to answering the research question that may have been included within the initial codebook. The final phase of coding consisted of axial and thematic coding to further fine-tune codes and

Table 2 Post-interview questions included in the semi-structured interview protocol

Variables measured	Sample questions
Computing identity	Do you intend to continue as a computer science major? Do you see what you learned as valuable? Why/how or why not?
Self-efficacy in computing	Do you feel good about the end of the semester? Do you feel confident about the material? Why or why not? What was most important to you—good grade or understanding content?
SEP-CyLE experience and attitudes	How was your experience? Did SEP-CyLE meet your expectations? How or how not? What would you have liked to see? What is your favorite part of the tool?
Game elements	What are your thoughts on the virtual points you earn for completing activities? Helpful or not? How did earning them make you feel? What are your thoughts on the leaderboard? Did it make SEP-CyLE more competitive? Why or why not? How do you feel about virtual teams and virtual collaboration? Helpful or not? Why? Did you find the forums to be helpful? Why or why not?

create broader categories to explain and describe the experiences of the phenomena of working with SEP-CyLE. All phases of coding were completed collaboratively through investigator triangulation utilizing three different members of the research team to maintain the validity and consistency of findings. Meetings were conducted throughout the different phases of analysis to discuss perspectives, interpretations, and redundancy of existing codes. Data collection was halted once data saturation was met, and no new themes were emerging from the thematic analysis.

Quantitative phase

Data collection

Quantitative data was collected throughout the semester by the tool and included data points related to time in the module, time on quizzes, and quiz results. The data were not analyzed until the semester was completed. The post-semester data was extracted directly from SEP-CyLE at the end of every semester, including fall 2017, spring 2018, and fall 2018 semesters from the relevant SEP-CyLE courses. In total, the sample included 181 undergraduate CS students. The data from SEP-CyLE included students' personal information such as their identification number, age, gender, quiz scores, the total time spent on the system, and total virtual points they obtained from the gamified elements in the application. However, for the students' final grades, we solicited the instructor and matched the students' ID with their final grades. Total virtual points were considered a criterion for gamification in this study and students' final grades as a criterion for their performance.

Quantitative data analysis

Analysis of the quantitative data was completed using descriptive and inferential statistics to assess differences between genders. All analyses were conducted using the R statistical language (R Core Team 2013). The criterion factor of our quantitative study was the final grade for each of the students. The final grade was identified as one factor that could be measured for student performance. The research team acknowledges that there are less biased means of evaluating performance; however, the tool's design did not allow for such data collection at the time. We executed a correlation study, in which data were collected from each of the students. Different variables, including gender, total time spent on SEP-CyLE, and total virtual points were compared to the course's final grade.

Quantitative data were analyzed to explore if any significant gender differences were seen in earning virtual points and final grades. Backward elimination, a stepwise type of regression, was applied to see which candidate variables positively or negatively affected the dependent variable. In the beginning, a full model with all candidate variables was constructed. In each step, the variable with the most insignificant deterioration was eliminated from the model, and a new model was reconstructed. This process was repeated until no further variables could be eliminated from the model. The main advantage of using stepwise regression is that it searches

among many possible models to find the best one. Following are the steps of the backward elimination:

1. Choosing the significance level: P-value is used to determine if each predictor variable is statistically significant or not. If the p-value for a given test is above our set alpha of 0.05, the maximum acceptable chance of Type-I error (false positive), then it is treated as not significant (that is, the null hypothesis of no association between predictor and outcome is NOT rejected unless the p-value is less than 0.05). An alpha of 0.05 is commonly used as it acceptably balances the chances of Type-I and Type-II errors (false negatives), which are somewhat inversely related. Given the sample size in this analysis, reducing alpha to limit Type-I error would also likely lead to significant Type-II error as the sample's statistical power is relatively low. Therefore, an alpha level of 0.05 was used to determine the significance of staying in the model.
2. We fitted the full model with all possible independent variables, which include gender (x_1), total time (x_2), and total virtual points (x_3)—the independent variable (y) in this model is the final grades of students.

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \varepsilon \tag{1}$$

3. We checked the variable with the highest p-value. If the p-value of this variable was more than the determined significance level, we took the variable out.
4. We fitted the model with the remaining variables again to check the effects of the removed variable on all other variables in the regression. At this step, we go back to step 3 and repeat these steps again until we have a model that the value of the variable with the highest *p*-value is less than the defined significance model (0.5).

Findings

Qualitative

To strengthen the rigor and quality of our study, we refer to Morschheuser et al.'s (2018) framework for effectively engineering gamification across a multitude of domains, including education where they compared and contrasted results from other studies and general gamification design practices. We use these best practices as an analytical framework for interpreting our results due to its strong use of grounded theory and design science. These methodologies apply a holistic approach to systematically synthesizing results across gamification studies. Additionally, Morschheuser's work integrated experience and advice from 90 gamification experts in the field to strengthen its findings.

During the qualitative analysis of the interviews, when asked to describe their experiences with SEP-CyLE and its gamified features along with information given by participants' regarding past CS experiences, three major themes

emerged around their experiences with gamification, including: (1) their experience with the user interface (UI) in the tool, (2) their perceptions and feelings around gamification (loved it or were apathetic towards it), and (3) how it explicitly or implicitly affected their self-efficacy and CS identity development. As such, these themes are described in detail below.

User experience with UI and implementation improvements

When students were asked to describe their experiences with SEP-CyLE, many students expressed that they dealt with a multitude of issues while using the tool. These issues included glitches, "gaming the system," and improvements needed. Experiencing these issues was one of the most frequent themes expressed during the interviews found during the thematic coding portion of the data analysis. Participants expressed confusion and frustration using the tool due to these issues and glitches, specifically describing problems submitting their quizzes and the marking of answers incorrectly by the software:

> I had the problem where when I would submit it, it would just automatically refresh the quiz or the practice, and it wouldn't give me my results. So, I did it, but I couldn't get my results back. So, since the results wouldn't come out, I guess it says I didn't do [the quiz].—Batgirl.

> […] it would mark all the answers like regardless of what you put, it would just mark it as wrong even if the proctors had marked it as right… and I think she reopened the assignments for us to do it, but I don't know, there's just confusion there.—Jackie.

> There were some glitches, it would say all the answers you put are wrong.—Rose

This theme reveals a lot about how the design and implementation of gamification within a software platform affects user behavior and interaction with the tool, along with how it affects the effectiveness of the gamification. According to Morschheuser et al. (2018) "[…] continued user and playtesting after development cycles, is a recommended practice to evaluate and optimize the designed gamification, ensuring its effectivity and success […]" (pp. 227–228). Although we did not do any formal usability or UX tests for SEP-CyLE at this university, some of the collaborators at other universities did do usability/UX studies involving SEP-CyLE in computer science (Alomari et al. 2020). The authors' experiments demonstrated that students could efficiently use SEP-CyLE to complete their tasks and improve their software development skills. However, they also found that the tool needs some improvements regarding the navigations and visibility of the tool's current design that could confuse the students somehow. Further testing and debugging of the software could ensure that these issues are avoided for future users of SEP-CyLE and improve gamification's effectiveness.

In addition to these software utilization challenges, some of the participants expressed concern that the quiz questions did not change. Participants said they could "game the system" by retaking the quiz many times without understanding the answers. As one participant aptly described it:

> […] if you do the practice or quizzes wrong, the questions don't change, so if you already know what you put… what the right answers were for the previous attempt, then you can just do it without… [you could] just change it without actually trying to understand it.—Jinx.

Morschheuser's culmination of best practices for gamification found that gamification should seek to control and curb the ability for cheating and gaming the system to prevent discouraging users and reversing the positive effects of gamification (p. 224) since gamification is used to promote motivation and engagement in learning a topic. Practice is essential to learning content. However, using a more extensive test bank for practice quizzes would help minimize cheating efforts by students. Zichermann and Cunningham (2011) do emphasize however, that any system that is of value, people will attempt to exploit, and that in a game or gamification design, you should first "focus on the novice [user's] needs, and build anti-exploitation features over time" (p. 73), suggesting that future iterations of SEP-CyLE (and other gamification designs) should aim to reduce these vulnerabilities as they are discovered, even if elimination is impossible.

One last subtheme discovered during analysis included participants' desire to see their grades later on. This theme is best explained by one participant below:

> [I wish] that I could see my grades… it doesn't let me see my grades and I [receive] 100% despite whatever answer I put… I don't know if that grade registers or the grade that I put in… I don't know which one registers, so I'm kind of nervous about it.—Ndog.

Making this improvement may alleviate some of the stress, confusion, and frustration experienced by participants when interacting with SEP-CyLE and increase the frequency in which users interact with the tool. Morschheuser notes that "[…] a gamified software thus has the double requirements of being 1) operationally well designed to function as intended, 2) facilitate engagement with the software so as to ensure manifestation of appreciated behaviors and behavioral change […]" (p. 220). Saving the users' points earned somewhere to reference it later will further bolster the positive motivational effects typically sought after with a gamified platform.

Through these descriptions, it is evident that how these students interacted with the software itself may have had a significant impact on how they experienced SEP-CyLE's implementation of gamification. This suggests the software environment and user interface gamification is being applied is critical to its perception and overall usability. While all software may experience glitches and bugs, these issues can negatively affect the frequency and general motivation in using the tool due to frustrations they may experience while using it. As noted

by Morschheuser et al. "[…] the literature recommends continuous monitoring and optimization of gamification projects as a prerequisite for long-term success […]" (p. 222). Findings from this portion of qualitative analysis agree with these principles, suggesting that fixing these problems early on would minimize and prevent any reversal of positive effects from gamification.

Experiences with gamification

Two additional emergent themes present in the findings were enjoyment or love of gamification and apathy towards gamification. Those who enjoyed or loved gamification were vocal and expressed why they loved it. This group's primary motivation for completing SEP-CyLE was the extra credit the professor provided if they completed it. Secondary to this motivation, these participants enjoyed the competition in addition to the extra credit they would receive. The apathetic group described the gamification employed as meager in quantity, and the connotations associated with their words chosen to describe their experiences were generally unenthusiastic. In this section, we will first describe the group that enjoyed their gamification experiences, and then we will go on to describe the apathetic group's experiences.

Enjoyment or love of gamification due to extrinsic motivation

When prompted to discuss their favorite parts and overall experiences about SEP-CyLE, this group of participants expressed that they enjoyed competing for extra credit points. Additionally, they noted that the point systems and leaderboard drove them to complete their SEP-CyLE quizzes and practice quizzes. These participants were enthusiastic in tone with their descriptions of their experience, as two participants described below:

> What I did like about SEP-CyLE, though, is the point system. So, groups would basically go against each other, and that does motivate a lot of students… It's like how people are addicted to games, because of reward systems… We would always be on top of it and be like "Yo, do your SEP-CyLE assignment so we can get more points, so we can get extra credit."—Jinx.

> […] I didn't expect it to have a leaderboard and she gave us extra credit if we were on the leaderboard, so I was like–I have to be on the leaderboard! I need all the extra credit I can get… It was a lot of motivation too. It was like, oh I'm going to get points! I like that… [I felt] proud… Like I really, really love it… Competitiveness can be fun. So, it's kind of like a fun way of learning.—Nicole.

These findings generally fall in line with the literature that state the positive effects of gamification on motivation and usage (McDaniel et al. 2012; Dominguez et al. 2013), demonstrating that gamification increases motivation

through competition and "pointsification," even though the motivation was extrinsic due to the use of extra credit. As noted in the background section, further studies will need to be conducted using theoretical frameworks that can accurately contextualize gamification's effects on factors such as motivation, especially with regards to the differences between extrinsic and intrinsic motivations and their impact on self-efficacy.

Apathetic towards gamification

As mentioned previously, the second theme that emerged from thematic analysis was the apathy towards the employed gamification. These participants were in the majority and noted that these gamified features were not interesting to them when prompted to discuss their feelings about them. Many indicated that they used SEP-CyLE simply to review or learn new content, and they did not care about the points they received for completing practice quizzes and quizzes and that they were not competitive people in general. Two participants' experiences below demonstrate this apathetic feeling towards gamification:

> Oh, I don't understand the virtual points because some people have like 45, but I only got 25 for completing two, so I don't really know how they're scoring it. So, they don't mean that much… I'd [complete SEP-CyLE] even if there weren't any points, it's mandatory… SEP-CyLE just didn't do it for me… I don't really look at [the leaderboard] … I understand that [competition] was their point in making it, but I don't think it came across as that… It [didn't] make a difference.—Machi.
>
> I mean [the leaderboard] was alright… Kind of confusing, but I think it was just because they had such a big class it was like, all the names there, you're kind of like, okay, I don't really know who they are… I feel like it would have been [more competitive] if it was a smaller class, then it would be kind of like a [another gamified learning platform] for the homework. So, if it's a smaller class where you kind of know more people's names, then yeah, but considering programming I is such a big class, it's kind of like, whatever… I didn't notice the virtual [points].—Jackie.

As noted by Jackie, the leaderboard did not have an impact on her because she was unfamiliar with the peers in her class. This finding should be noted for future researchers, as this is part of the context—peer relationships or the absence of peer relationships may hinder or promote the use of the tool. The use of the leaderboard may be better suited for smaller classes with a stronger sense of familiarity and community amongst students to promote friendly competition and a sense of self-confidence to those at the top of the leaderboard. Furthermore, as noted by Machi, the scoring system that the gamified tool utilizes may negatively impact motivation. If the scoring system is not clear to users, users may become confused or disillusioned by its purpose and ignore it; possibly negatively affecting motivation.

The mix of different perceptions from women of this gamification design has crucial implications for future design considerations for gamified platforms and again agree with Morschheuser's findings that "[…] motivational outcomes of

gamification depend especially on the fulfillment of user needs […]" (p. 224). Moreover, Zichermann and Cunningham (2011) note that "the more you know about who is playing your game—both current and prospective players—the easier it is to design an experience that will drive their behavior in the desired way" (p. 21), explaining that there are generally four types of players based on the Bartle taxonomy of player types. These notions underline the idea that in gamification design, understanding the intrinsic and extrinsic motivations of the users should be prioritized before choosing and designing an implementation. For example, these aforementioned player types include explorers, achievers, socializers, and killers or griefers, and each are intrinsically motivated to "play" in different ways (Bartle 1996), meaning different game elements or gamification designs that suit their "player types'' may engage them more effectively.

While Bartle's player types have traditionally been discussed within the context of video games, these player types have been adapted to a gamification context by Marczewski and include players, socializers, free spirits, achievers, and philanthropists, each of the player types motivated by different constructs (Marczewski 2013). This idea of player types falls in line with many of the findings in education literature that note points are not motivating for all users (Frith et al. 2012; Christy and Fox 2014), and even with gender studies that mention that women have more social benefits from gamification (Gaffney and Dunphy 2015; Koivisto et al. 2014). Future gamification studies should focus on how specific gamification designs or game elements affect the motivations of these aforementioned players types, and how these player types vary based on gender or other personality traits. While these taxonomies have been met with criticism, their basis of understanding the motivations of the user is critical to choosing game elements and gamification designs that actually motivate women and have a positive impact on self-efficacy to ultimately affect CS identity development.

Gamification's impact on self-efficacy and CS identity development

A majority of the students interviewed for this study had improved performance/competence and self-efficacy with regards to CS by the end of their programming I course, as they had been interviewed at the start of the semester and at the very end; this improvement happened regardless of their own personal background or pathways. For many, this was the first time they had encountered CS in their personal lives, and it was challenging to adapt to the new languages (both discourse and programming). Regardless of the initial struggle, almost all of the participants explained that even if they were having a difficult time at the start, they knew they could learn and improve throughout the programming I class, demonstrating their ability to persist in the face of hardships or struggles. They mentioned that CS and programming were challenging, and even if they were not fully confident, they believed they could overcome those challenges through their own abilities to learn. It's important to note that not all of the participants were CS majors; some were undecided or in other majors unrelated to computing. Two participants' experiences

below describe this improvement in performance/competence and self-efficacy, which are sub-constructs of identity defined within social identity theory:

> It's challenging because of… it takes me a little while to understand it but once I understand it, I start liking it. So, I am doing a program right now and at first, it took me hours to figure out what to do and now I am like understanding what to do. And so, now it's going more smoothly but the process of my understanding at first takes a long time.—Rose.
> In the beginning, I had a hard time, like I was kind of struggling with it, but I don't know, it's just you have to learn a whole new thing. But now that I've kind of got into it, I like the challenge. It's definitely a challenge, but it's something I'm willing to put effort into… Because even if I'm not like a hundred percent confident, I feel like I'm getting there. Like I can easily work my way towards that.—Sarah.

Notably, with regards to gamification and its effect on computing identity and self-efficacy, there were no themes found amongst the participants that indicated that the tool's game elements had any explicit impact. Many participants noted that the SEP-CyLE practice quiz feature helped them with the quiz portion of SEP-CyLE which in turn enabled them to grasp new concepts effectively. Additionally, some did say that the supplementary nature of the content was helpful to their overall CS knowledge. Two participants below describe these findings accurately:

> The practice quizzes I liked because you can do them like any amount of times you want until you get all the answers and they really help you to prepare for the quizzes. So, I like that.—Machi
> I also liked that it discusses certain things that are not discussed in [other learning platforms] or the assigned material that we have to study. So, it's like, it helps you know more… it helps you learn more things than are in… that you won't learn from [other learning platforms] or whatever.—Jinx.

Noone specified that the gamified features of SEP-CyLE made them feel any more *confident* with their ability to learn CS topics. As shown above, Nicole was the only participant that explicitly denoted she felt proud of earning points, which could promote a feeling of improved competency and self-efficacy. Still, she was the only participant that mentioned this. Others believed they did not benefit from SEP-CyLE due to the glitches they experienced while using the tool, demonstrating a virtual learning tool's potential ability to negatively impact a student's self-efficacy. When prompted about whether the participant believed that they benefited from SEP-CyLE, they said:

> No… because it wasn't really working… I didn't know if I did or didn't get it right, because then also some things I just didn't know, so I was like, I don't know if I'm getting it wrong because it's genuinely wrong or if it's because [of the tool].—Jackie.

As noted by Morschheuser, "[…] gamified software could fail if legal and ethical constraints are not considered in the design phase […]" (p. 224). In this case,

Jackie could have negatively been dissuaded from furthering her CS education due to this confusion and feeling that she was incompetent. While this may simply be a bug that is easily fixed within the tool, its ramifications may be far-reaching to users over an extended period of time, especially if the tool were used as a larger platform for learning core CS content. Kim (2015) agrees with Morschheuser's findings, also mentioning that gamification can be harmful by possibly undermining the intrinsic motivation of the user (p. 33). Negative experiences with a gamified tool could affect self-efficacy and ultimately, intrinsic motivation. As mentioned previously, future studies should focus on what motivates and discourages users, specifically women, and individual game elements that support or discourage those motivations, as our finding suggests potential negative impacts. Future gamification designs should take these factors into consideration to prevent damaging self-efficacy and CS identity development.

As noted by participants, the supplementary content and repetitive features such as practice quizzes afforded by the SEP-CyLE tool promoted their competence and self-efficacy in these spaces, suggesting a promotion in the beginning of the development of a CS identity but not necessarily the designation of a CS identity. As suggested by the background section, findings from the qualitative analysis agree that further studies focused on the design of point systems, leaderboards, social and classroom environment, and other factors need to be individually assessed in order to fully understand their impact on women's CS identity.

Overall, the participants generally discussed the tool's strengths and weaknesses and how that affected their learning experience with CS material. Most mentioned that the tool could be improved in terms of fixing existing glitches or pitfalls but that the tool was beneficial in providing supplementary material that may not have been discussed during their regular class time. Additionally, many participants mentioned that they enjoyed the practice quiz feature of SEP-CyLE, improving their ability to do well on the real SEP-CyLE quizzes. Most of the participants vocalized that they felt that while CS was difficult, they had the ability to adapt and learn the concepts through practice and study, demonstrating the development of a CS identity with positive self-efficacy.

With regards to gamification, while some enjoyed the leaderboard and the virtual points due to their competitive nature and ability to earn extra credit, it did not impact most participants' explicit motivation to use SEP-CyLE. Furthermore, most participants explicitly stated that they did not enjoy the gamified elements or were apathetic to them. None of the participants indicated that they felt more confident in their CS competence or abilities due to the gamification within SEP-CyLE, suggesting that the tool's implementation of gamification did not affect their self-efficacy or CS identity development. However, participants did note that the supplementary material helped add to their knowledge of CS topics. In the next section, we will explore the quantitative results evaluating gamification and learning outcomes to ascertain whether any differences among the learning achievements of each gender were significant.

Table 3 Final regression model with N = 181 and Adjusted $R^2 = 0.09115$

Predictor	b	SE	Beta	Significance
Intercept	78.982	1.525	0.000	$p < 0.05$
X3	0.064	0.014	0.310	$p < 0.05$

Quantitative

As mentioned earlier, a backward elimination regression analysis was used to determine predictors of performance, and the variable that contributed a significant difference in the final grade was total virtual points. The final model is shown below, where y is the dependent variable (final grades) and x_3 is the dependent variable (total virtual points). The final model is shown below with results reported in Tables 3–5 and illustrated in Figs. 1–2. As we can see in Table 3, this variable has a positive correlation with final grade with $p < 0.05$.

$$y = b_3 x_3 \tag{2}$$

We further tested for an interaction between gender and total virtual points. We found the interaction (which would indicate a differential impact of total virtual points on grade) to be non-significant. This indicates that the association between total virtual points and grades is similar for men and women. Additional analysis comparing the groups' means showed that there were no significant differences found between gender on any of the other variables, including final grades. Therefore, results indicated that while gamification has a significant impact on the students' performance, gender has no significant impact on it, disagreeing with Khan's findings that it was not equally effective for both genders in terms of learning outcomes (2017) and also disagreeing with Pedro's findings that showed gamification did not affect women's performance (2015).

To add validity to the results, an independent sample t-test was conducted to evaluate whether there was a difference between the female and male students regarding the obtained virtual points. The results indicated that there was no gender difference between the mean of the female (M = 98.44, SD = 60.18) and the male students (M = 85.37, SD = 56.26), t (179) = 1.205, $p > 0.05$. A bivariate correlation was conducted to evaluate the effect size of the correlation between virtual points and final grades. Results showed that these two variables were

Table 4 Bivariate correlation between gamification and performance

	Virtual points	Final grade
Virtual points	1	.310**
Sig. (2-tailed)		.000
N	181	181

Table 5 Levene's test for equality of variances

		t-test for equality of means								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Virtual points	Equal variances assumed	.229	.633	1.205	179	.230	13.074	10.848	− 8.33	34.48

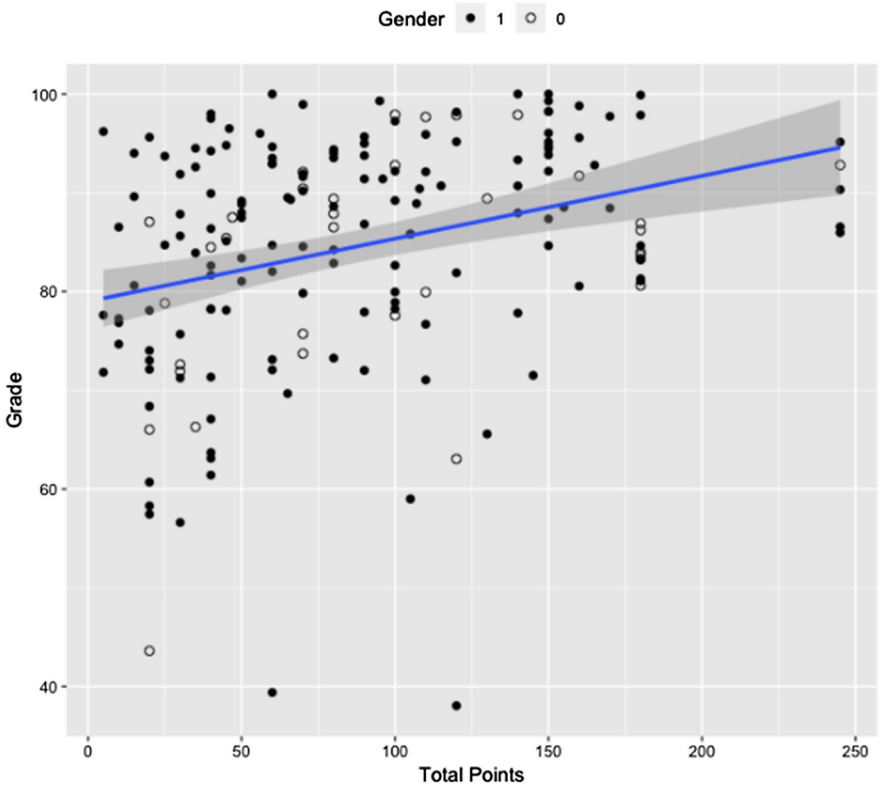

Fig. 5 Total points plotted against final grades, for all students

positively correlated, $r = 0.310$ ($p < 0.001$). This indicates a medium effect size between these two variables (Table 4). Further, Levene's test was conducted to evaluate whether we can assume the equality of variances in the groups (by

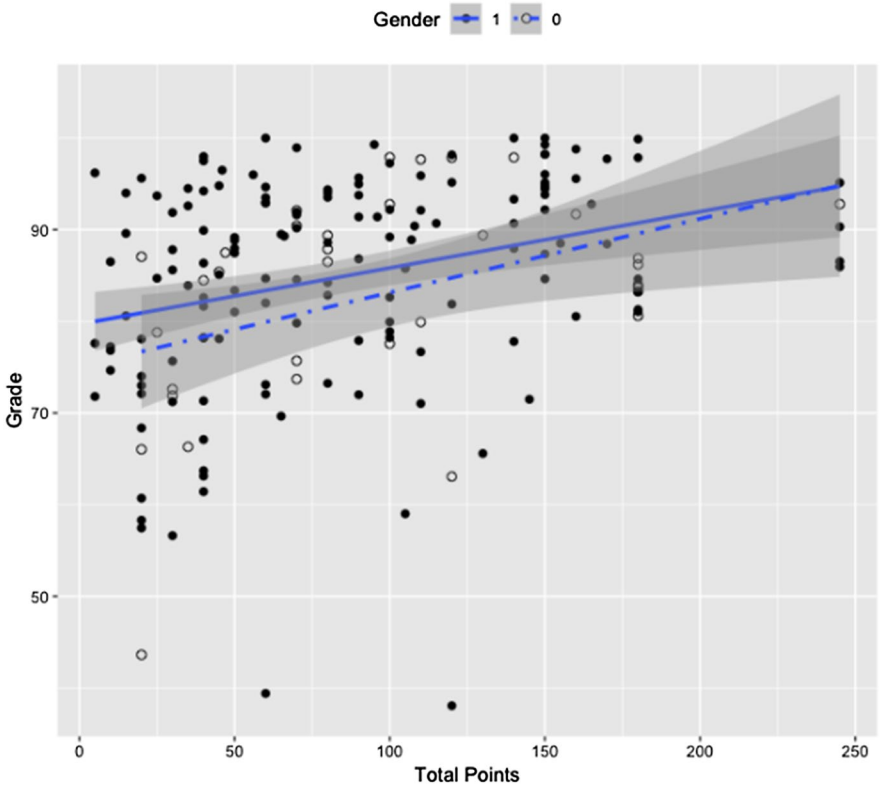

Fig. 6 Total points plotted against final grades, disaggregated by gender

gender) or not. The result showed that equal variances can be assumed, $p > 0.05$ (Table 5).

As an illustration of this model, Fig. 5 indicates the positive relationship between virtual points (horizontal axis) and final grades (vertical axis) for all the students ($p < 0.05$). This relationship is broken down by gender in Fig. 6 (the dashed line is female, the solid line is male). As can be seen, no significant interactions between gender and final grades were found; that is, the positive association between these virtual points and final grades is statistically equivalent for females and non-females (that is, the slopes of the two lines indicated in Fig. 6 are statistically equivalent).

Discussion and conclusion

Through this mixed-methods study, we have explored the impact of gamification on performance, self-efficacy, and CS identity development of female participants to better understand how to improve women's participation and retention in CS. Through quantitative analysis, the factor that was found to be positively correlated to the students' grades was the total virtual points of the students.

Therefore, quantitative results provide evidence that there is no significant difference in earning points regarding gender. The class, as a whole, performed better with the use of gamification in SEP-CyLE. Gamification as a pedagogical approach seems to be beneficial to both genders in improving performance within an online learning environment, given the results from this study. These results agree with previous studies that found a positive correlation between gamification and performance (Dominguez et al. 2013; Frith et al. 2012; McDaniel et al. 2012; Liu et al. 2011). However, the results are in conflict with other gender studies that found gamification did not benefit the performance of women or that gamification benefited women more than men (Khan et al. 2017; Pedro et al. 2015).

The qualitative analysis revealed that a majority of the female participants were apathetic or received the gamification of SEP-CyLE negatively when prompted to discuss their feelings about it. This suggests that the context in which gamification is applied along with the combination of game elements implemented should be carefully considered using theory, such as Bartle's player types or Marczewski's adaptation of these player types to fit gamification settings, when adding gamification to a learning environment (Seaborn et al. 2015). Only a few women actively enjoyed the gamified features of SEP-CyLE, suggesting that the way in which a tool motivates an individual may have an impact on their perceptions of gamification. These qualitative results provide insight that disagrees with the findings from previous studies around the positive correlation between gamification, engagement, and motivation (Gaffney and Dunphy 2015; Koivisto et al. 2014; McDaniel et al. 2012). Additionally, many participants complained about the glitches within the tool itself which may have impacted the way in which the gamification affected their motivation, as suggested by Morschheuser's design principles (2018) and other literature around gamification design recommendations (Kim 2015; Zichermann and Cunningham 2011). These inconveniences could have affected the participants' overall perceptions of SEP-CyLE and its application of gamification, potentially reducing the motivation to log on and possibly casting a negative pall on their overall gamified experience. Future gamification designs should iron out bugs as soon as possible to prevent potential frustrations with students.

Even though participants showed a marked increase in CS identity development and self-efficacy over the course of their programming I semester, there was no evidence that gamification had an explicit impact on these constructs. While the quantitative analysis demonstrated the positive increase in performance for both genders, this increase in performance from gamification did not directly indicate an improvement in CS identity development and self-efficacy. The strength and increase of self-efficacy and CS identity development are most likely attributed to the introductory nature of the programming I course itself. Many of the participants came into the class with little or no CS knowledge and acquired knowledge over the course of the semester. Overall, most participants enjoyed the supplementary nature of the tool along with the practice quiz feature; these features seemed to strengthen the participants' confidence with content and their CS knowledge, thus improving their self-efficacy and competency in CS, suggesting the beginning of a development of a CS identity.

The findings of this study converge on the single takeaway that gamification, while a novel and increasingly popular method of engagement, has little to no impact on women's interest and engagement in the field of computing. However, it is clear that experiences in an introductory programming course does influence female students' perceptions of the field and of themselves in the field. The women who participated in this study had an increased understanding of their computing identity salience enough to articulate it in the interviews. While they did not explicitly call out the tool as contributing, we can at least note that it did not detract from their identity development and their growth mindset—or commitment to completion and persistence in computing.

This study demonstrates only one potential implementation of gamification; therefore, we suggest that in further implementations of gamification, game elements should be carefully designed and strategically created to maximize their motivational potential. As the quantitative results demonstrate, gamification can positively affect both women and men's performance in course content while having no impact or even a negative impact on their motivation to engage with the learning tool. Gamification seems entirely dependent on the context in which it is applied along with individuals' intrinsic motivations, such as competition.

Limitations, implications, and directions for future work

The present study was limited to interviews of women to understand the implications of this learning engagement strategy on women; however, the addition of the insight of male students may have provided a contrasting narrative to the tool's effectiveness. Quantitative analysis results suggest that male students may also have the same perception about gamification, indicating that interviewing male students could further verify this phenomenon. The results of this study cannot be generalized due to the classroom observations being limited to one course, one instructor, one school, and 181 students in addition to the specificity of the learning environment itself.

Apart from these limitations, it should also be noted that the specific design and educational context of SEP-CyLE also affected the students' perceptions about gamification, and as a result, other researchers interested in gamification should also employ a mixed-methods methodology to provide human insight via qualitative data. Other researchers should standardize whether students' usage of a gamified learning platform is mandatory or for extra credit to fully understand how extrinsic motivation vs. intrinsic motivation may affect self-efficacy, as this study had mixed usage of the platform from assignment to assignment. Another limitation of this study is not having a control group to isolate the independent variable's effect on the experiment. A control group in future studies might help researchers identify alternate explanations of the results.

It should be noted that due to the lack of consistency of how SEP-CyLE was being used in class by the one instructor, the experiences of SEP-CyLE varied across individuals. Some classes worked in teams on SEP-CyLE, whereas some students worked individually. Sometimes the assignments on SEP-CyLE were mandatory, and other times the assignments were for extra credit. Additionally, the gamified

features of SEP-CyLE seemed to only appeal to those that were motivated by competition. Due to the mandatory or extrinsically motivated nature of the SEP-CyLE assignments, the virtual points and leaderboard for many were simply a supplementary feature that did not add or take away from the learning material; many were simply apathetic and did not care at all that these features existed.

Future studies should aim to understand the impact of individual game elements one at a time on different player types across the gender spectrum. Additionally, other studies should investigate the impact of personality traits on the perceptions of game elements to understand if employing gamification as a pedagogical practice is beneficial overall. Also, since the tool was designed to reward adult students, it is important to consider some other demographics—which were not collected in this study—as potential confounding variables when looking at gender. While this study did not assess the effect of the content within the tool itself on female students, future studies should investigate content delivery's impacts on self-efficacy and intrinsic motivations to ensure that gamification and pedagogy are not working against each other.

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