Meaningful Gamification of a Computer Science Department: Considerations and Challenges

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Abstract *– Gamification presents an opportunity to model and guide the enculturation process of computer science undergraduates. It can also make the matriculation journey more engaging for a broader range of students if done correctly. This paper looks at design considerations, potential benefits and the challenges with implementing meaningful gamification in a department of computer science. It describes the underlying theories of motivation and fun in gamification as well as the application of Werbach's gamification framework to gamifying a Computer Science department.*

Keywords: Gamification, Computer Science Culture**.**

1 Introduction

Research has shown that computer science (CS) students are not prepared for life after graduation. Students lack effective communication and collaborative skills, as well as the technical skills to support large-scale development[1][2]. Research also shows that students have not developed the high level cognitive skills of design [3]. These shortcomings can be attributed to the fact that students are not participating in enough holistic development outside of the classroom. Gamification may be a means of influencing behavioral change that can address these issues.

Gamification as a research topic has increasingly been trending in academia [4] because of its potential to engage students and produce behavioral change [5]. Most of the published research in higher education lacks a theoretical underpinning that can help readers understand the researchers' motivation and the justifications for how their gamification approach is supported by any theory of change. This means that findings are difficult to generalize and don't contribute to the larger body of gamification knowledge.

Gamification is widely defined as "…the use of game design elements in none-game contexts" [6]. Game design elements fall into three categories, dynamics, mechanics and components [7]. Most implementations of gamification research focus on the implementation of game components, with little attention to dynamics and mechanics.

Game dynamics are the targeted behavior, and the emotions that game designers seek to elicit from gameplay [7]. Elements of the game dynamic that should be designed for are: motivators, tradeoffs, progression loops, narrative and the interactions between players. Mechanics are the structure that drive player engagement loops [7]. They consists of the objectives, procedures, and rules. Mechanics include but are not limited to challenges, chance, competition, feedback, resource acquisition, rewards, transactions, and turns and win states. Game components are the specific instantiations of the desired dynamics and mechanics [7]. Available components for gamification are, achievements, avatars, badges, major projects, collections, competitions, content unlocking, gifting, leaderboards, points, levels, quests, social graphs, teams and virtual goods.

Meaningful gamification has been successfully incorporated outside of higher education. Examples include Nike+ and Stack Overflow. These efforts have led to high levels of engagement and in the case of Stack Overflow, engagement in tasks that are highly cognitive. Stack Overflow gives points and badges for answering software related questions by allowing users to vote for the best answers to posted questions. When a user's answer is selected they get a sense of competence and being a useful member of the community when their answer is selected. This approach also employs a variable reward schedule. The user is not guaranteed recognition for each of their submission. This creates a sense of anticipation that heightens the users sense of success [8]. One of the major criticisms that can be applied to most gamification efforts thus far is that it has just been a 'pointsification' [9] or 'exploitationware' [10] approach of focusing on game components (points, badges and leaderboards (PBL)). The approaches don't reflect a true understanding of what makes gamification engaging.

Section two of this paper looks at gamification in higher education. Section three meaningful gamification, motivation theory, fun and what higher education can learn from gamers. Section four discusses the application of gamification to a department of computer science. More specifically it discusses the objectives, target behaviors, the players, fun and deploying the appropriate tools. Section five discusses some of the potential challenges of applying gamification to a CS department and section six discusses our conclusions.

2 Gamification in higher education

It has been argued that gamification is a fad and runs the risk of learning becoming a game where people participate only to achieve the game components rather than to improve their skills or knowledge [11]. This can be true if gamification is not done correctly. A good example of this is the conventional model of higher education. Institutions of higher

learning are already gamified [12]. Students get points for assignments and exams. These exams translate to grades which affect GPA. GPA gets students on the Dean's list, which is the equivalent of an achievement or badge. When students successfully pass a year of classes they 'level up.' At the end of their matriculation some students get honors, which could be considered the equivalent of another badge or an achievement. One student or a select few make it to the top of the leaderboard and receive class superlatives, such as, valedictorian, salutatorian, summa cum laude, or magna cum laude. This system can lead to some students being highly performance learning oriented and focused on their GPA and resume and not enough on mastering their practical skills and knowledge [13].

Supplementing or changing the conventional model of higher education gamification may represent an opportunity to address the motivation and engagement problems being experienced. One of the main problems with the conventional model of higher education gamification is the fact that 'badges' and 'achievements' are reserved for a select few who demonstrate mastery in a specific way. This form of gamification does not reward the masses.

Researchers continue to implement new gamification research efforts in the pattern of the conventional model of higher education [14][15][16][5][17] [18][19][20][28] [21]. They focus mainly on academic achievement and create new instantiations of points, badges and leaderboards that parallel traditional classroom assessment. Publications regarding higher education gamification research also often lack a theoretical underpinning that can help readers understand the researchers' motivation and the justifications for how their gamification approach is supported by any theory of change. One can say it has been a throw it against the wall and see what sticks approach. This means that findings are difficult to generalize and don't really contribute to the larger body of gamification knowledge. For a literature review of empirical studies on gamification the reader is referred to [4].

Thus far we have only come across two instances of applied gamification [22][5] that reflect a true understanding of what makes games successful and gives some insight into their game dynamics and mechanics. One of them is at RIT [22][23], the other is at Queensland University of Technology Brisbane, Australia [5]. RIT's effort, [22], was designed to give students a more balanced perspective of achievement (academic and social) and took into consideration motivation, engagement and fun. The fact that this gamification effort was carried out in their School of Interactive Games and Media goes to show that other researchers need to have an understanding of the theory and underpinnings of engaging games. One of their major accomplishments is that their approach led to an emergence of peer tutoring sessions that students continued into successive semesters.

3 Meaningful gamification

The current emphasis on game components overlooks the true nature and potential of gamification which is to create experiences that users engage with voluntarily. Gamification is a process of creating engagement loops that influence users to perform desired activities [24]. Meaningful gamification can be done without the explicit integration of game components [25]. This viewpoint moves researchers from the shallow perspective of the implementation of game components and puts the focus on the most important aspects of gamification, 'gamefulness' [26]. Gamefulness focuses the system designer on designing, motivation, engagement and fun that lead to change [27][28].

3.1 Motivation

Motivation has been shown to increase time on task, direct behavior toward goals, increase effort and persistence as well as affect cognitive processes that impact learning [29]. Characteristics of motivated learners include enthusiasm, focus, persistence and self-regulation, all of which this research seeks to foster or increase.

There are two types of motivation, extrinsic and intrinsic motivation. Extrinsic motivation exists when motivation is aroused by forces outside of an individual. Extrinsic motivators in higher education include grades, scholarships, internships and honors. Intrinsic motivation is aroused from within an individual. Self Determination Theory suggests that there are three intrinsic tendencies that motivate people, autonomy, relatedness, and competence [30]. Maslow's Hierarchy of Needs also supports this theory. It recognizes a person's need for competence and relatedness in the form of self-actualization and belonging respectively [29]. The reader is referred to [31] for an in-depth understanding of how relatedness, competency and autonomy is applied to gamification

Motivation is one of the foremost problems in education [32]. Of the two types of motivators, intrinsic motivators are the more desired. Csikszentmihalyi describes an extreme state of intrinsic motivation and self-regulation called flow [33]. Flow is characterized by a state of complete absorption, focus, and concentration in a challenging activity, to the point that the learner loses track of time and completely ignores other tasks. Flow is only achieved when a task is in the correct balance between not being too easy or too hard and is something that a user is interested in.

Higher education often stifles students' sense of autonomy by not giving them assignments that are socially relevant and by imposing deadlines that are inflexible. Students who are competent in one learning outcome of a class are left languishing, while in the same class they can be penalized for not making a deadline on another learning outcome. In the current structure of higher education there is also little incentive for students to help other students in communities of practice. Faculty take it upon themselves to structure the learning environment without much input from their students. This leads to a learning environment that heavily emphasizes extrinsic motivators.

Research in behavioral economics has shown that extrinsic motivators such as rewards offer short term boosts in activity but can reduce long term intrinsic motivation [34]. In developing and enhancing intrinsic motivation in students,

extrinsic motivators should be avoided [35]. The reward and achievement structure of academia is currently totally hinged on extrinsic motivators.

The most useful taxonomy for motivation of students in the context of gamification is Bartle's' player dimension. Bartle categorized players into 4 categories: achievers, explorers, socializers and killers [36]. Achievers enjoy mastering situations and seek out status. They are ambitious, high achieving students, who strive to gain mastery. These students need to be influenced to view mastery beyond solely academic achievement. Explorers enjoy new knowledge and are always looking for a new challenge. They are curious and do not require mastery of material, merely competence. These students should be rewarded for bringing new perspectives to the learning environment. Socializers participate mainly because they enjoy interacting with and being affirmed by other members in the community. They are easily influenced and their standards rise and fall with the standards of the group. These students would benefit most and thrive from communities of practice. These are the students who should be recognized for creating events that improve technical and non-technical aspects of members of the community. Killers enjoy competition. They want to excel and achieve at the expense of other students. They seek to demonstrate superiority and are highly motivated by status and reputation. These are the students who should be targeted to represent their department externally. Their competitiveness can affect the comfort of explorers and socializers. The current dynamics and mechanics of higher education mostly appeal to achievers and killers. A more inclusive and engaging environment should also strive to recognize and reward the other players types.

3.2 Defining fun

An understanding of fun contributes to the discussion of engaging learners. Leblanc, [37], describes fun from the perspective of the motivation of the player. He describes 8 types of fun: sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission. Sensation fun is fun that is pleasing to a player's sense. Fantasy fun is fun that engages escapism and immersion. Narrative fun is fun that unfolds a story. Challenge fun engages the players need to test themselves, overcome and achieve. Fellowship fun engages players in social interaction and cooperation. Fellowship fun does not however encompass competition. Discovery fun is fun that is derived from exploration and learning new things. Expression fun is fun that is derived from expressing creativity. Submission fun is fun derived from gaining accomplishments for tasks that are not cognitively taxing.

3.3 Learning from game designers

Characteristics of good games are [38]:

1. The objective or goal of the game is achievable but not too easily.
2. The task is perceived to be fair, i.e. all participants have a similar chance of winning.
3. The stakes for failure are not high.
4. There is sufficient feedback, both positive and negative.
5. There are some elements of chance.

Most gamers would not play a game where they can achieve the objectives on their first attempt, because the lack of challenge does not make them feel competent or self-actualized. Usually as a player develops mastery and increases in level, games get progressively harder. Good game designers ensure that their players can achieve a state of flow. In order to achieve this they allow users the option to control the level of difficulty. This caters to a players need for autonomy while still allowing them to 'win'/feel competent. This can be done in higher education through progressively scaffolded assignments for students who are struggling, or creating 'authentic' projects outside of the classroom for higher achieving students. Higher achieving students would have to earn their way into being members of these projects. Struggling students avoid being overwhelmed and frustrated and high achieving students earn the 'achievement' of the opportunity to work with a team on real world problems that are of interest to them.

Good games reduce the stakes of failure by celebrating learning and reinforcing experiential learning. Formative failure, agency, and choice are seen as critical elements of a true gaming experience [33]. Players are allowed to continue from nearby checkpoints after failure. This ensures that players get frequent feedback on their progress while reducing the stakes of failure. By making the consequences of failure small and integrating elements of chance, game designers allow players to attribute a lack of success to chance and maintain their self-worth. Self-worth, self-concept and affect have been shown to have a complex relationship with motivation and determines whether or not an individual will continue a task [16]. Checkpoints in higher learning are usually summative, measured in semesters in which failure is very hard to recover. The increasing pervasiveness of auto graders and online courses can make it easier for students to get more frequent feedback and feel a sense of accomplishment. Sufficient feedback helps reinforce motivation and gives the player cues on how to interact [42]. Faculty should also consider rewarding more competent students for helping other members of the community.

Good games are designed for collaboration and encourage interaction between players both in game and out of game. In-game chats allow players to point out errors in other players' game play or strategy. Forums, blogs and wikis allow player generated and moderated content to benefit the community as a whole. More experienced players are spotlighted which satiates their sense of competence and increases their sense of relatedness while creating role models for other members of the community. Clear and immediate feedback to students does not necessarily have to come at the cost of faculty and TA's time. Higher education should emulate this type of collaborative environment. A good gamified example of this kind of dynamic at very little long term cost in man hours to the creators is Stack Overflow.

3.4 Gamification framework

To address meaningful gamification Werbach, [7], has put forward an iterative user centric six step Gamification Design Framework: 1. Define objectives; 2. Delineate target behaviors; 3. Describe the players**;** 4. Devise the activity cycles; 5. Do not forget the fun**;** 6. Deploy the appropriate tools**.**

The first five steps of this approach address the sociocultural aspect of gamification that is necessary to ensure that it is meaningful. Step 6 is the deployment of technical components that act as reinforcers to facilitate the changes desired in the first five steps.

4 Departmental gamification

Gamification can be used to improve the holistic development of a department's students by creating an ecosystem that can be used to influence a department's culture both inside and outside the classroom. Social Cognitive Theory states that social interactions act as response-consequence contingencies that help to model appropriate behavior, beliefs and attitudes [37]. Social interactions, the environment and the cognitive models of members of a community, all have reciprocal relationships on each other and influence the culture of a community. Gamification can be used to guide the enculturation of new students to the CS community while giving feedback to current members of the community about the needs and values of other members. Understanding the current culture of the community and its environment is critical to influencing change through gamification.

Any gamification effort should take into consideration how it may impact a department's learning environment. A department's learning environment consists of the "… physical surroundings, psychosocial or emotional conditions and social or cultural influences" present [29]. Each of these factors plays a role in influencing a student's sense of belonging and their achievement. Research shows that there may be a need to address the fact that CS environmental culture can be more competitive than collaborative [39][40]. Research, [41][42] , also shows that artifacts in the environment can affect a student's sense of belonging. Gamification can be used to enhance inclusivity and diversity. Inclusivity and diversity in this context includes race, gender, areas of study in the field, and achievement (not limited to academic).

This process, like any process that involves humans, needs to be adaptive and nondeterministic. What it means to be a computer scientist is subjective and the field of computer science is continuously changing. Internal and external feedback on the game mechanics and dynamics used are essential to ensure that the process is objective and truly holistic in the development of the student. In order to define the objectives and target behaviors of members of the community, feedback should be sought from all stakeholders of the department as well as members of the education community. We have sought input from, students, alumni, faculty, industry partners, faculty of other programs, the CS education community, educational psychologist and sociologist. One process that we have found useful for understanding and designing our gamification approach is Google Venture's approach to design sprints [43] and the "How might we", HMW, approach [44].

4.1 Defining objectives

Through mini design sprints [43][45] the following high level objectives have been identified:

1. Emphasize inclusivity and diversity in the ecosystem.
2. Improve department members' sense of community index [46].
3. Foster mastery learning orientation versus performance learning orientation ,[13], by creating formative 'fail often, fail fast' innovative communities of practice that encourage students to learn through experimentation and trial and error.
4. Create an explicit onboarding system that successfully assimilates students into the CS community.
5. Emphasize the importance of non-technical skills as well as technical skills to success.
6. Encourage students to contribute to the development of academic content as well as mentoring their peers.
7. Create a system of recognition for students that also takes into consideration factors other than solely academic achievement.
8. Highlight role models and their paths to success.
9. Allow students to give immediate feedback to faculty regarding their pedagogy throughout the semester.
10. Create a method of data capture that helps the department to understand how students are spending their time preparing for life after academia (workshops, extracurricular projects, hackathons, networking, groups, internship, etc.).

Every department and their current culture is unique and the objectives for a gamified system should vary.

4.2 Delineating target behaviors

Based on the aforementioned objectives a few of the high level target behaviors we have identified for students are as follows:

1. Increased student participation in extracurricular CS related activities.
2. Increased social interaction and networking between students and faculty/alumni/ industry partners.
3. Student initiated and regulated communities of practice.
4. Community generated materials for learning.
5. Student alumni/faculty/industry partnership and mentorship.
6. Community Regulation. Members of the community shall be involved in the assessment of other members.

4.3 Describing the players

Each department's has their own unique set of stakeholders. Each department's students/ alumni/industry

partners and faculty members will have different demographics, needs and skills to offer. With regards to our students we have done literature reviews, spoken to alumni and to industry partners to see where we are hitting the mark and where we are falling short with regards to preparation for life after graduation. As a Historically Black College and University (HBCU), we have identified threats to belonging [47] in the CS community that affect underrepresented students and have been working to remediate these through interventions and, changing the social and classroom culture of the department.

4.4 Devise the activity cycle

Activity cycles consists of two types of loops, progression loops and engagement loops [7]. Progression loops are a series of cycles of growth followed by intermediate stages of mastery. In each cycle the student is learning or acquiring new skills, followed by a period of demonstration of mastery. After the student has demonstrated mastery of content or skill they enter a new cycle in order to master a new skill or activity. The progression loop continues until the student progressively masters all of the cycles. Engagement loops are cycles of motivation, action and feedback that reinforce the user for doing an action and motivates them to continue performing the desired target behaviors. For a thorough review of engagement strategies in games and how they can inform the instructional design of activity cycles the reader is referred to [19][8][48]. To ensure that our game components cater to all of Bartle's player types, we ask, 'How might we make this target behavior appealing to {achievers, explorers, socializers, killers}?' [42].

4.5 Not forgetting the fun

In order to ensure that the ecosystem being developed is truly engaging to all our stakeholders, we have been systematically including our stakeholders in design sprints so that we can get their feedback. As we design and develop the dynamics, mechanics and components of the system we ask, 'How might we include {sensation, fantasy, narrative, challenge, fellowship, discovery, expression, submission} fun into this aspect of the ecosystem?' [43]

4.6 Deploy the appropriate tools

The specific instantiations of game components used should be different from department to department. Achievements can be virtual in the form of badges, titles, levels or ranks, or they can be tangible in the form of recognition in front of peers, certificates, awards, recognition in the college magazine, unlocking special invitations to industry partner recruiting events, etc. One thing that we would like to highlight is that game lore and narratives play a big part in the engagement process of full video games. Currently our department does not have an explicit method of passing on stories about outstanding achievements of students, alumni, faculty, the department and members of underrepresented groups in CS. Content about these achievements shall be strategically pushed throughout the ecosystem via mobile/web/and interactive displays throughout the department.

4.7 Assessing the gamification process

Measuring the effects of gamification can be categorized into two categories, behavioral outcomes and psychological outcomes [4]. Behavioral outcome assessment tracks the delineated targeted outcomes that have been set for the enculturation process. They include soft skills (team work, communication) and professional development (leadership and interviewing), technical skills (requirements analysis, system design, software version control, project management, testing and large scale software development competence), and community interaction. Most of these behavioral outcomes shall be assessed using descriptive and inferential statistics. Psychological outcomes focus on tracking internal changes such as motivation, engagement, self-efficacy, self-regulation [49], co-regulation [50], time management [50], help seeking [50], attitudes toward CS [51], learning goal orientation [13], and sense of community [46]. Research is currently being done into finding other validated psychometric tools that would be appropriate.

5 Potential challenges

Several challenges have been identified in implementing meaningful gamification in a CS department. A few are:

1. Not increasing the demand for faculty time.
2. Maintaining an appropriate equilibrium between pursuing technical ability and other aspects of membership of the discipline.
3. Validating and adapting technical ability and membership of the discipline achievements beyond peer review.
4. Designing a system so that rewards do not decrease students' intrinsic motivation.
5. Legal risks [52]
   a. Sweepstake laws if tangible rewards are introduced to system
   b. Privacy - protecting personably identifiable information
   c. Intellectual property concerns regarding content or artifacts generated by community members.
6. Ethical Risks
   a. System is too addictive & causes burn outs.
   b. Peer pressure forces students to participate.
   c. Leaderboards – could result in an over focus on status and may only be effective in the short term [53].
   d. FERPA prohibits access to an educational institution's database of resumes. Could a student's profile be considered a resume?
7. Preventing gaming the System (Cheating and collusion.)
8. Designing flexible engagement and progression loops so that they support flow yet achieve the desired outcome.

6 Conclusion

Gamification presents an opportunity to model and guide the enculturation process of computer science undergraduates. It also has the potential to make the matriculation journey more engaging for a broader range of students if done correctly. Understanding the current culture of CS and the readers department is critical to influencing change through gamification. This process, like any process that involves humans, needs to be adaptive and nondeterministic. What it means to be a computer scientist is subjective and the field of computer science is continuously changing. Werbach's iterative design framework offers a good reference point for seeking change through gamification. Meaningful gamification should focus on creating engagement loops that motivate users to perform desired activity and can be done without explicit integration of game components.

An in depth understanding of motivation and fun highlights why some approaches to gamification are not as successful as the researchers would have expected. Both internal and external feedback on the game mechanics and dynamics used are essential to ensure that any gamification process is objective and truly holistic in the development of the student.

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