Gamification of Information Systems and Security Training: Issues and Case Studies

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ABSTRACT: *This paper discusses gamification, the application of gaming elements in non-game contexts, with regard to information systems and information security training. The authors have developed gamification tools for use in the classroom as well as several educational games in order to explore the viability of gamified curricula in both high school and college environments. Early results indicate positive student attitudes toward gamified approaches, as well as improved attendance and success rate. Issues encountered in curriculum gamification and game development are described along with best practices for both.*

Keywords: Gamification, Security Training, Game Development, Serious Games

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1. Introduction to the Theory of Game-based Learning

For as long as education has existed, educators have struggled to motivate learners (McMillan & Forsyth, 1991). At first blush, the idea of game-based learning sounds like a tantalizing symbiosis. However, balancing the factors of understanding and entertainment requires careful design (Kiili, 2005). If poorly implemented, a so-called "*educational game*" can become either a tedious bore or a vacuous waste of time (Prensky, 2001).

Does game-based learning work, and if so, how? There is still a great deal of contention on this issue. Lainema and Saarinen (2010) introduce the two views of game-based learning: experiential learning and constructivism. They describe that the experiential learning theory is based on learning through direct experience while the constructivism learning paradigm is based more on constructing knowledge rather than acquiring it. This method of learning is exemplified in the form of problem-based learning. In this learning process, the skills are built and critical thinking is mastered by solving a set of problems (Duffy & Cunningham, 1996). Thus, a game may provide a student the opportunity to learn in a deeper, more immersive way than what is offered from a classic lecture or even more modernized instructional media.

There have been several attempts in assessing the effectiveness of game-based learning and the limitations of such an undertaking (Anderson & Lawton, 2009; Gosen & Washbush, 2004; Jonassen, 1992). In view of these, Lainema & Saarinen (2010) assert that "*every game forms its unique case of learning potential, which might not be relevant compared to other games*". Further, the

authors pointed out the somewhat contradictory relation between the experiential nature of game-based learning and the objectivist view of some learning assessment methodologies.

The availability of game-based learning tools, by itself, does not close the gap between personal experiences and classroom learning. Published works (Alvermann, 2002; Norton-Meier, 2005) recognize the connection of out-of-school experiences to what students learn in school. In the study by Abrams (2010), the influence of these direct and peripheral factors that affect the choice of the types of game and the quality of learning are expounded. Recognizing these factors plays an important role in choosing the best game genre and features towards achieving the learning goals.

The process of game design requires creativity and innovation (Pedersen, 2003). Tang & Hanneghan (2010) describe two approaches to designing educational games: a) using the instructor perspective, where the emphasis is on curriculum and student outcomes and b) the entertainer perspective, where fun and memorable experiences receive the most attention. Studies (Pivec, Dziabenko, & Schinnerl, 2003, Prensky, 2001, and Denis & Jouvelt, 2005) on game design principles and models, that are focused on educational games, can be abundantly found in the literature.

Zichermann and Cunningham (2011) describe several common game design elements which can be used to guide the design methodology. These elements are briefly described in the following:

• **Point Systems** - Present from the earliest digital games, this feature provides measures to track the progress of the game, the skill of the player, the interaction between player and the game, and status of the player.

• **Levels** - Popularized by role-playing games, this feature provides a measure of the status of difficulty. A good gaming system must provide a seamless transition for the player to transition to each level of difficulty with reasonable amount of challenge. Ironically, students are, in fact, "*leveling up*" in real life when they learn, yet may receive extra motivation from an in-game reward.

• **Badges or Trophies** - Primarily a social element, this feature provides a token of achievement towards the goal indicating and encouraging progress, in large part through "*bragging rights*".

• **Leaderboards** - Similar to badges, leaderboards provide a ranking of players. This component tends to be more motivational for competitive players.

• **Challenges and Quests** - This is roughly the equivalent of an educational task, or assignment. Quests keep players engaged by providing them with activities and pursuits that continually challenge their skills.

• **Onboarding** - This often takes the form of a playable tutorial and provides a way to delicately usher a novice player into the system. The system must facilitate this transition because the first few minutes of the game are the most critical stage, which determine whether the player embraces the system or not. In nearly all digital gaming, the practice of referring to an instruction manual is defunct.

• **Engagement Loops** - This feature is concerned with short periods of enhanced challenge and/or interaction, which often create the most memorable and compelling moments for the player.

2. Pedagogical Elements of Educational Games

According to Tang, Hanneghan, & El-Rhalibi (2007), educational games "*take advantage of gaming principles and technologies to create educational content*". They go on to describe the primary activities through which educational games can impart knowledge. They include the following:

• Observing the properties and behaviors of actors and objects

• Understanding the relationships between actors and objects and their effects

• Performing tasks and solving problems

While the above activities and learning can take place in a non-gaming environment, games seem to have a distinct ability to keep players engaged for extended periods of time. Self-determination theory may have something to say about why. This

theory suggests that motivational human experiences require three characteristics: competence, autonomy, and relatedness (Niemiec, 2009). Educational games and curriculum gamification have analogous qualities that could be mapped to each of these characteristics. Well-designed games guide students through gracefully curved levels of mastery, which help lead to increased competence; they allow students some degree of choice and customization of their learning experience, which can give players a sense of autonomy; and multi-player games may require student cooperation and competition, which can lead to a feeling of relatedness.

Further, in regard to mastery and motivation, Mihaly Csikszentmihalyi's concept of Flow provides guidance concerning the aforementioned learning curves. Flow, often compared to "*hyperfocus*", has been described by Csikszentmihalyi as a state of complete absorption with the current activity. To achieve this, he advises that a person's skills must be involved with a challenge that is "*just about manageable*". He goes on to say:

> "*The climber will feel it when the mountain demands all his strength, the singer when the song demands the full range of her vocal ability, the weaver when the design of the tapestry is more complex than anything attempted before, and the surgeon when the operation involves new procedures or requires an unexpected variation*. (*Csikszentmihalyi*, 1997)"

As shown in Figure 1, a player's challenge level and their skill level must grow commensurately to ensure Flow. A task which becomes too easy leads to control, followed by relaxation, and finally to boredom and apathy. Similarly, an overly difficult task can progressively lead to arousal, anxiety, and worry.

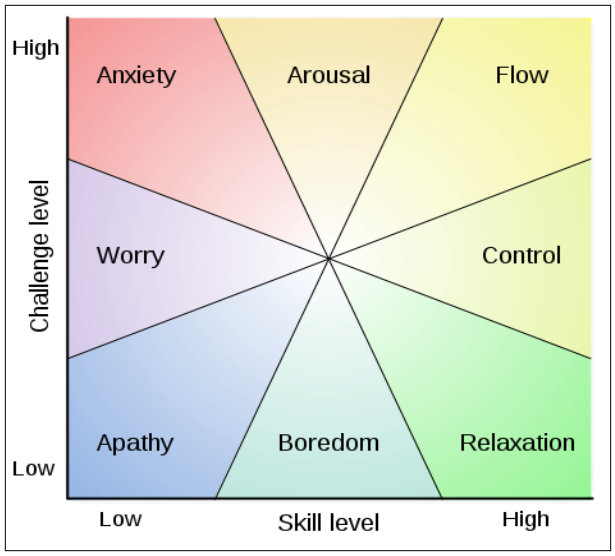


Figure 1. A graphical explanation of the need for matching the growth of skill and challenge in order to experience Flow

One of the most critical factors in the success of educational games is the ability of the system to maintain the learner's motivation and interest by adapting to the learner's needs, preferences, goals, and abilities (Felicia, 2012). These learner's needs can be best met through individualized instructions. A study by Benjamin Bloom (1984) reveals that students receiving a one-to-one tutoring perform on the average as well as those receiving classroom instructions. Further, the results of an empirical study by Vogel, et al. (2006) indicate a better attitude on learning by students who use computerized simulations or games as compared to those in traditional classroom settings.

Decades before, Benjamin Bloom (of the Bloom Taxonomy) developed the concept of Mastery Learning. In short, it advises that students should be able to learn at their own pace (consistent with Csikszentmihalyi's Flow concept), with their progress being assessed periodically to determine whether or not they are ready for the next unit of course content. Students who failed the formative assessment could then be prescribed remedial activities. Similar models, like the Keller Plan, or Personalized System of Instruction, soon followed. These approaches have enjoyed an increasing following in recent years, because they tend to

produce higher student performance (Anderson, 2000; Gusky & Gates, 1986). However, this comes at the cost of added educator workload, since the student's heterogeneous paces produce increased classroom upkeep. Another challenge of mastery learning is that when students can work at their own pace, some of them tend to work slowly. If gamification can motivate students, and mastery learning can provide a challenge commensurate with their abilities, educators have a truly compelling combination.

3. Game Implementation Considerations

3.1 Choosing an Appropriate Game Engine

An early decision any game developer must make is which game engine to employ for implementation. Fortunately, there are a myriad of game engines to choose from. Most educators looking to try gamification in their courses will likely have little or no budget to support this. Fortunately, several excellent entry-level engines are available that are either open-source or have a free, limited version. Table 1 provides a comparison of some of the more popular, affordable game engines.

Name	Ease of Use	2D or 3D Graphics	Platforms	Price
Game Maker	Easy	2D	Windows, MacOS, iOS, Android	Lite Version - Free Studio - $99 Export Modules - $100-200 each
PyGame	Intermediate	2D	Windows, MacOS, Linux	Free
Unity	Intermediate	3D	Windows, MacOS, iOS, Android	Lite Version - Free Pro Version - $1500 Export Modules - $1500 each
Unreal Engine	Intermediate	3D	Windows, MacOS, iOS, Android	Free for educational use Commercial - $99 plus royalties
Panda 3D	Advanced	3D	Windows, MacOS, Linux	Free

Table 1. Comparison of popular, affordable game engines

The software tool currently employed at Jacksonville State University for 2D game development is Game Maker, which is an easy-to-learn, multiplatform, and highly configurable game engine produced by YoYo Games. It supports fast application development through built-in libraries and functions relevant to digital gaming. It was created by professor Mark Overmars, head of the Center for Advanced Gaming and Simulation at Utrecht University. Its features include the following: artificial intelligence (AI) path-finding, advanced collision detection, animated graphics, built-in image editor, particle effects, joystick/gamepad support, multi-channel audio/video playback, and a powerful scripting language. One of the most useful features of Game Maker is its multi-format export feature. Once a game is developed, it can be released for multiple platforms, including Apple iOS, Android, and HTML5 (these export modules are not free). The engine is well documented, and the company website (www.yoyogames.com) features a vast library of tutorials and sample games, many of them user-submitted.

For an educator interested in gamification with 3D simulations, Unity is an excellent starting choice. Even with the best engine, however, developing 3D games is an order of magnitude more complex and time-consuming. For most users, starting with 2D games is recommended.

3.2 Finding and Developing Graphical and Audio Assets

An educator without a considerable budget or some modicum of artistic skill will need to depend on free images and sound to complement their games. Fortunately, there are several high-quality sources for each. A list of the authors' most recommended royalty-free media sites are listed in Table 2.

Images (clipart, illustrations, photos)	Audio (music, sound effects)
office.microsoft.com/en-us/images/	soundbible.com/
www.dreamstime.com/	http://www.mattmcfarland.com/royalty-free-music
www.clker.com/	http://incompetech.com/music/royalty-free/
www.spriters-resource.com/	www.freesound.org/
	http://www.youtube.com/audiolibrary

Table 2. Free sources for game media

Once a developer has collected necessary graphical and audio game assets, it is likely those assets will need to be modified to be suitable for a game. One of the most popular free image editors is the GNU Image Manipulation Program, or simply GIMP, available for free download at www.gimp.org. For audiophiles, sound editors like Audacity (audacity.sourceforge.net) and GoldWave (www.goldwave.com) provide free and free-to-try versions, respectively.

4. Designing Gamification

4.1 General Guidelines and Specific Considerations

In a continuation of the approach discussed by Zichermann and Cunningham (2011), the authors recommend the following guidelines when seeking to gamify curriculum:

1. Award points, or experience points (XP) instead of grades - This may seem like a distinction without a difference. The main upshot of this approach is that student's scores are always increasing, giving a continual sense of progress.

2. Use points to define levels and/or titles - As students gain points, they should ascend levels. Most games use an exponential curve to define these. So, for instance, a player beginning at level 1 could ascend to level 2 at 100 points, to level 3 at 300, to level 6 at 600, etc. Such a curve rewards players early, but gives them diminishing returns, goading them to work harder to receive the same psychological reward. Educators may also include titles at various levels, depending on their discipline. In our computer programming course, a level 1 student is a "*keyboard masher*", while a level 5 student is a "*system admin*".

3. Divide course content into chunks, with "*gatekeepers*" - Because students should be able to progress (inasmuch as possible) at their own pace, educators should define "*levels*" of content which students can only gain access to by attaining that level. In this way, accelerated students can complete the course at a faster pace, while students who are progressing more slowly do not become overwhelmed. This also contributes to competition, along with levels, title, and points.

4. Multiple learning paths - Pursuant to a desire for autonomy, educators should create multiple versions of an assignment which vary slightly, while still covering the same concept. Students should then be allowed to choose which version of the assignment to complete. This can be a time-consuming mechanic, but readers should keep in mind that even the illusion of choice can be motivating (Stipek, 1996).

5. Geometric rewards - A counterpart to the aforementioned diminishing returns, this mechanic is intended to produce a flurry, or "*combo*", of activity. The authors used this mechanic in regard to student attendance points. For a class meeting 3 times per week, a student would receive 1 point for the first day attended, 2 points for the second, and 4 for the last. Thus, a student attending all 3 days earns 7 points, while a student attending 2 days would receive 3 points. The results of this approach are discussed below.

6. Loot (expendable items, perks) - Because the "*course is the game*", students should be rewarded with special abilities or privileges for completing key milestones in the course. One example item used in the author's course was the Pearl of Wisdom, which could be used in one of two ways: 1) A one-week, 10% boost to any assignments completed, and 2) a one-time, 25% boost to a single assignment.

7. Immediate (or near immediate) feedback - In digital games, players are generally accustomed to being notified within seconds about their progress. In the average course, a student may have to wait a week or more to receive useful feedback. While there is no "*silver bullet*" solution to this problem (especially for complex/nuanced feedback), educators can supplement more complex assignments with online quizzes and assignments that are automatically graded. However, to prevent students from simply re-taking the quizzes blindly, an educator must take care to cleverly craft the true-false, multiple-choice, or fill-in-the-

blank questions. Educators may also consider peer grading, where applicable, to offload some of the grading work.

8. "*Multiplayer*" (team assignments) - Where applicable, group work can be a powerful learning experience. In a course that can support multiple student roles, students can work together to mentor team members as well as customize their learning experience by taking on their preferred component of the larger project.

4.2 The Benefits and Cost of Gamification

The authors have studied gamification in their department's information systems courses for 3 academic semesters with approximately 150 students (plus 150 control students), with four instructors total. Each instructor has taught at least one semester of the traditional style of instruction and the gamified approach. While they are still collecting data, they have observed the following results so far:

• **Students asked more questions in class and studied outside of class more** – Student participation increased from a mean of 5.7 to 8.2 per class meeting. This seems to be partially a result of the "*chunked course content*". Since students could see the challenge before they understood how to solve it, they sought the answer before the lecture that would have covered the content and came to class better prepared.

• **Students tend to drop later and succeed mor**e - Students stayed in the course longer (instead of dropping). This led to a somewhat higher success rate (61%, compared to a control of 54%). This may be a result of using an accumulating point total instead of standard grading, as students anecdotally reported a sense of continual progress.

• **Student attendance increased** - Even though the authors did not offer more bonus points, the fact that they increased geometrically seemed to have an effect. Students attended an average of 4 days more (30 days per semester, compared with a control of 26 days).

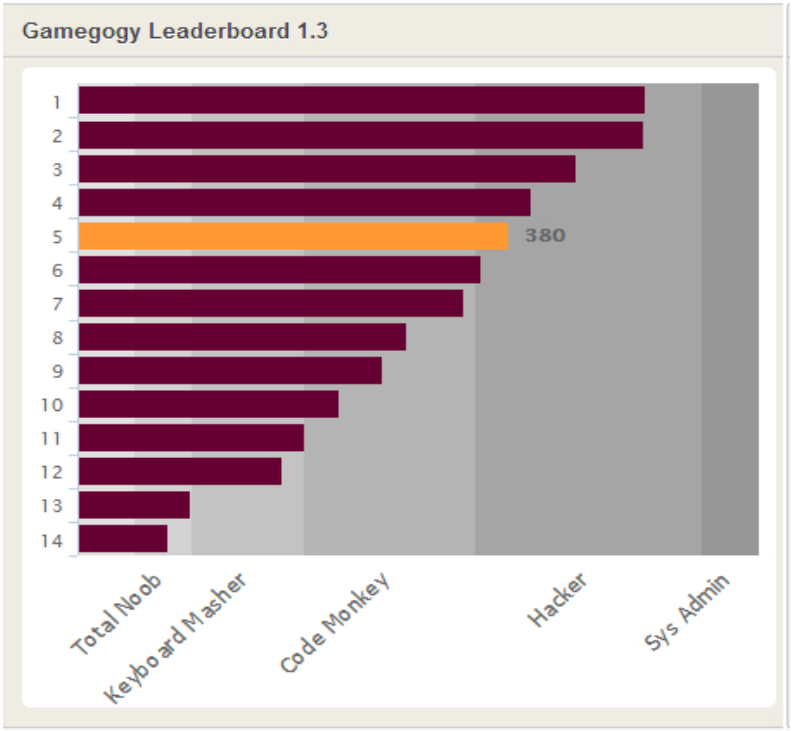
• **Advanced students completed early** - Seven students in the gamified group completed the course before the semester ended, in an average of 6 weeks (of a 15-week semester). The control version of this course was not designed with the option to complete early.

Finally, Table 3 summarizes the positive response from students who participated in our gamified courses. While the questions related to motivation and attendance are self-reported, they provide a useful comparison with the collected quantitative data.

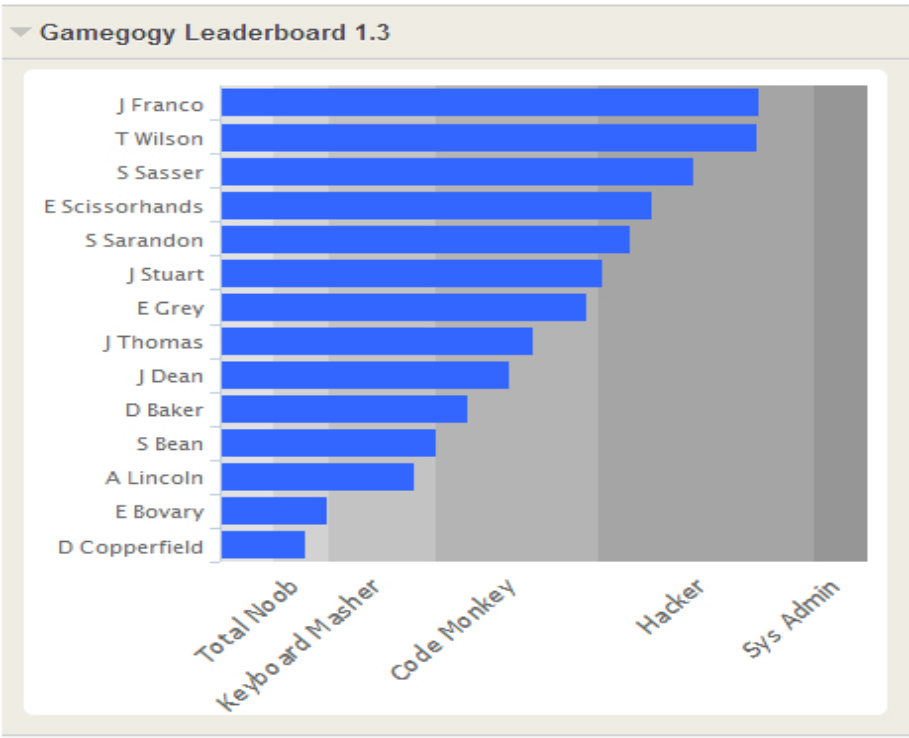
Question	Mean	Std. Dev.
How did the Leaderboard affect your motivation? (1 Very Demotivating, 5 Very Motivating)?	4.28	0.89
How did the Pearl of Wisdom affect your motivation? (1 Very Demotivating, 5 Very Motivating)	4.13	0.99
How did the attendance policy affect your attendance, compared to other courses? (1 Attended Less Often, 5 Attended More Often)	4.34	1.07
I would like to have the leaderboard in my future courses. (1 Highly Disagree, 5 Highly Agree)	4.68	0.87
I would like to have the Pearl of Wisdom in my future courses. (1 Highly Disagree, 5 Highly Agree)	4.39	1.03
I would like to have the attendance policy in my future courses. (1 Highly Disagree, 5 Highly Agree)	4.87	0.61

Table 3. Student Survey Results

While these results are promising, they did not come without cost. It is important to incorporate formative evaluation to gauge your student's behavior and reported satisfaction continually when first deploying a new gamification mechanism. While some of these approaches may be useful for a given educator's course, other may fall flat. Another concern is sustainability. Educators are encouraged to introduce these approaches a few at a time, so as not to be overwhelmed. Some mechanisms require an upfront time-cost to develop, so it is best to plan ahead.



Students see this



Instructors see this

Figure 2. The Leaderboard Building Block, designed to facilitate gamification through competition and immediate progress feedback

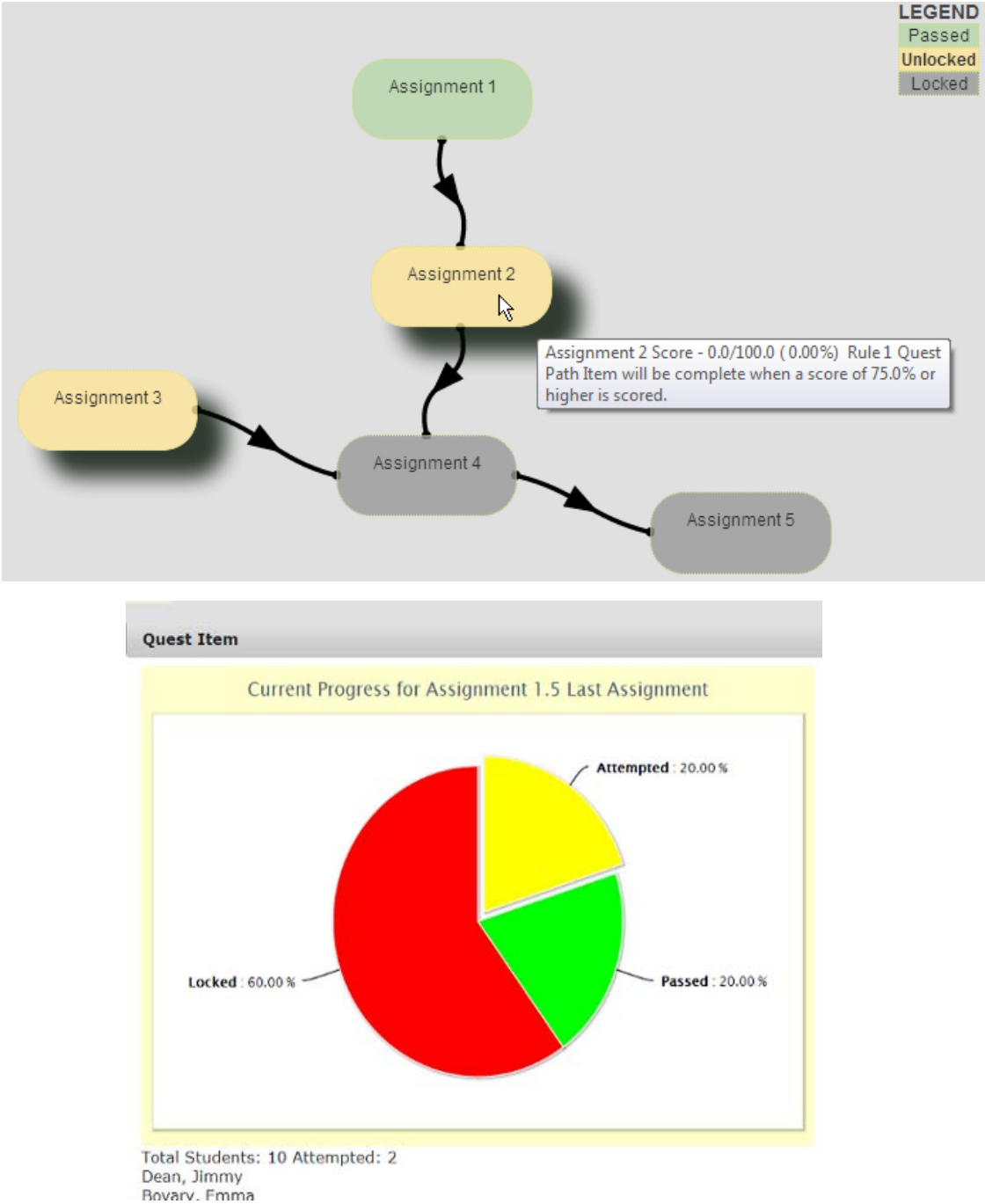


Figure 3. The Quest Path Building Block, displaying an interactive course "*learning map*"

4.3 Gamification Tools

For educators who are looking to try out gamification in their curriculum, there are many free software tools to support them. Socrative (socrative.com), a student response tool, allows educators to pose questions to their class and receive answers from practically any device with a web browser. This also includes the ability to create and deploy competitive team-based quiz games. Classroom Dojo (www.classdojo.com) provides behavior management software, complete with an avatar creator feature. Instructors can reinforce desirable behavior by awarding points to a student's avatar, which can be publicly viewed by other students.

For educators using the Blackboard learning management system (www.blackboard.com/platforms/learn/overview.aspx), a fully

featured Achievements/Trophy block is now built-in by default, with integration for displaying digital badges via the Mozilla Backpack (backpack.openbadges.org). In addition, the authors have developed web-based gamification tools for use in their programming courses (shown in Figures 2 and 3). Educators who use Blackboard can install these easy-to-use open-source tools by visiting the Blackboard OSCELOT project website (http://projects.oscelot.org/gf/).

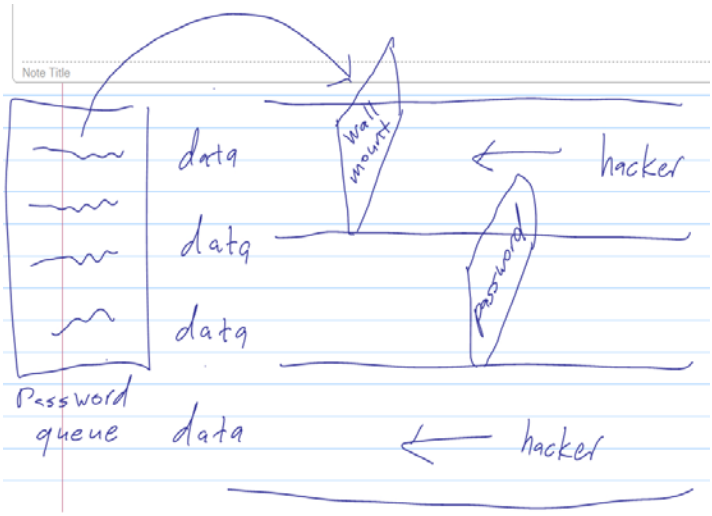


Figure 4. An early concept sketch of the "*Brute Force*" tower defense game

5. Game-making Workshop for Information Security Awareness Curriculum - A Case Study

Made possible in part by DoD-NSA grant H98230-12-1-0427, the authors hosted a two-day game-making workshop focused on information security and awareness training games with sixteen high school teachers and community college instructors. The workshop was designed to intersperse lecture and hands-on activities on topics such as information security awareness, introduction to computer security, digital forensics, and game development. Educators would then employ educational security training games (developed by the authors) in their curriculum and gauge their effectiveness.

5.1 Workshop Game Development

As aforementioned, the authors hosted a game-making workshop focused on information security and awareness training games. Part of that workshop included the design and implementation of two sample games, *Brute Force* (to teach students to choose good passwords) and *Friend or Foe* (for phishing awareness). This section chronicles the development of *Brute Force*. In developing our information security games, we were driven first by educational objectives. First, we reviewed the real-world security scenario we were trying to improve, then searched for an appropriate fit of genre and mechanics.

Some of the most common and avoidable security errors committed by end users are related to account passwords. Thus, our first game's objective was to encourage users to choose strong (computationally complex), memorable, unique (not re-used) passwords. In real life, hackers often attack user accounts using a password cracking program which systematically "*guesses*" the user's password from some or all of the following: a list of commonly used passwords, a dictionary of words, and brute force permutations. It is only a matter of time until a user's account will be compromised, assuming there is no account lockout. As such, one could visualize a password as a sort of wall or barrier that hackers are continually breaking down in order to access the user's account and personal data. This metaphor led us to our chosen game genre: the tower defense game.

In tower defense games, players must defend a resource (often a "*home base*" of some sort) from increasingly stronger waves of enemies. To do this, players erect defensive structures called "*towers*" which prevent enemies from reaching the resource. One of the more popular commercial examples of a tower defense game is "*Plants vs. Zombies*" by PopCap Games (http://www.popcap.com/plants-vs-zombies-1). In our game, players would erect walls from passwords that they chose or created. In this way, they would first learn to recognize a good password, then synthesize their own to reinforce learning. An early concept sketch is shown in Figure 4.

During the first week of design, we developed the following list of major actions and mechanics, which are depicted in the concept sketch:

1. The password queue generates a steady stream of passwords of varying strength.

2. Players drag and drop passwords from the password queue onto the wall mount structures.

3. Once dropped on a wall mount, a password becomes a wall, whose material (straw, wood, brick, steel) reflects its durability.

4. Hackers are regularly generated with increasing strength, whose goal is to smash through the walls. After trying for a period of time without reaching a player's personal data, a hacker will give up.

The next step was to create a basic playable prototype, to ensure that all the outlined mechanics were fun and that players could not "*game the system*", effectively winning the game but avoiding learning. At this point, polished graphics and sound were not necessary, so the screenshot in Figure 5 may remind some readers of video games from the early 1980's.

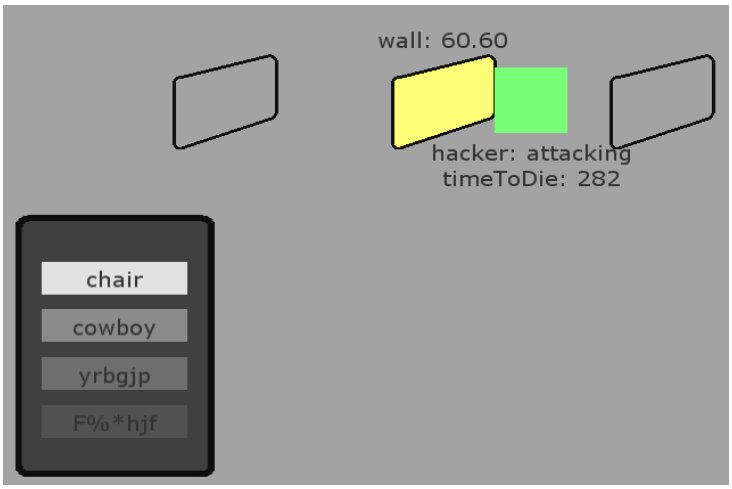


Figure 5. Early playable prototype of "*Brute Force*"

While this prototype was reasonably fun, it helped us to identify some weaknesses to address. We were not addressing the topic of password reuse. As such, we adjusted the Password Queue to periodically produce duplicates within a short span of each other. An unvigilant player would therefore likely reuse a password, falling into our trap (a.k.a. opportunity for learning). Next, we added the following mechanic: *If a hacker breaks a password that is currently being reused anywhere else on the screen, all instances of that password are instantly broken.* This was intended to give players an unpleasant surprise, one of the golden opportunities for learning (Fenker, 2008).

Next, players could not yet create custom passwords. We decided to allow them to create custom passwords periodically in order to produce cycles of recognition and synthesis. Since creating a password would require increased attention from the player, the game would need to supply an extra reward for this behavior. Therefore, the following mechanic was born: *Periodically, players may generate custom passwords, which have the potential to be stronger than those produced by the password queue.* After playing this new version, however, it was easy to cheat the game by simply randomly striking keys, thus yielding a strong but not memorable password. In order to discourage this, we added the "*rubble*" mechanic, as follows: *To encourage players to choose memorable but strong passwords instead of simply "button mashing" to create a custom password, any broken custom password leaves a pile of rubble which can be cleared more quickly by typing in the old password correctly.* Players who could not remember the password they entered could not remove the rubble, which remained in place for twenty seconds and blocked the placement of a new password wall.

The last major component of missing game logic was some form of tutoring or help to guide the player. The first component of this is the aforementioned onboarding feature. Roughly the first 30 seconds of the game are designed to allow the player to practice each type of action they can take once and view the consequences before the real challenge begins. The game will patiently wait for the player to complete each isolated task, and only continues to the next when the previous one is completed.

The next aspect is guidance. Providing too much guidance only serves to obfuscate. Just as educators provide well-designed, gradually tapering levels of support, our game would prompt players with helpful guidance upon detecting mistakes, but with a geometric dropoff. Thus, the first time a player chooses a weak password, they are prompted with one of several helpful

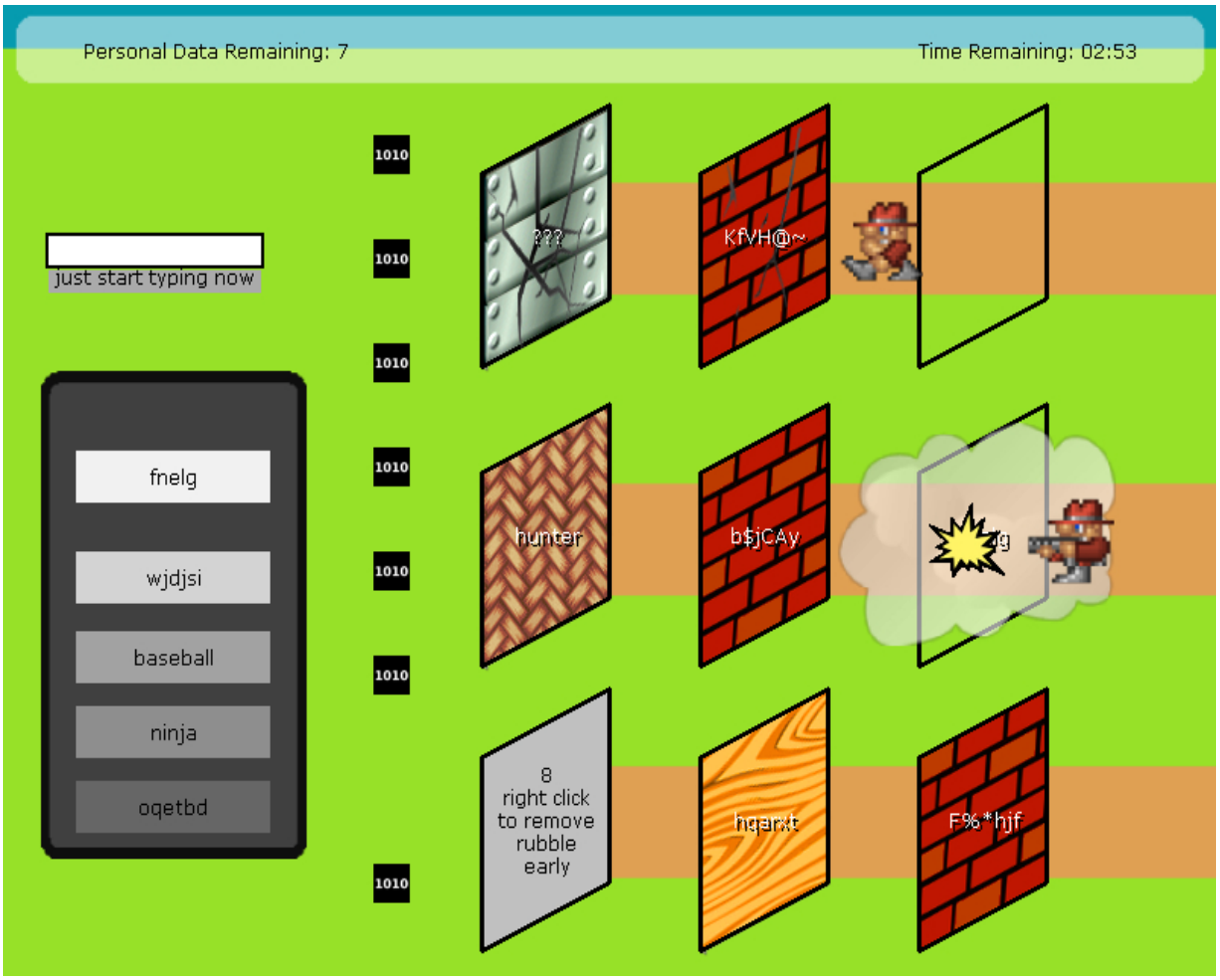


Figure 6. *Brute Force*, a tower defense game for teaching end users to choose strong, unique, and memorable passwords. Developed at Jacksonville State University with DoD-NSA grant H98230-12-1-0427

Question	Before	After
Game Development Skill Level, Intermediate to Advanced	12%	78%
Information Security Awareness, Aware-Highly Aware	43%	100%
Workshop Satisfaction, Satisfied-Very Satisfied	N/A	100%
Pace of Instruction, Satisfied-Very Satisfied	N/A	100%
Course Material Utilization in Classroom, Likely-Very Likely	N/A	100%
Comparison with other Workshops, Better-Much Better	N/A	100%

Table 4. Workshop Survey Results

Question	Mean	Std. Dev.
I am more aware about what makes a strong password	4.14	1.03
I am more aware of the importance of not re-using passwords.	4.26	1.09
I am more aware of common signs of a phishing scam	4.09	1.04

Table 5. Game Deployment Survey Results (1 = strongly disagree, 5 = strongly agree)

messages, such as "*Use a mix of uppercase and lowercase letters, numbers, and symbols*". The player will be reminded with a similar message on mistake 2, 4, 8, 16, etc. The threshold for what is deemed a weak password also rises gradually during the game as the challenge increases, as the tutoring system expects greater levels of performance from players who play longer.

Once all the major game logic was in place, two development phases remained-adding media and game balancing. These last two phases required approximately 40% of the development hours, even though some portions of the media were acquired from royalty-free sources. As in any software engineering project, testing should begin early, with several players who are outside of the development team. The first release version of Brute Force is shown in Figure 6.

5.2 Workshop Results

The pre-workshop survey indicated that eighty-eight percent (88%) of the teachers had no knowledge or very little knowledge of game development. The entire group was introduced to gaming concepts and game development during the first day. They were then given a homework assignment to develop their own games after the first day. At the end of the workshop, seventy-eight percent of the teachers claimed to have an intermediate to advanced skill level in game development. While these results are self-reported (and thus, probably generous to the participants), the pre-and post-surveys shown in Table 4 indicated a positive change in results.

In the fall of 2013, the workshop participants employed the authors' games (covered in the section *Game Development Post-Mortem*) with approximately 180 students in order to enhance their information security awareness curriculum. Students who played *Brute Force* and *Friend or Foe* consistently reported increased awareness, as summarized in Table 5. While these results are self-reported, they reflect a positive attitude toward the effectiveness of education games in the context of information security awareness.

6. Conclusions

We have presented the results of a project on the gamification of information systems and security training. We studied the impact of game development on teachers and the game-based curriculum modules on students. The results of both studies reveal encouraging information to support the utilization of gamification in the curriculum. Additionally, we described some general-purpose gamification tools for use in the classroom as well as several educational games that we designed and developed in-house. Preliminary results on a study on the benefits of these tools are quite promising, including positive student attitudes toward these approaches and improved attendance and success rate.

While gamification may not be applicable to all curriculum, there is a large sector of students who may benefit greatly from well-designed, thoughtful use of its principles. The authors agree with James Gee (2007), a vocal proponent of game-based learning: "*There are many good principles of learning built into good computer and video games. These are all principles that could and should be applied to school learning tomorrow…*"

The challenge for the authors is on the continuous improvement of these gamification tools and curriculum modules. Future plans include:

- The design and development of additional gamified cross-disciplinary curriculum modules;
- The continuous development of a compilation of best practices in gamification;
- The deployment and maintenance of a web server that will provide a repository for gamification tools and gamified curriculum modules to enhance dissemination and stimulate participation.

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