

**Motivation, Engagement, and Effectiveness of Serious Games
for Teaching Cyber Security and Database Defense**

by

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Abstract

This study uses an exploratory case study methodology, employing a mixed methods approach to explore the merits of a serious game, called *Database Defender*, to improve motivation, engagement, and learning of cybersecurity topics specifically database threats, database backup, and recovery. Results from Likert scale, open-ended questions, and interview responses show that game-based learning can be an effective way to increase or maintain a high level of motivation, be highly engaging, be very enjoyable, and reinforce knowledge taught in class on the topic of database defense to higher education students. Pre-test and post-test score differences showed no statistical significance between the control and game groups. However, student responses on the post-test indicated that students in the game group (as compared to the control group) demonstrated a better understanding and remembered the aspects of database defense, which the game sought to teach. This study fills a gap in the literature applying digital game-based learning to the specific topic of cybersecurity and database defense and to a specific audience of higher education students.

Keywords

Database Defense, Cybersecurity, Information Technology, Ransomware, Threats, Hardware Failure, Computer Virus, Natural Disaster, Recover Data, Data Recovery, System Administrator, Sys Admin, Cyber Attack, Database Backups, Self-Determination Theory, Flow Theory, Motivation, Engagement, Enjoyment, Fun, Serious Games, Game-based Learning, Post-Secondary, Higher Education, Post-Secondary, Knowledge Retention, Learn, Teach, Real-World, Intrinsic Motivation, Extrinsic Motivation, Amotivation, Effective, Tower Defense, Strategy Game, Digital Game, Video Game, *Database Defender*, Student Perception, Case Study, Pre-Test Post-Test Experimental Design, In-depth Interview, Mixed Methods, Survey.

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Chapter 1: Introduction

Introduction

Problem Statement

Cybersecurity and database protection are important topics in information technology (IT) because of the alarming rate of cyber attacks and the damage caused by these incidents (Boopathi et al., 2015; Dudjak et al., 2017; Jin et al., 2018; Min et al., 2018; Preston, 2007; Yang et al., 2010). Cyber attacks are becoming more and more of a concern because of the increasing financial losses that result, for example, "an estimate of \$106 billion was recorded for cyber hacks in the United States in 2016 alone" (Awojana & Chou, 2019, p. 1). In a recent ransomware attack, TransLink, the Vancouver transit authority in British Columbia, Canada, was ransomed \$7.5 million dollars when their payment system was taken offline (Hurst & Holliday, 2021; Translink, 2021). Ransomware is just one of many such cyberattacks that is a "growing concern in enterprise and government organizations, because it may cause financial damages or loss of important data" (Min et al., 2018, p. 243). "With nearly 100% of our world's information stored on computers and databases, the threat of compromising this information looms as arguably the most critical risk that we must deal with as a global society" (Peslak & Hunsinger, 2019, p. 62). As a result of the increase of data storage needs and the importance of protecting this data against database attacks, there is currently a significant demand for highly trained IT professionals with a predicted global shortage of millions of cybersecurity specialists by 2022 (Jin et al., 2018). Canada also has an increasing demand for, difficulty employing and maintaining IT professionals (Cukier et al., 2009; Nithithanatchinnapat & Joshi, 2019; Serenko et al., 2020).

There are many types of threats to the data contained within a database, and, if access to this data is interrupted, it can have huge impacts to a company's revenue and its business reputation, even if unavailable for only a few minutes (Information Technology Intelligence Consulting Corp., 2020; Jade Software Corporation Limited, 2018; Weber & Staiger, 2014). Threats to a database include, but are not

necessarily limited to: hardware failures, natural disasters, database corruption, operating system crashes, power failures, human error, malicious intervention, ransomware, malware, and viruses (Jade Software Corporation Limited, 2018; Son et al., 2017; Zaman & Butt, 2013). Each of these database threats will affect the data differently. Some threats negatively affect only a small portion of the data, while others have more wide spread damage. Some threats such as hardware failures may have very localized damage, affecting only a single computer, whereas natural disasters may damage multiple computers, destroying much more data. The affect of database threats also varies based on the type of data. For example, a human error may inadvertently destroy historical data while leaving more recent data unaffected. Since data is crucial to the proper functioning of so many businesses, is it critical to have a well formulated database backup and recovery plan (Zaman & Butt, 2013).

Regardless of the type of database threat, there needs to be a way to recover data in the unfortunate event that the data is destroyed. A database backup is a way to copy the data and store it, such that it can be properly recovered. However, there are many different types of backups and storage methods, each with their own options and configurations; with their own advantages and disadvantages. Some are faster than others, while others are slower, but better at obtaining a consistent snapshot of the data. Some data may change frequently and may need to be backed up regularly, while other data may be more constant and may not need to be backed up more than once. Another important consideration is where the database backup is stored. A database backup may be useless if it only stored on the same computer as the original database, because if that computer is destroyed or stolen, both the database and the backup will be lost, without any way to recover the data. It is the combination of these backup types, their attributes, and storage locations, that can defend against a specific set of cybersecurity threats. In order to protect against all of them, multiple different backup types used in conjunction are required. A properly designed database backup and recovery plan includes

these multiple different backup types and gives IT professionals the ability to recover from as many database threats as possible (Kim et al., 2020).

Purpose of the Study

There is currently a significant demand for highly trained IT professionals "to protect against the cyber threats" (Jin et al., 2018, p. 150). These IT professionals must be proficient in each database backup type, all that backup's attributes, and proper backup storage techniques. An IT professional must be able to analyze the risks and potential consequences of all the possible threats and devise a defense plan specific to each computer, as it pertains to that company, in that location. IT professionals are the defenders of the data within their organization's databases.

As an instructor at the British Columbia Institute of Technology (BCIT), I teach database administration and management in the Computer Information Technology (CIT) program, a two-year diploma program. The CIT program trains students to become industry ready for entry-level positions as IT professionals, such as system, network, database, and security administrators (British Columbia Institute of Technology, n.d.). Graduates of the CIT program would be negligent in their jobs if they did not have a strong understanding of cybersecurity threats and were not proficient in defending against them (Yang et al., 2010). Graduates who have not been taught in school these critical database backup and recovery skills and cybersecurity concepts, are liable to make mistakes in their junior entry-level positions. These mistakes, if left unchecked and unfixed, may lead the company they work for, to be vulnerable to a cyber attack, which may result in significant financial losses and damaged reputation. Up to 95% of cyber threats to organizations are due to user mistakes and poor cybersecurity skills (Carlton et al., 2019).

It has been my personal observation that database backups and recovery may be poorly understood in my classes, as one third of students on final exams provide unsatisfactory answers (less than or equal to 60%) on test questions relating to the topic of database backups. For example, students

often explain that a single backup type is suitable to defend against all types of database threats, which is incorrect, or that certain backup types will properly defend against certain threats which they would not. It is important that all students have a solid foundation on this topic. There is supporting evidence in academic literature that database backups and recovery are undertaught according to Jones et al. (2018) and that cybersecurity topics are difficult subjects to master (Awojana & Chou, 2019; Bhardwaj, 2019; Crick et al., 2020; Hendrix et al., 2016). It has also been shown that typically the general public scores very low on cybersecurity questions relating to security threats and defenses (Olmstead & Smith, 2017). As such, I have been looking for an alternate way to teach this topic to students. This has led me to research game-based learning as a way to improve student understanding of database backups and threats.

Game-based learning is a popular tactic to encourage motivation and engagement in schools because digital games are associated with autonomy and competence, which are core components of the self-determination theory (Proulx et al., 2017). And while there are some articles demonstrating applied digital game-based learning (DGBL) to teach non-computer related topics (Barzilai & Blau, 2014; Felicia, 2014; Gaeta et al., 2019), there are only a few that focus on DGBL for computer programming (Krassmann et al., 2015; Mathrani et al., 2016; Papadakis & Kalogiannakis, 2019) and IT related topics (Awojana & Chou, 2019; Boopathi et al., 2015; Jin et al., 2018).

Justification of the Study

Much of the existing research on the use of serious games and DGBL (incorporating serious games into teaching materials) has focused on younger ages and research is limited for DGBL in higher education (HE) (Coleman & Money, 2020; Felicia, 2014). According to Felicia (2014), students now, might expect highly engaging learning experiences and "due to their alleged affinity with technologies, it is claimed that today's students expect to be similarly engaged by their educational environments with participatory, sensory-rich environments and experiential/discovery-based learning activities" (p. 237).

This gap in research leads to an opportunity for exploration of the possibility of using serious games and DGBL for HE.

To further the research on DGBL for HE, particularly in cybersecurity and database protection, I have created a serious game called *Database Defender*, designed to teach the common database backup tools, attributes, and storage techniques. This serious game challenges students to address the following scenario: In a perilous world where everyone and everything is out to get you, how will you defend your database castle? You must always be vigilant and be prepared for the latest attack, as viruses, natural disasters, problematic software updates and rogue hackers plague your network infrastructure and threaten the precious uptime of your database servers. Making learning fun and relating to the gaming culture that the students already know and love has the potential to facilitate learning and knowledge retention (Annetta, 2008). I am interested in knowing if the application of DGBL would help teach database protection and cybersecurity in HE.

Research Questions

Research question: How does playing a serious game affect higher education students' ability to apply concepts of database and cybersecurity threats and defenses to real-world cybersecurity scenarios?

Sub-questions:

1. How does playing a serious game affect higher education students' motivation to learn concepts of database and cybersecurity threats and defenses and apply these concepts to real-world cybersecurity scenarios?
2. How does playing a serious game affect higher education students' engagement to learn concepts of database and cybersecurity threats and defenses and apply these concepts to real-world cybersecurity scenarios?

3. What are higher education students' perceptions of playing serious games to learn concepts of database and cybersecurity threats and defenses?
4. How does implicit in-game learning of concepts of database and cybersecurity threats and defenses affect higher education students' ability to apply this acquired knowledge to explicit real-world cybersecurity scenarios?

Definitions of Key Terms

Below is a list of terms used within this paper with their definitions and context as they relate to this research.

Cybersecurity

Cybersecurity is defending computers, servers, mobile devices, electronic systems, networks, and data from malicious users and attacks (Bhardwaj, 2019; Kaspersky Labs, 2021).

Database

A database is an organized collection of structured information, or data, typically stored electronically in a computer system and configured for rapid search and retrieval (Merriam-Webster, n.d.; Oracle, 2021).

Database Backup

A database backup is the process of copying and archiving computer data so it may be used to restore the original data after a data loss event (Zaman & Butt, 2013).

Database Recovery

Database recovery is the process of restoring the data within a database, from a database backup, to a state prior to a disaster event such as hardware failure, system crashes, and other reasons (Kim et al., 2020, p. 405).

Digital Game-Based Learning (DGBL)

Digital game-based learning is the design and use of digital games (on computers, tablets, mobile phones, or online) with the goal of developing new knowledge or skills, or to enforce existing knowledge or skills. These digital games are also referred to as *Serious Games* (Boller & Kapp, 2017).

Gamer

Someone who self-identifies as an experienced or frequent player of digital games (Bedwell et al., 2012).

Information Technology (IT)

"Information technology (IT) is the use of any computers, storage, networking and other physical devices, infrastructure and processes to create, process, store, secure and exchange all forms of electronic data. Typically, IT is used in the context of business operations, as opposed to technology used for personal or entertainment purposes." (Castasgna & Bigelow, 2021).

Information Technology Professional (IT Professional)

IT Professionals are those employed to maintain IT systems. An IT Professional's tasks include (but not necessarily limited to) testing, building, installing, repairing, and maintaining the computer hardware and software associated with complex computer systems for managing information, in one or more locations (Dynamix Solutions, 2017).

Ransomware

Ransomware is the process involving the use of a software program designed to encrypt (or lock) files and ransoming access (the key) to those files for a fee (Kruse et al., 2017). Ransomware is one of many database threats that destroy data in a database.

Serious Games

Serious games are games designed with a purpose other than pure entertainment (Djaouti et al., 2011). Serious games utilize game mechanics, aesthetics, and game elements to improve engagement,

motivation, and enjoyment to promote learning in interactive learning environments (Enders & Kapp, 2013; Prensky, 2001). See also *Digital Game Based Learning*.

Chapter 2: Literature Review

The literature review for this study will examine the existing research into DGBL and its potential for teaching cybersecurity in HE. More and more, DGBL has been used to teach because of its potential benefits such as increasing the learners' motivation and engagement, however, DGBL may not be applicable for all situations. Research into DGBL has typically focused on teaching students in elementary and secondary schools and research is limited for DGBL in HE. There are a few exceptions for DGBL in HE such as simulations used to teach in medical education. However, research is limited for DGBL used to teach cybersecurity. There is a need to teach database defense and cybersecurity to properly train IT professionals to be work-force ready. DGBL could be a potentially effective way to encourage motivation and engagement for teaching cybersecurity.

Theoretical Framework

In order to answer the research question, particularly the sub-questions regarding motivation and engagement and their effects on learning and retaining knowledge, it is important to have a solid foundation of the current theories and understandings of sources of motivation and engagement, and how they pertain to a teaching and learning environment. This is why, for this research, I used the self-determination theory of motivation and flow theory of engagement as the theoretical frameworks for this research. As described by Abdul Jabbar and Felicia (2015), engagement affects learning and motivation, and has been increasingly important in studies involving educational games.

Self-Determination Theory of Motivation

The theory of self-determination by Ryan and Deci (2000), describes motivation as the "energy, direction, persistence and equifinality--all aspects of activation and intention" (p. 69). As a teacher, student motivation is crucial for academic success; if you can motivate your students, they will learn better (Ryan & Deci, 2000; Taylor et al., 2014). In the self-determination theory of motivation, Ryan and Deci (2002), categorize and rank the different types of motivation: from amotivation - the least

autonomy, to extrinsic motivation - moderate autonomy, and to intrinsic motivation - the most autonomy as shown in Table 1.

Table 1

Categories of Motivation and a Scale of their Relative Autonomy

Amotivation	Extrinsic Motivation	Intrinsic Motivation
Lowest Autonomy	←————→	Highest Autonomy

Note. This table is a summary of the Self-Determination Continuum as presented by Ryan and Deci (2002).

Within the theory of self-determination, amotivation is defined as the lack of motivation or desire to complete a task or activity. Amotivation may lead a student to go through the motions and lack intentionality, which can be caused by a number of factors including: lack of contingency, lack of perceived competence or lack of perceived value in the activity or outcomes (Ryan & Deci, 2002). Extrinsic motivation has four subcategories: 1) external regulation, 2) introjected regulation, 3) identified regulation, and 4) integrated regulation. Extrinsic motivation is generally defined as completing a task as a means to an end rather than for pleasure, often with goal of achieving an externally imposed reward. Intrinsic motivation is doing an activity out of interest, for enjoyment or inherent satisfaction. Intrinsic motivation is at the peak of motivation (Ryan & Deci, 2002) and evidence from a research meta-analysis performed by Taylor et al. (2014) confirms that "intrinsic motivation is consistently the most beneficial form of motivation for student's achievement" (p. 357).

From an instructional design perspective, Keller and Suzuki (2004) created the ARCS model to describe motivation in education. The ARCS model is closely related to the theory of self-determination as it incorporates themes of intrinsic and extrinsic motivation and describes how they can make teaching more effective (Keller, 2009). In the ARCS model, Keller and Suzuki introduce four conditions

for creating motivating course content: 1) attention, 2) relevance, 3) confidence, and 4) satisfaction.

Firstly, Keller and Suzuki explain that for a lesson to be motivating, it should gain and sustain a learner's attention through aesthetics, animations, or events that introduce mystery, conflict, or unsolved problems. The second requirement is relevance. Relevance is having clear instructional goals that are interesting and related to the learner's future job or academic requirements. The third requirement is confidence. Confidence is established when students are able to see success in their accomplishments from their abilities and efforts, rather than luck or the task being too easy or difficult. The last condition, satisfaction, is learners having a positive feeling about their learning experiences. Any extrinsic motivation reinforcements, such as positive rewards and recognition should be used with caution as to not have a detrimental effect on intrinsic motivation (Keller & Suzuki, 2004).

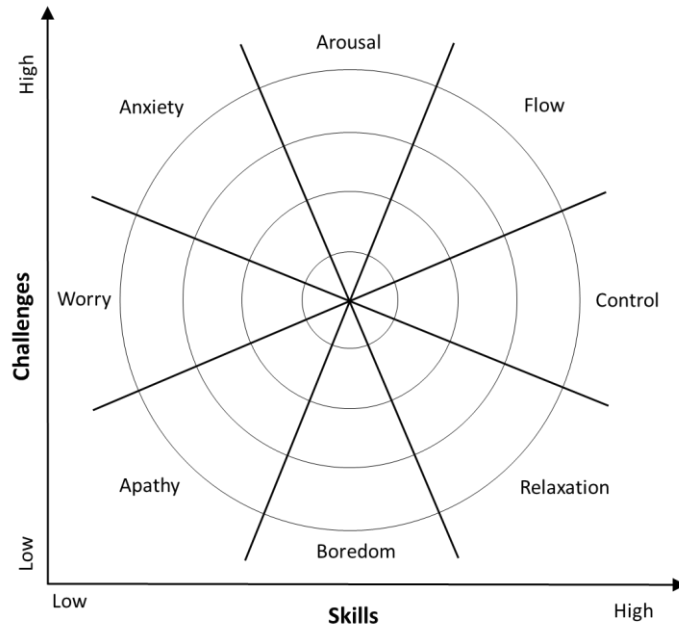
From a DGBL perspective, Prensky (2001) describes serious games as motivating because they include game aspects that make learning fun. Enjoyment and fun are important to learning because the learner is relaxed and motivated, and more willing to learn. Enjoyment and fun leads to learners learning better (Prensky, 2001). Games show us teaching can be effective when the work of learning is correctly balanced with fun (Boller & Kapp, 2017; Dimitriadou et al., 2021; Gee, 2007).

Flow Theory of Engagement

Engagement is described by Whitton (2011) as the combination of qualities that "pull people in" such as a sense of authenticity, ability of the environment to adapt to the actions of the user, a sense of immersion, and creating an experience of flow. When in a state of flow, a person is fully immersed with intense involvement (Weibel et al., 2008). While fun and engagement are often experienced together, engagement is not predicated on fun. For example, a horror film may be engaging, but at the same time scary rather than fun (Whitton, 2011). Whether the experience is pleasant or not, "flow works as a hook that engages players and gets them to play again and again" (Kiili et al., 2012). When flow level of

engagement is achieved, individuals function at their fullest capacity and the experience itself becomes its own reward (Shernoff et al., 2014).

Many game-related research articles use flow theory as conceptualized by Mihaly Csikszentmihalyi to describe engagement and the compelling nature of digital games (Whitton, 2011). Factors that contribute to flow include: 1) a challenge that requires skill to achieve, with attainable goals and known rules, 2) complete absorption in the activity, 3) clear goals, 4) immediate feedback, 5) concentration on the task at hand, 6) a sense of control, 7) loss of self-consciousness, and 8) transformation of the perception of time (Csikszentmihalyi, 1990). As shown in Figure 1, a state of flow can be achieved when a learner perceives that their skill and the challenge levels for a task are aligned and are both high. Digital games have a unique affordance of achieving flow for an individual player as the game can adjust the difficulty levels according to the current player's skill level and increase in difficulty as the player's skill progresses. The individualized customization in terms of matching the challenges of the learning activity to the players' skill (Hamari et al., 2016) of these adaptive games are particularly good at ensuring flow (Caserman et al., 2020).

Figure 1*The Current Model of Flow*

Note. The current model of flow, adapted from Csikszentmihalyi (1997). Flow is experienced when perceived challenges and skills are both high.

Motivation and engagement are interrelated as they share a number of aspects such as: doing an activity for the sheer sake of doing it (Malone & Lepper, 2005; Ryan & Deci, 2002; Whitton, 2011); requiring a sense of control and autonomy (Ryan & Deci, 2002; Whitton, 2011); and needing relevant, authentic academic work that relates to real world problems (Keller & Suzuki, 2004; Shernoff et al., 2014). Indeed, articles often define engagement in terms of motivation or vice versa. Shernoff et al. (2014) describes flow engagement intrinsically motivating and links high engagement during tasks in high school to having a significant predictor of continuing motivation and commitment in college. Whitton (2011) also provides evidence that a link exists between intrinsic motivation to learn, engagement, and instructional effectiveness. This study investigates the introduction of DGBL into the database course that I teach, and its effect on motivation, engagement, and quality of instruction.

Literature Review

DGBL Research is Increasing

Given the potential of being motivating and engaging, game-based learning is becoming more common as a tactic for teaching (Proulx et al., 2017). Studies by Hwang and Wu (2012) and Byun and Joung (2018) show an increasing trend of the number of research articles on DGBL being published each year since 2001. Boyle et al. (2016) saw DGBL articles rise in number to 512 in 2014 (articles dated 2009 to 2014), up from 129 in 2009 (articles dated 2004 to 2009). Connolly et al. (2012) show DGBL being used in many disciplines including: business, computing, engineering, geography, health, history, language, mathematics, military, science, social issues, and statistics. While there are many articles demonstrating applied DGBL to teach non-computer related topics (Barzilai & Blau, 2014; Felicia, 2014; Gaeta et al., 2019), there are only a few that focus on DGBL for Computer Programming (Krassmann et al., 2015; Mathrani et al., 2016; Papadakis & Kalogiannakis, 2019) and IT related topics (Awojana & Chou, 2019; Boopathi et al., 2015; Jin et al., 2018). In a recent study by Karagiannis and Magkos (2021), the authors describe cybersecurity training using serious games, a "young and developing field" (p. 3) and that further study into DGBL is required to provide more data to confirm benefits of DGBL relating to learning outcomes and acquired skills.

Benefits of DGBL

This increase in articles on DGBL may be, at least in part, due to the supporting evidence of its effectiveness in teaching. Papastergiou (2009) explains that games are "believed to hold the potential to render learning of academic subjects more learner-centered, easier, more enjoyable, more interesting, and, thus, more effective" (p. 1). Mao et al. (2021), present evidence that DGBL had a large, significant positive effect on student's critical thinking which was consistent across participants school level (elementary, secondary or college). Proulx et al. (2017) and Wouters et al. (2013) confirm that players are more willing to spend time and energy to complete an activity if they see it as fun and are

intrinsically motivated. Hamari et al. (2016) present evidence showing that both conditions for flow (challenge and skill) have a positive association with learning. Annetta (2008) explains that educators repeatedly conclude that the advantage of serious games is that they have higher engagement, more motivation and greater appeal, which leads to better achievement. Serious games "reach learners who do not do well in conventional settings (Dede, 2004)" (Annetta, 2008, p. 233). Because games encourage interest and curiosity, through achievement and control, they can provide motivation when other methods fail (Dörner et al., 2016).

In a meta-analysis of DGBL by Boyle et al. (2016) of articles with participants aged 14 or older, and where the article studied serious games classified for knowledge acquisition, DGBL led to better performance than the control conditions in a majority of studies. Boyle et al. did, however, find a study where the results for knowledge acquisition indicated DGBL was comparable to traditional methods, and yet another study where traditional lecture was more effective than DGBL, though these studies are the exceptions to their findings of generally positive results of DGBL. Several researchers also encourage the use of serious games to promote learning in the classroom (Boller & Kapp, 2017; Kapp, 2012; McGonigal, 2011; Prensky, 2001). In answer to the question whether learning games actually facilitate learning, Boller and Kapp (2017), answer definitively yes, by summarizing several meta-analysis articles indicating game-based learning is more effective than traditional instructional methods and Kapp (2012) further explains games yield better attitudes towards learning. Prensky (2001) explains that DGBL works by getting the right combination of engagement and interactive learning. McGonigal (2011) says that games provide a safe environment that makes failure fun and direct vivid feedback which help make work more satisfying. Reeves (2006) points to five essential strategies for increasing student engagement, one of which is providing continuous feedback. Perhaps the reason games are so satisfying (and addictive), is rooted in human biology. Evidence in a study by Howard-Jones et al. (2015), shows completing tasks in-game releases dopamine (a drug that acts as a reward) within the brain and

dopamine is associated with "improved ability to store and explicitly recall information" (Howard-Jones et al., 2015, p. 143).

Limitations of DGBL

Proulx et al. (2017) cautions that not all games used for teaching are effective or even motivating and that "the technology itself does not necessarily foster student motivation" (p. 82) but instead the "technology could have the *potential* [emphasis added] to have a positive impact on student's motivation" (p. 82). Kenny and Gunter (2007) note that games will fail to teach effectively if a careful balance between good pedagogy, with engagement, motivation and/or immersion is not achieved and Plass et al. (2020) indicate that incorrectly integrated game mechanics could "detract from achieving the learning objectives" (p. 18). Kapp (2012) also emphasizes that games may not be the right tool for all learning outcomes and that games should not be seen as a panacea. Along these lines and based on two corporate serious game success stories, Prensky (2001) suggests that DGBL is best suited for:

- Material that is dry, technical and, yes, boring
- Subject matter that is really difficult
- Audiences that are hard to reach
- Difficult assessment and certification issues
- Complex process understanding
- Sophisticated "what-if" analyses
- Strategy development and communication (pp. 20-21)

When designing a serious game, it is important to consider the target audience. Not all students will be motivated by the same game elements (Proulx et al., 2017) and not all engaging game elements promote effective learning (Marklund & Romin, 2020). Proulx et al. (2017) provides evidence that some

game mechanics for some students in certain contexts (e.g. competition among highly confident students) may be highly motivating, while for others, will have the opposite effect by being highly demotivating. It is important not to assume the audience is homogeneous; if the audience is diverse in age, gender, education, competitiveness, or experience with games, a serious game may fail to engage and motivate everyone equally. Carefully identifying the game's target audience and play testing early prototypes of the game with subsets of the intended audience, can help serious games appeal to diverse audience (Moschini, 2006). Research confirms males and females learn differently from serious games (Garber et al., 2017) and may be motivated by different aspects of learning (Stege et al., 2011). Another concern is when a game is purely extrinsically motivating instead of intrinsically motivating. When only extrinsically motivated, learners may focus solely on the reward(s) at the end and may miss the point of the serious game - which is to retain knowledge or acquire new behaviours. If solely extrinsically motivated, the learner may not pay attention to the learning task and may skip directly to gaining the reward (Kapp, 2012). Also, those learners driven exclusively by extrinsic motivation might be inclined to only perform desired learned behaviour within the game when rewarded, and not afterwards (Hyrynsalmi et al., 2017).

DGBL Focuses on Younger Ages

Despite the increasing number of articles for DGBL, most research focuses on a younger age group. Meta analysis articles on DGBL, for teaching science-related topics (Tsai & Tsai, 2020), math-related topics (Byun & Joung, 2018), or across multiple topics (Coleman & Money, 2020) show that a vast majority of game-based learning is used in the K-12 level and only a very small minority in HE. Tsai and Tsai (2020) found only two out of 14 articles which studied the effects of DGBL for science in HE (with the remaining 12 articles for K-12 levels); Byun and Joung (2018) discovered a decreasing amount DGBL articles through the progression of K-12, with 22 articles for elementary, eight for middle school, two for high-school and none found for post-secondary; and Coleman and Money (2020) only show

some articles for single-player games and limited articles for multi-player games studying adults (17 years or older) as opposed to most articles studying children (under 17 years old). From the perspective of DGBL for cybersecurity, this ratio holds, with only two out of 13 articles applying DGBL to adults (Hendrix et al., 2016). Boyle et al. (2016, p. 184) confirms this by finding that fewer secondary school teachers were in favour of DGBL than primary school teachers. Perhaps there is a mindset that suggests that "play and games are simply preparation for work" (Prensky, 2001, p. 60), games are "inappropriate for the business of formal education" (Felicia, 2014, p. 241), and that game-play is childish and a "waste of time" (Gee, 2003, p. 40; McGonigal, 2011, p. 4). Breuer and Bente (2010) and Dimitriadou et al. (2021) even suggest that the very term "serious games" is potentially an oxymoron or a contradiction for some people, as games are generally not considered for anything else other than entertainment.

DGBL has potential for HE

It has been suggested that students today learn differently (Felicia, 2014; Kapp, 2012; McGonigal, 2011). The youth of today are exposed to more games than previous generations and continue to play games into adulthood. As much as 98% of children aged 12 to 18 years old play video games of some kind (Burke & Lucier-Greer, 2021). And according to a survey conducted in 2018 by the Nielsen Company, 66% of the U.S. population aged 13 and older, self identify as gamers and this number has seen a steady increase from 58% in 2013 (Nielsen Company, 2018). Felicia (2014) and Al-Azawi et al. (2016) suggest that students who have an affinity for technology might expect highly engaging learning experiences in their educational environment. For students who might see learning as boring, DGBL provides the potential for being engaging and an effective learning process in an environment that students are comfortable (Al-Azawi et al., 2016; Annetta, 2008). Perhaps DGBL is a solution for these students that "have become disengaged with traditional instruction" (Van Eck, 2006, p. 1). Kapp (2012) suggests we shouldn't think of DGBL the same way as you do games for children; serious games are an "approach to accelerating the experience curve of learning, teaching complex subjects and systems

thinking" (p. 13). Švábenský et al. (2021) shows evidence that games used for teaching cybersecurity include practical assignments, and are suitable for secondary, tertiary, and professional education.

Database Defense is Undertaught in Schools

Because databases are often the target of cybersecurity attacks, they are one of the most important topics for curriculum in an IT educational program (Rowe et al., 2011). However, there is minimal research on the extent to which database defense topics are in fact taught in schools and whether database defense is taught adequately. There is one such study, though, by Jones et al. (2018), that shows database defense was viewed as being undertaught in schools. Within the study, 44 cybersecurity IT professionals were surveyed about which knowledge, skills, and abilities (KSAs) are required to perform their job as IT professionals. As presented by the National Initiative for Cybersecurity Careers and Studies (NICCS), 32 IT-related KSAs were chosen as the most important skills for cybersecurity attackers and defenders. Each survey participant was asked to report how they learned the most about each of these 32 KSAs. Database backups and recovery (titled as: "Data backup, types of backups, and recovery concepts and tools") was one of the KSAs, and 65% of participants said they learned this skill at work; 16% learned database backups themselves (self-taught); and 5% learned from some other method (11% said they have not learned this skill yet). Only 2.3% of participants claim they learned that KSA (i.e., what they needed for proper database backup and recovery concepts), from school. As a KSA, the percentage of participants claiming they learned database backups and recovery in school is very low when compared to other KSAs such as "Programming language structures and logic" which showed 45% of participants learned this KSA at school or "Network security architecture concepts" showing 33% of participants learned it at school. In fact, of all the 32 KSAs, database backups and recovery was tied for last (along with "Incident response and handling methodologies") as the least taught KSAs in schools. The percentage of participants claiming they learned database backups and recovery in school is also very low when compared to the average of 11.2% for all the 32 KSAs.

Cybersecurity is a Difficult Topic to Teach

An IT professional's job is to build and maintain complex computer systems for managing information (Dynamix Solutions, 2017). This is challenging because these complex computer systems are comprised of servers, cables, computers, and many interconnected devices. Each new technological device that is added to the system whether hardware or software brings new features and their associated benefits. However, this also brings with it the potential for exploitation, i.e., the ability for those features to be misused and abused for malicious or nefarious behaviour such as stealing or revealing personal information (Cavelty, 2010). Tisdale (2015) describes cybersecurity as a "multi-dimensional, multi-disciplinary, issue that is subject to constant, complex, changes" (p. 192). "Cybersecurity prevention implies that security risks are recognized, demanding a thorough understanding of the threat and its impact" (Santos et al., 2017 Section C, para. 6). Cybersecurity is particularly complex because it is constantly changing. Cybersecurity threats are always evolving because new security vulnerabilities are identified and new types of malware are created every day (Esteves et al., 2017; Martin, 2021). RiskBased Security, a global leader in vulnerability intelligence, reported over 12,000 new potential cybersecurity threats in the first half of 2021 (Martin, 2021; RiskBased Security, n.d.). Keeping up to date with continual training is critical to combat the ever changing threats and the tools to detect, analyze and to respond to incidents (Esteves et al., 2017; Nagarajan et al., 2012). Bhardwaj (2019) suggests that traditional methods are failing to properly teach cybersecurity related topics. To put it simply, cybersecurity is complex and it is a topic that many in the general public find difficult to grasp (Olmstead & Smith, 2017).

DGBL for IT

In articles relating to Cybersecurity and IT, DGBL was well received by students and showed learning was fun and effective at improving learning outcomes (Awojana & Chou, 2019; Boopathi et al., 2015; Jin et al., 2018). Awojana and Chou (2019) found that the games stimulated learners' interest by

being fun and engaging. Some games lacked adequate learning content and other multi-player games involved time consuming activities with heavy consumption of Internet bandwidth and space. Boopathi et al. (2015) examined a few (4) capture the flag style games where learners are divided into teams, given computer systems to protect and told to attack other teams' systems while protecting their own. The capture the flag games presented by Boopathi et al., show games are a good approach to teaching post-secondary students about the foundations of cybersecurity, however, this style of game is not of the digital video game category. A research study by Jin et al. (2018) is probably the closest to this research study, not only because it relates to cybersecurity, but also because of the use of the tower defense game genre. However, it involves high-school students, not students in HE. Jin et al. showed a positive reaction from high-school students who used a tower defense DGBL activity to identify cybersecurity threats (such as: trojans, spyware, viruses, and ransomware) and defend against them (in ways such as: software updates, firewalls, antivirus programs, and encryption). Despite finding some articles on DGBL for cybersecurity, none were found relating specifically to database defense.

Game Types vs. Learning Content

Another important consideration when creating a serious game designed for learning, is what type of game is best for which type of learning. Game types vary from reflex games to concentration games, invention games to role playing games. Equally so, not all learning is the same. The content being taught can vary from facts to skills, judgement to theory, and from process to creativity. Prensky (2001) proposed a taxonomy of learning types and the types of games that would be best suited to teach each content type. For example, for learning facts, such as laws, policies, and product specifications, which involve drilling and memorization, the recommended game style would be game show competitions, flashcard type games, mnemonics, action, and/or sports games. When looking at different definitions of the term cybersecurity, words like evaluating risk, protection, process and system come up frequently (Schatz et al., 2017). For cybersecurity and according to Prensky's taxonomy, the recommended game

style would be strategy, adventure, simulation and/or puzzle type games. Nagarajan et al. (2012)

suggest that strategy games are appropriate for teaching cybersecurity topics when the game focuses on teaching different strategies and priorities in defending against attacks.

Tower Defense Games

Tower defense games are a sub-category of strategy games, particularly real-time strategy games (Clarke et al., 2017; Dalrymple & Mark, 2010). Generally, in tower defense games, players are given something to defend (e.g. a castle) and have to withstand an advancing onslaught of enemies by using defensive strategies (Brich et al., 2015); and "this genre is made appealing by its easy-to-understand mechanics as well as its challenging and addictive nature" (p. 186). An example of a popular and award-winning tower defense game, is Plants-vs-Zombies, where you defend your house and back lawn from a swarm of marauding zombies (Electronic Arts, n.d.). In terms of cybersecurity, "adversary thinking is an essential skill for cybersecurity experts, enabling them to understand cyber attacks and set up effective defenses" (Švábenský et al., 2018). Awojana and Chou (2019) also suggest that games which involve the interactions of cybersecurity attacks and defenses helps learners in the real-world of cybersecurity. "Therefore cyber security appears to be a topic that is especially well-suited to training via digital games" (Hendrix et al., 2016, p. 1). A few articles exist studying tower defense games for education, such as LiverDefense, which lets "players experience the behaviour of the human immune system" (Brich et al., 2015, pp. 186-187); Vivace, which teaches musical notes and chords (Ashraf et al., 2012), and Cyber Tower Defense Game, which (as mentioned earlier) simulates various cybersecurity threats and defenses (Jin et al., 2018). However, other than Jin et al. (2018), no other cybersecurity tower defense serious game has been studied to date.

Summary

There is large amount of research concluding the potential for DGBL being very effective for teaching when used appropriately and in the correct context. Much of this research, however, is either

related to non-IT-related topics (e.g., math and science) or focused on teaching to a younger audience (primary and secondary school students). Research in DGBL is emerging for teaching cybersecurity, and more research is required. And more specifically, there is a gap in the research for using DGBL for teaching database defense (a very niche topic in cybersecurity) to an adult audience in HE.

For the reasons mentioned earlier - 1) the importance of cybersecurity and database defense; 2) research into DGBL for cybersecurity is emerging; 3) previous success of DGBL in other disciplines; 4) adults may be expecting interactive and highly engaging learning; 5) DGBL is a good fit for difficult topics to teach and cybersecurity is a complex topic; and 6) strategy games are recommended for teaching systems processes such as cybersecurity; the existing research justifies this research into DGBL for teaching database defense for HE.

Chapter 3: Methodology

My methodology for this thesis is an exploratory case study using a mixed method approach. The qualitative data includes open-ended question surveys and an in-depth interview. The quantitative data includes a pre-test, post-test control group experimental design. In the control group, students received my usual instruction. In the game group, students additionally had time to play a serious game, created by me, and designed specifically to teach database defense strategies. The pre-test and post-test scores of both the control and game groups were compared to evaluate the benefits/detriments (if any) of the game-based learning. Students were surveyed on their perceptions of their motivation, engagement, and the impact the game-based learning had on their ability to learn concepts of database and cybersecurity threats and defenses and apply these concepts to real-world cybersecurity scenarios. The in-depth interview was conducted to elaborate on the findings from the surveys.

Database Defender - A Serious Game

For this research, I designed and developed a tower defense-style serious game called *Database Defender* to teach IT students database protection. As with many tower defense games, there is a castle or home that needs defending from an onslaught of attacks (Brich et al., 2015; Hernández-Sabaté et al., 2015; Rusu et al., 2011). Within the digital game, players were given a virtual server with databases on them to defend. Various different types of simulated attacks, such as hardware failures, natural disasters, and human error, appear on the screen and slowly approach the servers. If and when an attack reaches a server, it will disrupt or destroy some or all the data within the server. It is up to the player to be prepared for such attacks, create the correct backup in advance, and be able to properly recover the affected data from the attack and quickly. If the players have not properly backed up and stored the data on their servers in time, the data will be lost. See Figure 2 for a screenshot of *Database Defender*. This simulates a real-life scenario where customers will arrive and need access to the data, for example, to see your shop's online inventory, in exchange for money when they make a purchase. If the

server is down when the customers arrive, the player will lose money because the data was missing. See Appendix A for screenshots of the different types of backups and types of database threats in *Database Defender*. To progress to the next level, the player must earn enough money and satisfy their customers. Students were presented with six levels with increasing difficulty as the players gain in skill and learn about the different types of database backups and storage methods. Each level has a new lesson to be learned as described in Appendix B. The target audience for this game is students in my database administration course - these are students enrolled in a two-year diploma program with the goal of preparing students with industry-ready skills for their first entry-level job as IT specialists. The game also could be used by higher education instructors teaching concepts of database backups. The goal of this serious game is to teach players which database backups protect against which cybersecurity threats (and that a single backup or storage method cannot protect against all attacks). A secondary goal of this game is to encourage student motivation, engagement, and enjoyment to improve the quality of teaching about database defense.

Database Defender was designed using the agile programming methodology, whereby the game was designed and developed in small phases (of about one week), incrementally adding new key functionality and features into the game. In agile programming the primary principle is to provide "early and continuous delivery of valuable software" (Beck et al., 2001, First principle). These phases included:

1. creating the log in page
2. creating and animating the customers
3. creating and animating the database
4. creating and animating the backups
5. creating and animating database threats
6. creating a popup window to interact with customers, databases, and backups
7. creating the tutorial system

8. creating levels 1 to 3
9. creating level 4
10. creating level 5
11. creating level 6
12. final testing, bug fixing, and adjustments

The login screen (shown in Appendix C) prompts the player for their IPC. This IPC was the same code participants used in the consent, pre-test and post-test question, and Learning Survey. This IPC was used to record the time the participants started the game, the time they started of each level and the time they either failed or completed each level. A multipage tutorial system was designed and implemented to help explain key concepts within the game. In-game tutorials are often used to "explain the game mechanics and teach the required knowledge to progress through the following levels" (Roepke et al., 2021, p. 37) and to alleviate confusion at the start of the game (Mitsis et al., 2019; Murray et al., 2021; Roepke et al., 2021). Before each level begins, a tutorial screen appears and introduces the new game elements and the goal for that level (see an example tutorial in Appendix D). Players are shown simple animations and images of the new database backup types and threats that they will be required to defend against for that level. See Appendix E for screenshots showing the tutorial for each threat and the best backup to use to protect against each one.

As part of the design for the game, a number of game mechanics have been implemented to help improve motivation and engagement including: goals, challenges, feedback, freedom to fail, progressive level difficulty, and careful timing/urgency. These game mechanics have been shown to increase motivation, enjoyment, and engagement in gamified learning environments (Dicheva et al., 2015; Perrotta et al., 2013; Strmecki et al., 2015). The game, in particular, uses careful timing and a sense of urgency to enforce the concept that when a customer arrives, if the data is unavailable, you will lose their money and lose the level. Hanson (2018) describes urgency or immediacy as "a core pleasure

of games" (p. 26) and that immediacy within "real-time games require that a player remain engaged in gameplay" (p. 21). De Aizpurua et al. (2018) included urgency as a game mechanic and found it to very effective as "it was a motivator for action" (p. 96). Samoff (2017) also employed urgency and real-time gameplay to enhance the experience and found that "emotional engagement and immediacy of gameplay can lead to a deeper sense of immersion" (p. 45).

Figure 2

A Screenshot from Database Defender - A Serious Game Used to Teach Database Defense



Note. This is a screenshot of Level 6 of *Database Defender*. The database is indicated by the blue, green, purple, and orange stacked cylinders. Customers approach from the left-hand side of screen and, if the database is available, will give you 100 dollars (this current score is 100 and shown at the bottom). Backups are shown as cubes (the colors correspond to the color of the database). Database threats (tornados, failing hard drives, and junior programmers) approach from the right and will destroy the database when they reach it.

Database Defender was developed in the C# programming language using the Unity game engine. Unity was chosen as a development platform for a number of reasons including: 1) my previous expertise and proficiency in programming in C# (C# is needed for programming in Unity); 2) how easy it is to deploy a game with the Unity game engine as an embedded game within a website; and 3) the large number of online YouTube tutorials and extensive documentation available for creating Unity games (Bartneck et al., 2015; Foxman, 2019). The image assets, were either freely available (through a creative commons CC0 licenses) or purchased with a license that allows for modification and use within educational applications. The Unity game engine has a personal edition that is free to use for educational purposes (Unity Technologies, n.d.). I designed and developed *Database Defender* part-time during the three months, within this thesis, from January 2022 to March 2022.

Research Methodology

This research study is an exploratory case study, specifically the TYPE 1 (single-case holistic) approach as described by (Yin, 2018). The single case is defined in this study as a single instructor teaching a single course, at a single institution, and in a single country. Yin explains, case studies are suitable for answering "how" and "why" type questions such as how and why does DGBL affect learning of database protection topics. One of the rationales provided by Yin in support for single-case studies is that they can provide significant contributions to research knowledge by confirming, challenging, or extending theories. Case studies can also help to provide direction for future investigations in the field. Since DGBL has been successfully applied to many disciplines, this case study will serve to extend the theory of DGBL for cybersecurity in HE, and establish a starting point for further research.

This research study used a mixed methods approach, with a mix of quantitative and qualitative data following a deductive-simultaneous-sequential (quan [pre/post-test] + QUAL [survey] → QUAL [interview]) design as described by Schoonenboom and Johnson (2017). For the quantitative data, a pre-test, post-test control group experimental design was used. The pre-test, post-test control design was

chosen to reduce history, maturation, and regression effects as they would likely affect both the control and experimental groups equally and the only observed changes between pre-test and post-test scores would be examined (Johnson & Christensen, 2014). This design attempts to minimize the differences in instruction between the class assigned as the control group and the classes assigned as the experimental group so the effect of serious game given only to the experimental game group can be measured. To help mitigate history and maturation effects (where other forms of learning occurred and increased the post-test score), the control group will be given as near as possible the same instruction as the game group except for the game. To help mitigate regression effects (where some students score abnormally high or low on one or both the pre-test and/or post-test for external reasons), students are assigned to the control and game groups by class registration sets, which is essentially random.

A post-lesson survey was collected from students to further provide a mix of quantitative and qualitative data. For additional qualitative data, an in-depth interview was conducted with a student. This interview was originally planned to be a focus group, but because only one student provided consent, the focus group was redesigned as an in-depth interview. According to (Johnson, 2002), in-depth interviews are often used in conjunction with and as a follow-up to surveys, as interviews help verify and triangulate knowledge gained through observation. In-depth interviews are used to gain further depth (rather than breadth) into personal accounts and perceptions as compared to other methods of gathering qualitative data (Johnson, 2002; Morgan, 1996). Another change to the methodology was the increased weight of the qualitative data gathered during the survey in the form of open-ended questions. This change was made as a result of the lower than expected participation rates in the quantitative data collected in the pre and post-tests.

The mixed method approach was used here for a number of reasons: triangulation, randomized samples, and sample size. Firstly, mixed methods approaches are known for their potential to improve validity through the triangulation, achieving convergence, corroboration, and correspondence of results

from the quantitative and qualitative data (Schoonenboom & Johnson, 2017). Secondly, Ross and Morrison (2013) state that in a true experiment, participants must be randomly divided into the control and experimental groups. Oftentimes in educational settings, when splitting experimental groups by classes which were formed at the start of the academic year, these classes are not completely random and may lead to extraneous variability in the groups (Ross & Morrison, 2013). Gathering additional data through mixed methods helps strengthen the validity of the study if it turns out the classes were not completely randomized. Lastly, mixed methods approaches can help corroborate data with qualitative data when sample sizes are small for the quantitative data (He, 2018). Mixed methods can be used when the limitations of quantitative methods can be offset by the strengths of the qualitative methods and vice versa to help provide a more complete understanding of the research problem (Creswell & Clark, 2017).

Strategy and Design

The participants for this study were a subset of my students that volunteered (five out of a course of 60 students participated) attending my database administration and management class in the 2022 Winter term (January to April, 2022). Participants were assigned to one of two groups based on class assignments: 1) a control group that did not play the game until after the post-test (called "control group"); and 2) a group that were given the serious game for teaching database protection after the usual teaching and before the post-test (called "game group"). Because of the potential of perceived conflict of interest of me being an instructor to the student participants and me researching those same students, all activities relating to this study and the collection of data were facilitated by an impartial third party. See the ethical considerations section for more details.

Students from both groups were given a pre-test of database backup and recovery concepts, one week prior to when database backup and recovery is normally taught (see Appendix F). This pre-test served as a baseline to compare to post-test scores. Students were given 30 minutes of in-class time to

complete the pre-test and post-tests. Since the control group was given the same pre-test and post-test, some of the effects from the usual instruction in the control group can be accounted and compensated for when comparing it to the experimental game group. My usual instruction for database backups and recovery involved a 1-week module that included: pre-reading from the course textbook, an in-class lesson (approximately 60 minutes), and one week to complete a lab where students practiced database backups using a number of backup tools. This usual instruction remained the same for both the control group and game group. The game group was given one hour of class time to play *Database Defender*, the game, available online at <http://DatabaseDefender.com> and then given 30 minutes to complete the post-test survey. The control group, on the other hand, was given the post-test before playing the game. This way, playing the game would not affect their answers in the post-test. Both the control group and game group were also given 30 minutes to complete a short, online survey on their perspectives of learning database backup and recovery and their experience playing the game. A one-hour interview, relating to the effectiveness of the game in teaching database protection tools and strategies, was conducted with a student in the game group a week after they had played the game and completed the survey. See Table 2 for a schedule of the control and game groups.

Table 2

Schedule for Control and Game Groups

	Usual Instruction								
	Week 1	Week 2	Week 2-3	Week 3	Week 3-4	Week 4		Week 5	
	Consent*	Pre-test	Pre-Reading	Lesson	Lab	Post-test	Game	Learning Survey	Inter-view
	30 min	30 min	1 wk	60 min	1 wk	30 min	60 min	30 min	60 min
Control Group	✓	✓	✓	✓	✓	1 st	2 nd	3 rd	-
Game Group	✓	✓	✓	✓	✓	2 nd	1 st	3 rd	✓§

Note. The control and game groups had the same instruction with the exception of when they played the game.

The control and game groups both played the game, however, the control group completed the post-test before

the game, and the game group completed the post-test after playing the game. *Any data collected from students who did not consent was not included in the study. Students were free to withdraw from the study at any time without penalty. §There was a single participant who consented to the interview and was from the game group.

Data Collection

For the quantitative data, students from both the control and game groups were given the same pre-test and post-tests. This pre-test and post-test consisted of a single comprehensive question where students were asked to create a detailed backup and recovery plan for a fictional but realistic company and server configuration. The pre-test and post-test was marked by me, their instructor, using a standardized rubric. The expectation was that the pre-test scores would be very low because it would test how much students know before the initial instruction of the material, which is typically minimal as this course is often their first exposure to database backups. Post-test scores were expected to be much higher as students would then have learned how and why database backups are important. Students were expected to be able to identify and state the importance of: how often database backups should be performed; length of time to keep backups; the difference between full and partial backups; where to store backups; and how to backup database users, code, and configurations. The variability between the control and game groups was examined for confirmation or refutation of the benefits of DGBL.

Quantitative data was also collected from students while they played the *Database Defender* game. The quantitative data gathered in game included:

- Time and date of initial login.
- Time and date at the start of each level.
- Time and date of each failed attempt of a level.
- Time and date of each completed level.

For the online survey, referred to as the Learning Survey, a mixture of quantitative and qualitative data was gathered. The survey began with a small set of demographic questions to gather basic information (age, gender, level of education) and the students' interest and level of game-play (how much time per week they play games and what type of games they prefer). The game categories: action, strategy, simulation, puzzle, shooters, role playing games, and sports were chosen based on what is widely accepted in the game industry and in academic literature (Abdul Jabbar & Felicia, 2015; Baptista et al., 2015; Boyle et al., 2016; Clarke et al., 2017; Hong et al., 2009; Kapralos et al., 2011). Next, the Learning Survey asked a series of quantitative, Likert scale questions to assess the participants' level of motivation, engagement, enjoyment, and perceived effectiveness for the lesson (regardless of whether they were in the control group or the game group). These questions were adapted from a number of surveys available in academic literature (Barzilai & Blau, 2014; Brockmyer et al., 2009; Burch et al., 2015; Huang, 2011; Huang et al., 2006; Pintrich, 1991; Vallerand et al., 1993). Barzilai and Blau (2014) provide questions for engagement (flow), perceived learning, and enjoyment. Burch et al. (2015) offer survey questions for teaching engagement in the Burch Engagement Survey for Students (BESS) and Brockmyer et al. (2009) have survey questions specific to game-play engagement and flow in their Game Engagement Questionnaire (GEQ). The Academic Motivation Scale (AMS) created by Vallerand et al. (1993) has questions regarding motivation for both intrinsic and extrinsic motivation. Huang et al. (2006) and (Huang, 2011) collected questions into a survey called the Instructional Material Motivational Survey (IMMS) for assessing the motivation as it relates to the ARCS instructional model. Finally, the Motivated Strategies for Learning Questionnaire (MSLQ), created by Pintrich (1991), is an extensive set of questions used to determine student motivation. As shown in the literature, other researchers have also adapted from these surveys and questionnaires (the IMMS, GEQ, AMS, and MSLQ) including Proulx et al. (2017), Buckley and Doyle (2016), Lin et al. (2014), Jeng-Chung (2014), and Dörner et al. (2016). The 16 Likert scale questions were grouped by category: questions 1 to 4, to assess the students'

motivation; questions 5 to 8, engagement; questions 9 to 12 for enjoyment; and questions 13 to 16, reporting the students' perceived learning. Within the themes found in the literature examined, questions regarding motivation asked students about the level of interest, relevance, rewards, and curiosity (Huang, 2011; Huang et al., 2006; Pintrich, 1991; Vallerand et al., 1993). Questions regarding engagement asked about levels of enthusiasm, concentration, immersion, and involvement as reflected in the literature (Barzilai & Blau, 2014; Brockmyer et al., 2009; Burch et al., 2015). Barzilai and Blau (2014) provided similar questions for the enjoyment and perceived learning sections. The questions regarding enjoyment asked questions about fun, entertainment, and likability of the game and activities to learn database defense; and questions regarding perceived learning asked questions on usefulness, effectiveness, and the students' perception of their ability to learn and remember database defense topics. For a complete list of questions in the Learning Survey, please refer to Appendix G. The last section of the survey included a set of qualitative, open-ended questions that allowed participants to comment on what they learned from the database backup and recovery module, if they felt confident in designing a detailed database backup plan, and their thoughts on the benefits and drawbacks of the game-based learning had on their ability to learn database backups. The in-depth interview asked seven questions regarding their experience with the game. Seven questions were asked of the interviewee about whether they thought *Database Defender* was effective, their level of enjoyment, motivation, and engagement, and what they learned from playing the game. See Appendix H for a complete list of interview questions. The interview was recorded (and transcribed) in order to properly capture the opinions and reflections of the student.

Data Analysis

The quantitative data from the pre-test and post-test question were scored according to the rubric and were compared using statistical methods including arithmetic means, standard deviation, and t-test significance. IBM SPSS Statistical software was used to generate an independent samples t-test

report using the post-test to pre-test difference as the independent variable and the control and game groups as the group variable (Cohen, 2011; Gerald, 2018; IBM Corporation, 2022). The mean difference (pre-test and post-test scores) of the control group were compared to the mean difference of the game group. Statistical differences between the control group and game group were considered as evidence in support or rejecting the benefits of DGBL for teaching database backups to students in HE.

The survey questions relating to motivation, engagement, and enjoyment were examined to determine which have the greatest effect on perceived and actual learning. The results of the game-play were analysed to see how long students played the game, how many attempts were made at each level before completing it, whether they finished all the levels, and whether they played the game again from the start. Demographic data was also be examined for grouping and categorizing students to look for trends in the data. This was done to determine whether there were any of the demographics (such as age, gender, and/or level of education) that influenced student motivation, engagement, and perceptions of the DGBL.

Both the quantitative data from the game-play and qualitative data from the open-ended survey and interview questions were analyzed using a content analysis approach as described by Ritchie et al. (2013). In particular, the qualitative data was analyzed using an inductive thematic analysis as described as described by Kiger and Varpio (2020) and Maguire and Delahunt (2017). An inductive thematic analysis involves six steps including, identifying codes from the student responses, collating those codes into themes, refining those themes, and relating those themes to the research questions. The students' perceptions of the game in terms of motivation, engagement, enjoyment, and learning were identified, by analyzing themes within the content and context while recording their frequency of occurrence. These themes, were also linked to outside variables such as gender and other demographics (Ritchie et al., 2013). The quantitative data attempts to validate the qualitative data through triangulation.

Limitations and Delimitations

Both limitations and delimitations describe aspects of a study that affect the validity, reliability, and applicability of a study (Price & Murnan, 2004). Delimitations relate to decisions made by the researcher to limit scope by defining inclusions and exclusions for the study, however, limitations are typically aspects of the research process that researchers have little or no control over (Baron, 2008; Ellis & Levy, 2009).

This research study is for a partial completion of a Masters of Arts in Learning and Technology (MALAT) at Royal Roads University. This program sets a recommended timeline for completing the thesis track to one year. It is due to this tight timeline that the time for data collection is very limited (typically one to two weeks). I chose to look specifically at one of my courses that I teach into database administration, so the participants for this study were limited to the enrolment of the Winter 2022 term of the CIT program at BCIT. The CIT program typically attracts recent high-school graduates (ages 18 to 30) who are highly technologically savvy. For the quantitative portion of the mixed methods approach, despite being modelled after a pre-test post-test experimental design, the sample size was low and was only replicated once. This study involved only a single instructor, single course, teaching at a single institution, and a single country. This has the limitation of being not only a small sample size and very specific demographic, but also the topic of database protection is a very specific topic in cybersecurity. Caution should be taken before generalizing or applying any results, either confirming or refuting the overall success DGBL for teaching, to any group of students using DGBL for learning. Since the sample size of this study is small to begin with, sub-dividing into even smaller groups based on different demographics elicits even further caution when considering any trend inferences to a larger target population across large differences in measures, persons, settings, and times (Calder et al., 1982; Ferguson, 2004; Findley et al., 2021; King & He, 2005).

The total sample size was five students (two in the control group, three in the game group). This is lower than expected and may be because the Winter 2022 term was an unusual term. The COVID-19 pandemic caused a huge disruption in higher education as classes were forced online in 2020 (Hasanova et al., 2020; Marinoni et al., 2020; Neuwirth et al., 2021). As of September, 2021, classes resumed in person (Kang, 2021), however, as the COVID cases rose again over the holiday break, many classes at BCIT were still online for the first three weeks of the Winter 2022 term. Instructors were also asked to teach online if they were self-isolating due to illness, which was the case for me during weeks four and five. After the first five weeks of online teaching, classes resumed in person, however, if students had (or suspected they had) COVID, they were asked to self-isolate. Students who were self-isolating could review the lectures at home, as the in-person classes were recorded and made available online after class. Also, many students were less motivated to come to class if they knew that they could watch the lecture at home, since many students only had my class that day (which meant they could save a lengthy commute to and from school). Throughout their education, students in my classes had a mixture of online, in person, and hybrid learning depending on the term and their level of isolation. There is a fair amount of literature suggesting that the rapid switch to online learning environments have left students disengaged and negatively affecting their learning (Erickson & Wattiaux, 2021; Moser et al., 2021; Napierala et al., 2022; Tasci et al., 2021). Keep in mind, this research study, was only for those who could attend in person for all sessions, and if students were present for the pre-test but absent and self-isolating for the post-test or visa versa, they were not able to participate in the study.

While I am not aware of any differences between the students in each of my prospective classes, there may be differences in the composition and variability which would be a confounding variable. Also, because not all of the students who were assigned to control and game groups were included in the study, there is a possibility of volunteer sample bias affecting the validity of the results. As described by Light et al. (1990), harder working students (and possibly those with more motivation to

begin with) may be more likely to participate and thus the sample may be skewed to overstate or understate the effects of the study as it applies to the class as a whole. Likewise, this study does not claim that the student experiences (identified by the codes and themes in the thematic analysis) are necessarily shared by all students within the study, that they apply to the class as a whole, or that they would apply to all future classes of the same course.

While I made a conscious attempt at keeping the instruction consistent across each class, I realize that there may be natural variations in the way I taught the lessons to each group. I may have taught with more enthusiasm in the morning or in the afternoon depending on a number of uncontrollable variables. In order to mitigate any differences between my instruction to the different classes, I timed my lesson to ensure I kept on track and followed the lesson plan as laid out in the PowerPoint presentation for the topic.

Since this study relies at least in part on the results of Likert scale questions, acquiescence bias, is a likely possibility and should be taken into consideration when interpreting and extrapolating the results (Kuru & Pasek, 2016; Pew Research Center, n.d.). Acquiescence bias relates to participants having a tendency to and disproportionately responding "strongly agree" to Likert questions, possibly for a number of reasons including: conferring with the authority of or having compassion for the researcher; people wanting to be agreeable; and/or impulsively finding a quick and sufficient answer to the question (Kuru & Pasek, 2016; Rammstedt et al., 2017). The Likert questions in this study were all positively ranked, i.e., responding agree would indicate an increased positive effect of motivation, engagement, entertainment, or perceived learning.

Another possible limitation to consider is that the quality of the game design and development may not be of professional quality. There was limited time to develop *Database Defender* before the start of the study. While I do possess many skills for programming, project design, and game development, I am not a professional graphic designer, nor a professional game developer. Students

who are used to high quality commercial games may find the aesthetics of *Database Defender* to be primitive and inferior, which may detract from the motivation and engagement of the game. Developing successful commercial quality serious games often involve a lengthy development time from 2 months to 2 years or more of full-time work (Calvillo-Gómez et al., 2015; Laning, n.d.), many people with different skillsets (Boller & Kapp, 2017), and graphics and aesthetics often play an important role for the overall experience of the players (Kapp, 2012; Keller & Suzuki, 2004). This is supported in the literature review, theoretical framework of motivation, and ARCS model, in that the quality of the aesthetics can affect the motivation of the student(s). Play-testing is also an important part of creating top-quality games and for commercially successful games can take up to 3,000 hours of game-play by a team of multiple testers (Boller & Kapp, 2017; Kapp et al., 2014). *Database Defender* did not have a large development team, nor did it have a large group of people test the game ahead of time before given to students for this study. The game was play-tested with a small group of family (three people) and Jordanne, my thesis supervisor during the final month of development (the month of March). This simple and informal play-testing was to ensure that the game was possible to complete and had a logical flow and clear objectives. In response to play-test feedback, minor adjustments to color palettes were made to improve color contrast and readability of on-screen text to conform with Web Content Accessibility Guidelines (WCAG) 2 Level AA - the standard that many organizations strive to meet (W3C Web Accessibility Initiative, 2020). An online tool, created by the Institute for Disability Research, for checking color combinations for suitable contrast ratios and increased readability at <https://webaim.org/resources/contrastchecker/> was used to comply with WCAG 2 Level AA standards. As a result of this limited play-testing, *Database Defender* may lack elements that could improve engagement of the game.

Ethical Considerations

An impartial BCIT school-appointed mediator presented and collected the consent forms to participate in this study, facilitated the control and game groups during the gameplay, Learning Survey, and the conducted the interview. Having an external appointee collect the consent and conduct in class activities, helped mitigate my position of power as an instructor over the students (for their grades in the class), allowing them to freely decide and participate in this study without fear of negative consequence. The in-depth interview was recorded, but not transcribed by me until after the final grades for the course were entered, again to reduce any influence or bias I might have over the student participant. For those that did not consent, or opted-out part way, their data collected during the pre-test, post-test and/or learning survey, was not be considered part of this study. There was no penalty for not participating, and no grades were affected by non-participation. There was no reward for participating. Students were reminded that participation is optional and they could opt-out at anytime. Students were also reminded that grades for the pre-test and post-test do not apply to the course grade and were only used for determining the effect of DGBL for learning database protection. No portion of this study affected the students' grade, as none of the data collected aside from the usual instruction contributed to their course grade.

Students were asked to generate an Individual Participation Code (IPC). This IPC consisted of answers to questions that only they know. This IPC was used to uniquely identify each student, but not allow myself (their instructor) to know who they were. The IPC's were used for the purpose of tracking and linking their individual's pre-test and post-test scores with their gameplay and survey data. See Appendix I for the instructions students were given to create their IPC's. These IPC's permitted scoring pre-test and post-tests without revealing student names and thus preventing bias from me knowing the student's previous course and test score achievement or other biases while marking. Students could participate, including playing the game *Database Defender*, without providing consent by entering a

special code of 99999, instead of providing their IPC. To reduce treatment diffusion, students were not told ahead of time which of the groups they belong to (either the control or game group). Once the post-test data was collected for the control group in this study, the control group was allowed to play the game so that they were not disadvantaged as far as the course content and overall learning experience. Aggregated results are available to all students, upon request.

Once the pre-test and post-test scores and survey results were matched by IPC, the IPC's were replaced with pseudonyms (e.g. Alice, Bob, Charlie, Diane, Ellen). Also, any interview comments and themes expressed on an individual level have had the student's name replaced with a pseudonym to maintain student anonymity. Any personally identifiable information has been masked or made abstract to protect the participants' identities.

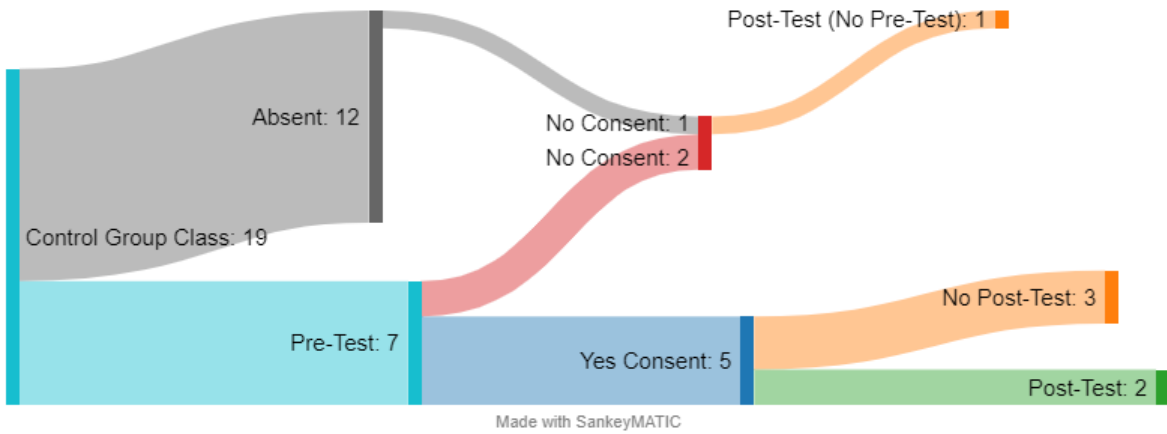
Chapter 4: Results

Number of Participants

The registration for my Winter 2022 term, had a total 60 students in three sets (Set A, Set B, and Set C). Set C, which had a registration of 19 students, was the recruitment pool for the control group, and Sets A and B, with a total of 41 students, were the recruitment pool for the game group. For the student data to be considered as part of the study, a student had to provide consent, submit both the pre-test and post-test, and complete the learning survey. If a student did not complete both the pre-test and post-test or did not provide consent, their data was not included in the study. This resulted in a control group consisting of two students and the game group consisting of three students, for a total of five students' data being included as part of the study. See Figure 3 and Figure 4 for a detailed breakdown of the control and game group participation.

Figure 3

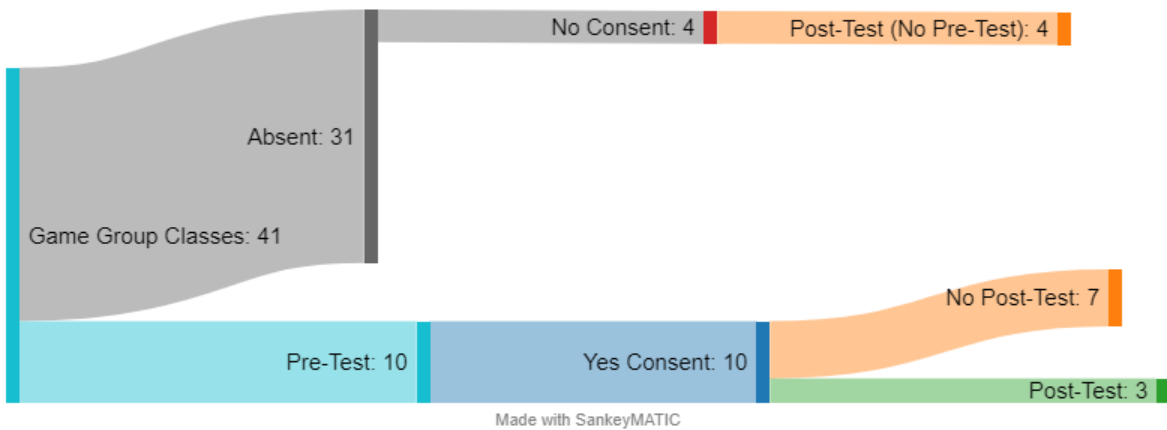
A Breakdown of the Participation of Students in the Control Group



Note. Despite having a pool of 19 students in the class designated as part of the control group, only seven students attended class, and chose to complete the pre-test. Of those seven, only five provided consent. Of those that provided consent (5), only two completed the post-test. Another student (1) completed the post-test, but did not complete the pre-test, nor the consent form, and thus was not included in the study data. This resulted in two students in the control group to be included in this study.

Figure 4

A Breakdown of the Participation of Students in the Game Group



Note. Despite having a pool of 41 students in the class designated as part of the game group, only 10 students attended class, and chose to complete the pre-test. Of those, all provided consent (10) but only three completed the post-test. Another four students completed the post-test, but did not complete the pre-test, nor the consent form, and thus were not included in the study data. This resulted in three students in the game group to be included in this study.

Demographics

Gender

The demographics for the study included students of male and female genders, and had a higher than usual proportion of females at: 60% female to 40% male (see Table 3 and Figure 5). The enrollment for the classes (60 total students including both control and game group pools) was approximately 20% female to 80% male which is fairly typical of the current enrollment in IT programs (Jiang et al., 2016; Sabin et al., 2020) and IT professionals (Verkroost et al., 2020). This higher than usual female to male ratio might be as a result of the small sample size for this study.

Table 3*Demographics Overview*

	Experiment Group	Demographics			Typical Gameplay	
		Gender	Age	Education	Game time	Game type
Alice	Control	F	31 to 40	Graduated	11 to 15	A, RPG, Sim, Strat
Bob	Control	M	31 to 40	2 years	6 to 10	Strat, P, I, C
Charlie	Game	M	26 to 27	Graduated	11 to 15	A, S, RPG, Sim, Strat
Diane	Game	F	22 to 23	1 year	1 to 5	P
Ellen	Game	F	28 to 30	Graduated	0	N/A

Note. Gender: M = Male, F = Female

Education: Graduated = Graduated from college or university (Certificate, Diploma or Bachelors),

2 years = 2 years of college or university (other than the BCIT CIT program),

1 year = 1 year of college or university (other than the BCIT CIT program)

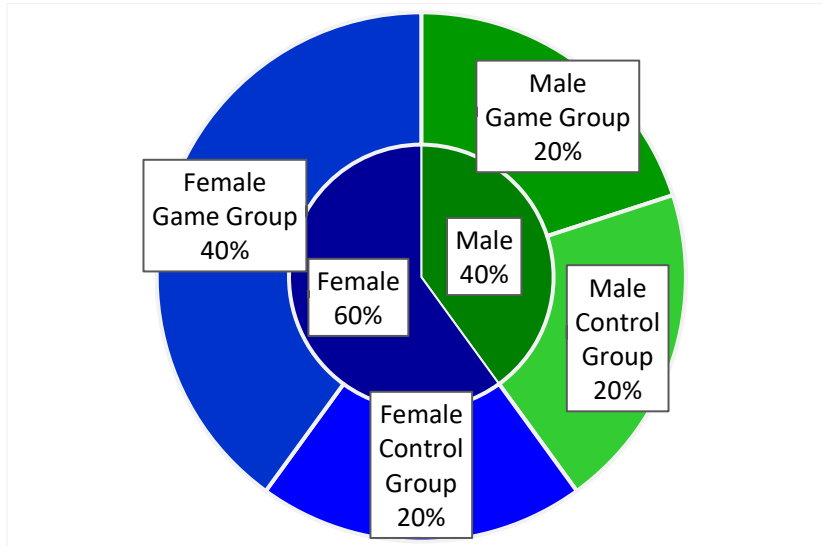
Game time: Typical time spent playing games (hours/week)

Game type: A = Action, S = Shooter, RPG = Role Playing Game, Strat = Strategy, P = Puzzle, I = Idler,

C = Collectible Card Game

Figure 5

Demographics - Gender Distribution



Age and Education

Most of the students included in this study were 26 years or older (only one student was under the age of 24). This age range seems a bit higher than expected, considering the entry requirements for students into this CIT program is just a high-school diploma (which would be around 18 years old), however, it is not entirely surprising, since many students will attend the CIT program after some post-secondary education. Indeed, all the students included in the study had some post-secondary education before attending BCIT, with a majority of students (3) having graduated from another post-secondary institution. See Table 3, Figure 6, and Figure 7.

Figure 6

Demographics - Age Histogram

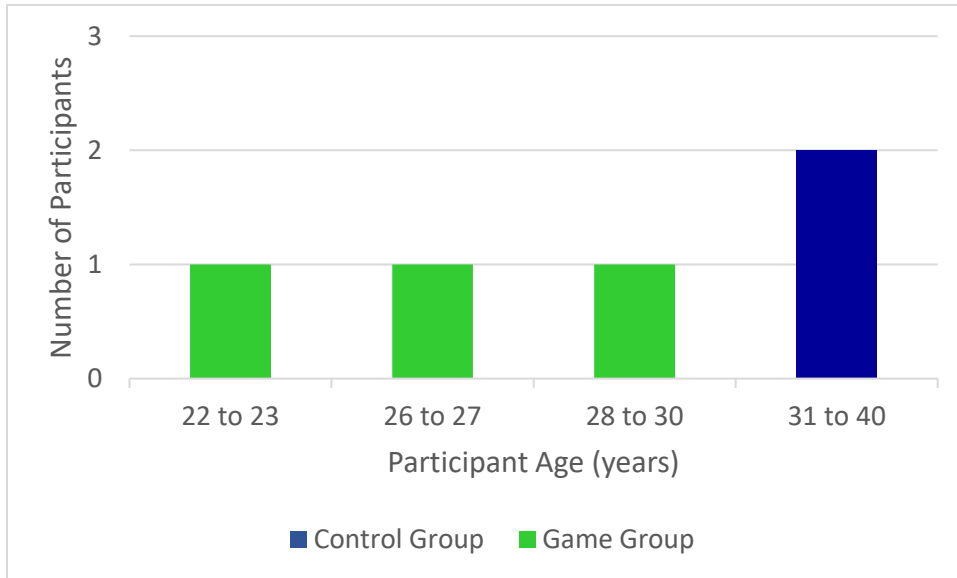
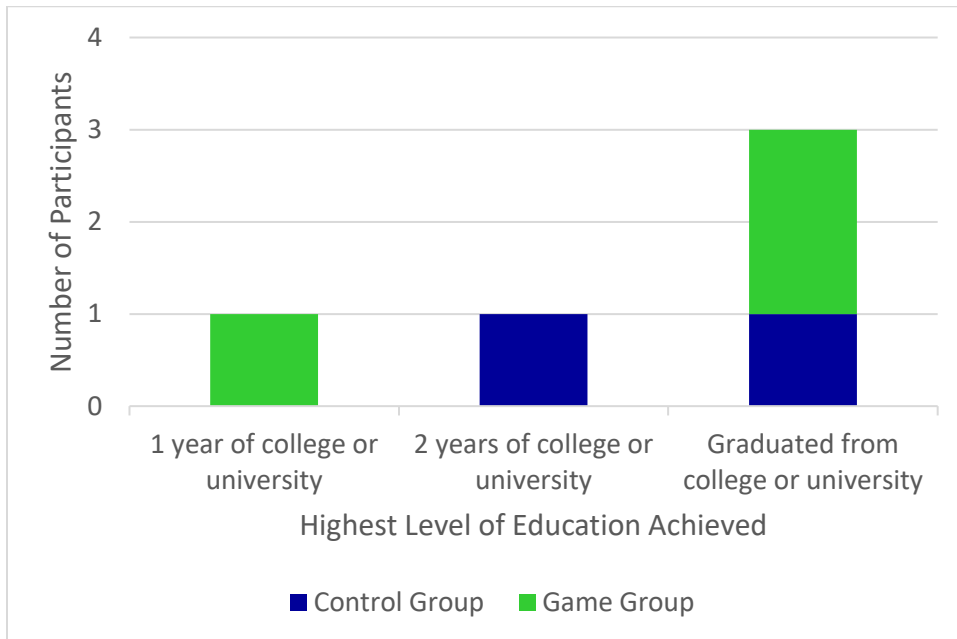


Figure 7

Demographics - Education



Typical Gameplay

Most of the students in this study play games in a typical week with a majority of students (3) self-reporting that they play at least six hours per week, which includes two students that reported 11 to 15 hours per week. There was only one participant that said they did not play games at all. This is generally what I expected to see according to literature (Felicia, 2014; Nielsen Company, 2018) and my personal experience when asking my students about their leisure time outside of class time. The typical game time played by students is however higher than those recorded in a survey within a study of university students in 2011, in which most students reported less than five hours per week of game time (Kapralos et al., 2011), but consistent with a more recent study by Hamlen (2017) which saw an average of 12 hours per week of game play for university students. See Table 3 and Figure 8 for more details on the time students typically play in a week. As for the types of games, students who played more frequently in a week tended to have a higher diversity of types of games they played (playing games within at least four or five different categories). The most popular game category was strategy games, with simulation, role playing, action, and puzzle games following closely behind. See Table 3 and Figure 9 for the preferred game categories. As mentioned in the literature review, tower defense games are a sub-category of strategy games (Clarke et al., 2017; Dalrymple & Mark, 2010) which likely leads to students in this study being more familiar and comfortable with games like *Database Defender* because of how commonly they played games in the strategy category. It is important also to note that typical gameplay does not decrease with age. A majority of students 26 years or older, play games at least six hours per week.

Figure 8

Demographics – Typical Time Spent Playing Games

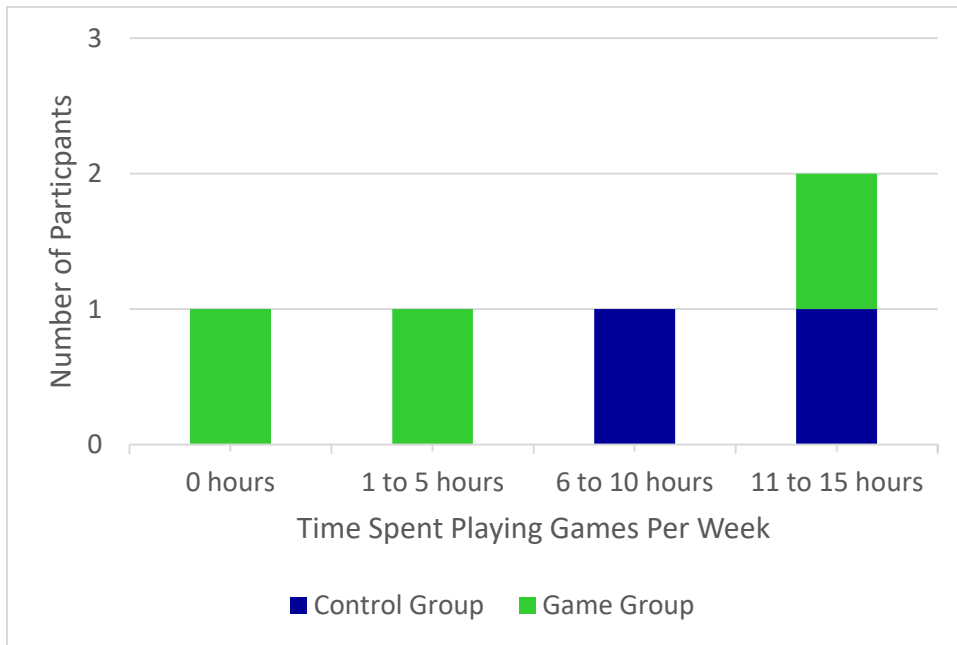
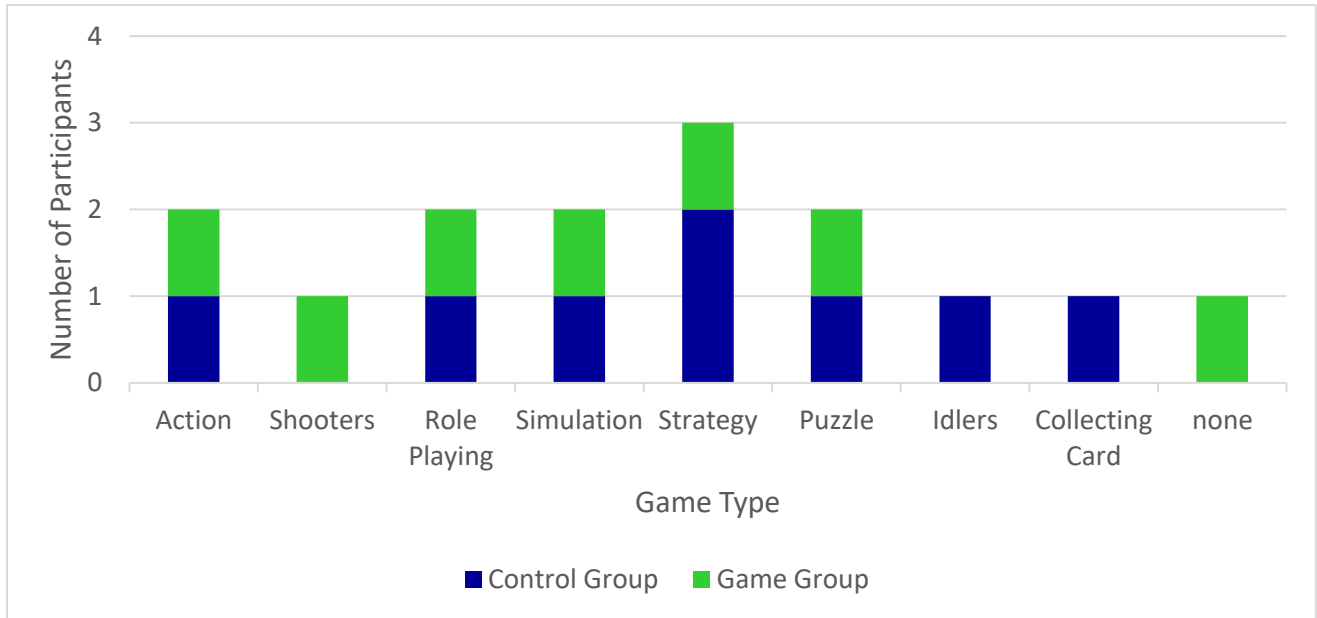


Figure 9

Demographics – Typical Types of Games Played



Pre-Test and Post-Test

Test scores for the pre-test were low for both the control and the game group with scores averaging 4.00 for the control group and 2.67 for the game group and all scores ranging from 2 to 4 out of 10. These low pre-test scores are to be expected since the test is given to students before any instruction on database defense. Three students were able to increase their test scores by 4 or 5 points in the post-test. However, two students did not see any increase in the post-test; they both scored 4 out of 10 on the pre and post-test. This results in post-test scores averaging at 6.50 for the control group and 5.67 for the game group. Overall, the post-test scores were lower than expected, as I would have expected the averages to be closer to 7.5 or higher. I also was not expecting so many students to have no increase in their post-test scores. Whether students saw an increase in their post-test score (or not) appears to be irrespective of which group they were in, suggesting that for the experimental game group, playing *Database Defender* before their post-test, had little effect on their post-test scores. The

statistical analysis, showed there was no significant difference between the control and game group.

This further indicates playing *Database Defender* did not improve the post-test scores. Levene's test

indicated a significance of .550 ($p > 0.05$) which indicates equal variances can be assumed (Cohen, 2011).

The statistical significance (two-sided p) was found to be 0.866, which is much higher than $p = 0.05$.

Thus, no significance was found, indicating that playing *Database Defender* did not increase post-test

scores in this test scenario. See Table 4 for pre and post-test scores, Figure 10 for a chart of pre and

post-test scores, and Table 5 for the statistical analysis details.

Table 4

Pre-Test and Post-Test Scores and Database Defender Gameplay Data

	Experiment Group	Test Scores			<i>Database Defender</i>				Time played
		Pre	Post	Diff	Failed Attempts				Time (m:s)
					Lvl 3	Lvl 4	Lvl 5	Lvl 6	
Alice	Control	4	4	0	0	1	0	1	10m:01s
Bob	Control	4	9	+5	0	0	0	6	15m:38s
Charlie	Game	2	7	+5	0	0	2	1	10m:32s
Diane	Game	4	4	0	16	1	-	-	14m:44s
Ellen	Game	2	6	+4	0	0	0	7	15m:15s
<u>Average Time</u>									<u>13m:14s</u>

Note. This table shows the pre-test, post-test, and difference between them. The test scores (for both the pre-test and post-test) are out of a maximum of 10 points. For example, Alice had no increase from her pre-test and post-test scores of 4 each; and Bob had a 5 point increase from 4 on the pre-test to 9 on the post-test. This table also shows the data from students playing *Database Defender*. It shows how many failed attempts on each level and the total time played the game (all levels they attempted). Levels 1 and 2 were very easy levels, which no one failed, so they were not included in this table. For example, Alice completed the game in just over 10 minutes, and needed to repeat levels 4 and 6, completing them on the second try; but completed levels 1, 2, 3, and 5 on the first try (no failures for these levels).

Figure 10

Pre-Test and Post-Test Scores

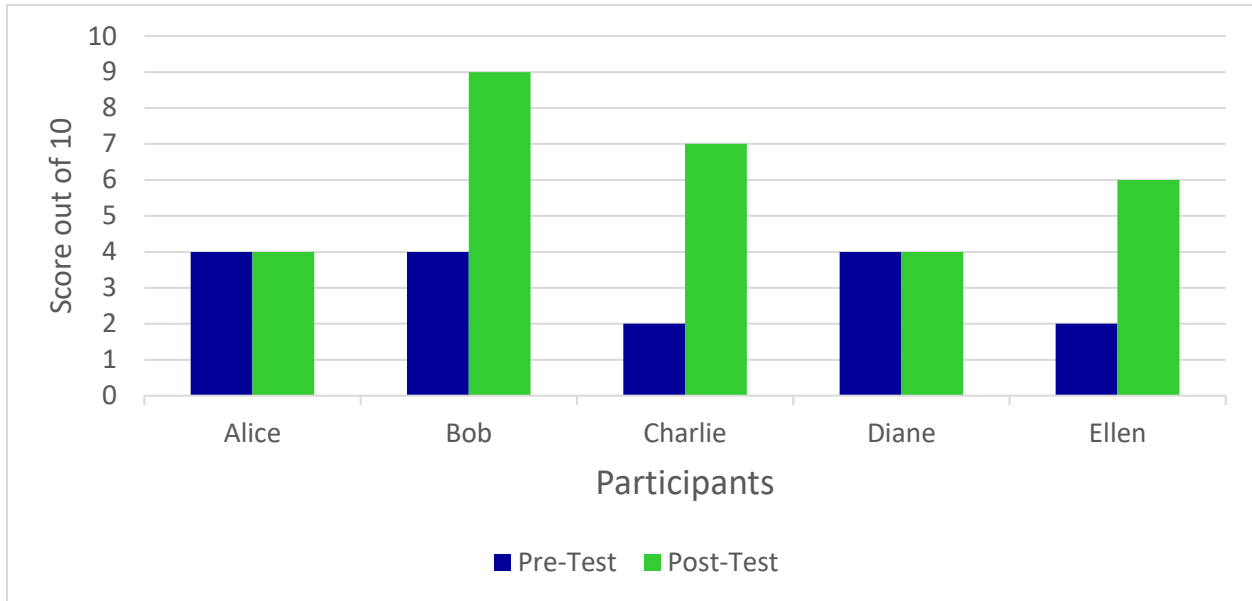


Table 5

Pre-Test and Post-Test Statistics and Significance

Statistics					
Group	N	Mean			Std. Dev.
		Pre-Test	Post-Test	Difference	
Control	2	4	6.50	2.50	3.536
Game	3	2.67	5.67	3.00	2.646
Levene's Test					
Equal variances assumed				F	Sig.
				0.450	0.550
Statistical Significance					
Two-sided p					
0.866					

Note. This table shows the statistical analysis of the pre-test and post-test scores and their differences between the control and game groups. It shows no statistical significance, since $p = 0.866 \gg 0.05$.

Database Defender Gameplay Experiences

All students played the game at least once, and one student, Charlie, played the game twice. The average play time was just over 13 minutes. A majority of students (4) completed the game, with only one student, Diane, that did not complete the game. Diane appeared to struggle on level 3, attempting 17 times before completing it. She proceeded to level 4, attempted once, failed, then gave up playing the game. In contrast, none of the other students had any difficulties with level 3, completing it on the first try. Levels 4 and 5 were fairly easy, with most completing it on their first try. One student, Alice, needed a second try on level 4, and Charlie needed a third try to complete level 5. Level 6, the final level, was the hardest, and in which two students, Alice and Charlie, needed a total of two tries to complete, and Bob and Ellen needed seven and eight tries to complete, respectively. See Table 4 and Figure 11.

Figure 11

Database Defender Gameplay Data – Levels Attempted and Completed



Note. This figure shows each of the students, and the levels they played, either completing the level (shown in green) or failing the level (shown in red). For example, all players completed levels 1 and 2 on their first try, however, Bob attempted the 6th level six times, before completing it on the 7th attempt. As shown, Charlie, played the game twice (Levels 1 through 6 being shown twice in sequence). Diane has the most attempts on level 3, and never proceeded beyond level 4.

Learning Survey Likert Scale Questions

The Likert scale questions within the Learning Survey were generally well received with 85% of students saying strongly agree or agree across all responses (for all questions). None of the students rated any of the questions as strongly disagree and few very (2.5%) responses were disagree. See Table 6 for an overview of the student responses. As mentioned in the Data Collection section of the Methodology, the questions are grouped in sets of four and designed to assess student motivation,

engagement, enjoyment, and perceived learning. The questions were worded positively such that a strongly agree would indicate an increase in motivation, engagement, enjoyment, or perceived learning. Questions 1 to 4, used to assess motivation, were 85% positive with 55% strongly agree, plus 30% agree. Only 15% responded neutral. Question 2, which asks whether the *Database Defender* game helped them see the relevance of database defense, was unanimously answered as strongly agree. In contrast, question 4, asking about if *Database Defender* made students curious to learn more, was less strongly positive with only one student replying strongly agree, and the rest replying an equal mix of agree and neutral. See Figure 12 for an overview chart and Figure 13 to Figure 16 for charts showing individual responses to questions in this category.

For the engagement group of questions (questions 5 to 8), these were slightly less strongly positive than the motivation question group. There were 45% responses for strongly agree (10% fewer than for motivation), 25% responses for neutral (an increase of 10% from motivation), and agree remained the same as motivation at 30%. The question with the most students responding strongly agree was question 8, which asked about how involved students were while playing *Database Defender*, with four strongly agrees and one agree. See Figure 17 and Figure 18 to Figure 21.

The enjoyment set of questions (questions 9 to 12), were the most strongly positive in responses compared to the other categories. There were 55% of students replying strongly agree and 45% agree. None of the students replied neutral or disagree. The questions in this category related to whether students found the game entertaining, fun, and whether they liked it. See Figure 22 and Figure 23 to Figure 26.

The last category, perceived learning (questions 13 to 16), were the questions with the least strongly positive responses, including a few students who responded with disagree. Overall, this category had 80% of student replying strongly agree or agree, 10% responding neutral, and 10% responding disagree. This category focused on questions regarding how and what was learned. The

question that received the disagrees was question 15, which asked if something new was learned.

Despite three students responding strongly agree, the other two responded disagree on this question. In contrast, question 14, which asked about how effectively students learned, most (3) responded strongly agree, and the remaining two responded agree. See Figure 27 and Figure 28 to Figure 31.

Table 6

Learning Survey Likert Scale Question Response Overview

	Motivation				Engagement				Enjoyment				Perceived Learning			
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Alice	SA	SA	A	A	A	A	N	A	A	A	A	A	A	A	D	N
Bob	A	SA	A	N	N	N	A	SA	A	A	A	A	N	A	D	A
Charlie	SA	SA	A	A	A	A	SA	SA	SA	A	SA	SA	SA	SA	SA	SA
Diane	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	A	SA	SA	SA
Ellen	SA	SA	N	N	N	N	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA

Note. Likert Scale Questions: SD = Strongly Disagree, D = Somewhat Disagree, N = Neither Agree nor Disagree, A = Somewhat Agree, SA = Strongly Agree

Figure 12

Learning Survey Likert Questions Relating to Motivation

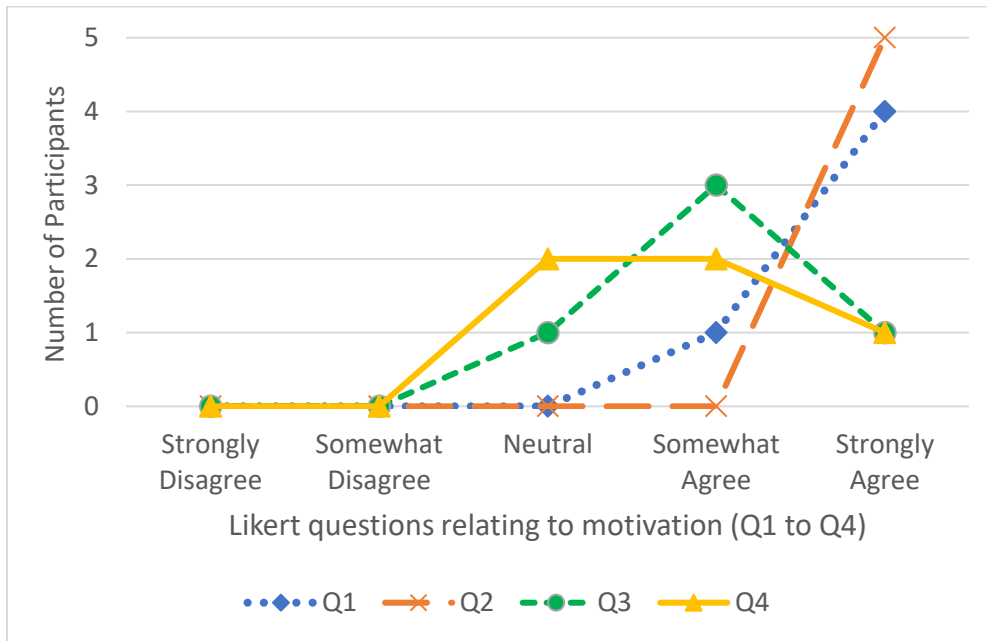


Figure 13

Learning Survey Likert Question 1 – The activities used to teach database defense helped me be interested in the topic

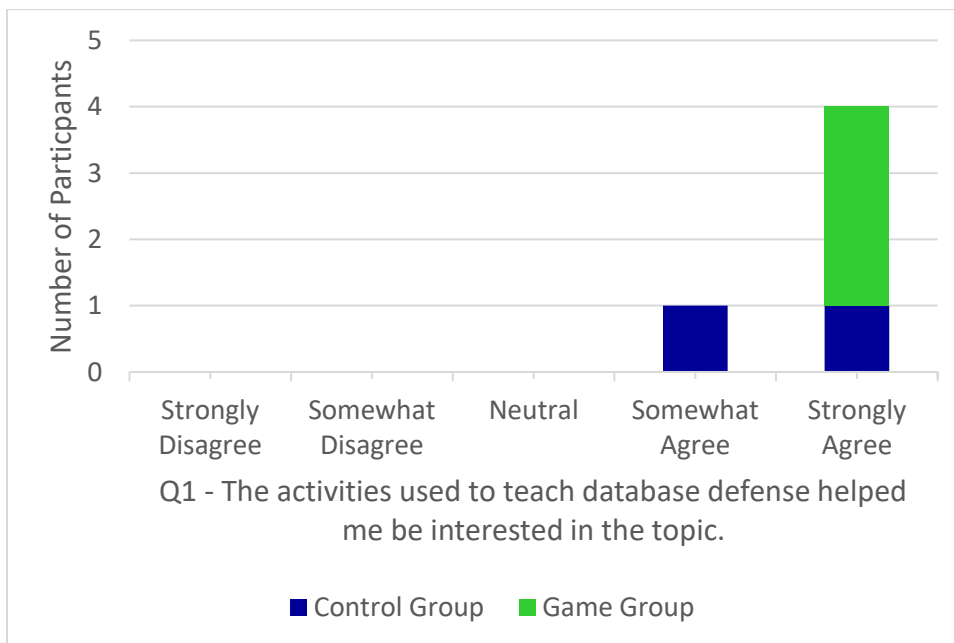


Figure 14

Learning Survey Likert Question 2 – The activities used to teach database defense helped me see the relevance of this topic

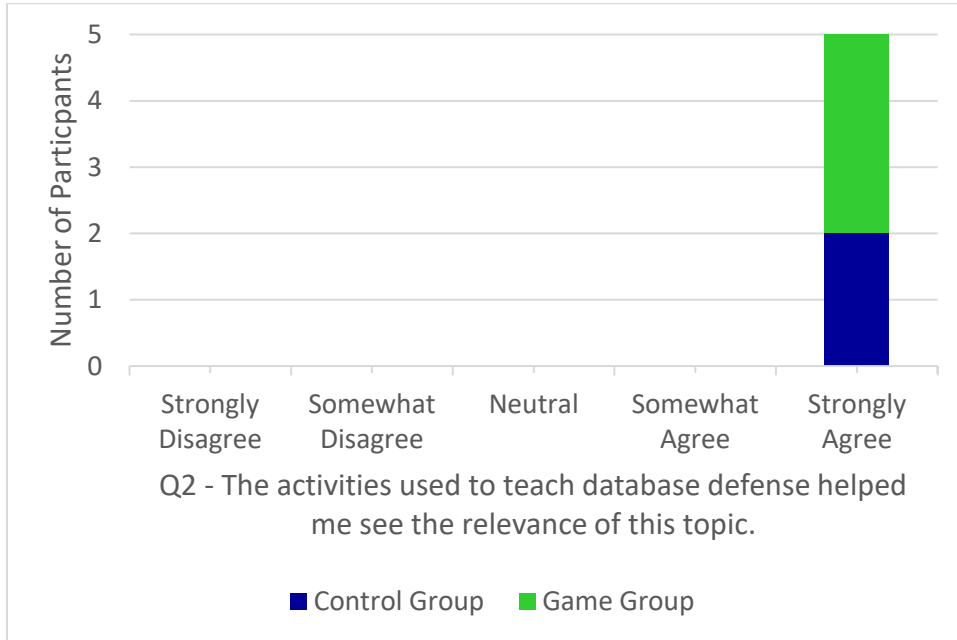


Figure 15

Learning Survey Likert Question 3 – When playing "Database Defender", I found the gameplay rewarding

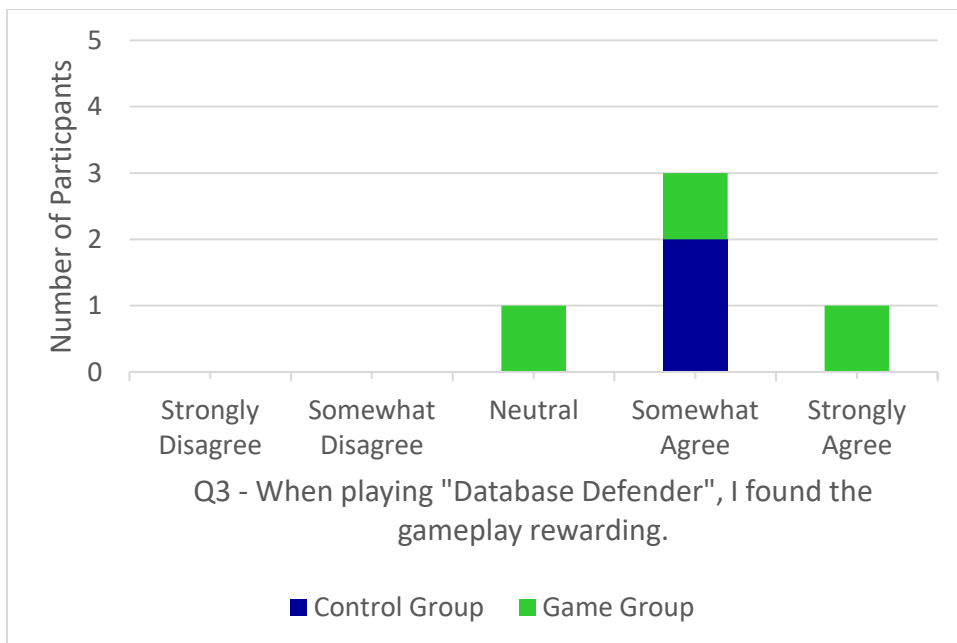


Figure 16

Learning Survey Likert Question 4 –Playing the game, "Database Defender", made me curious to learn more.

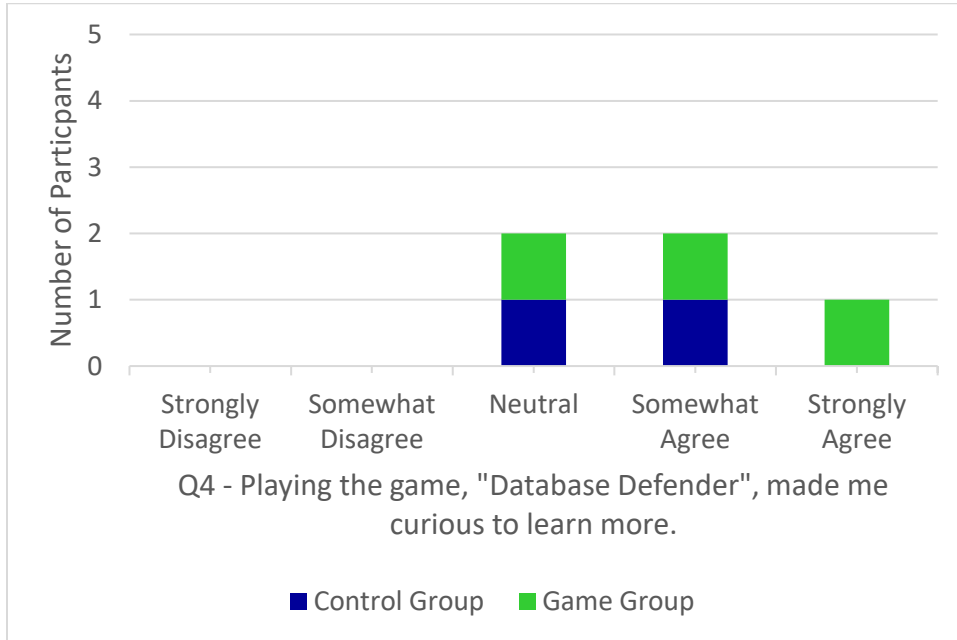


Figure 17

Learning Survey Likert Questions Relating to Engagement

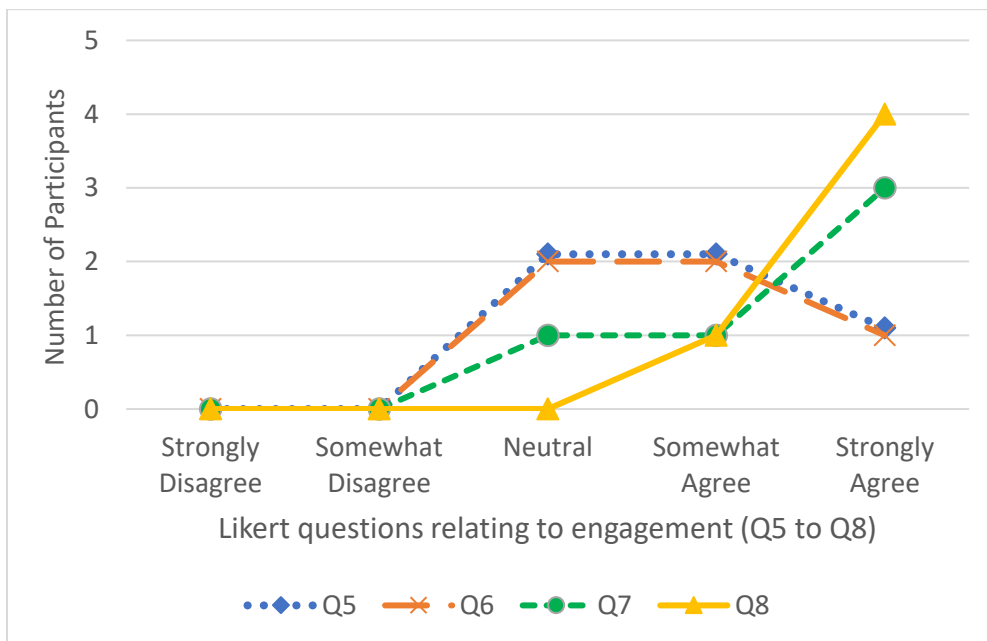


Figure 19

Learning Survey Likert Question 6 – The activities used to teach database defense helped me be concentrate on this topic

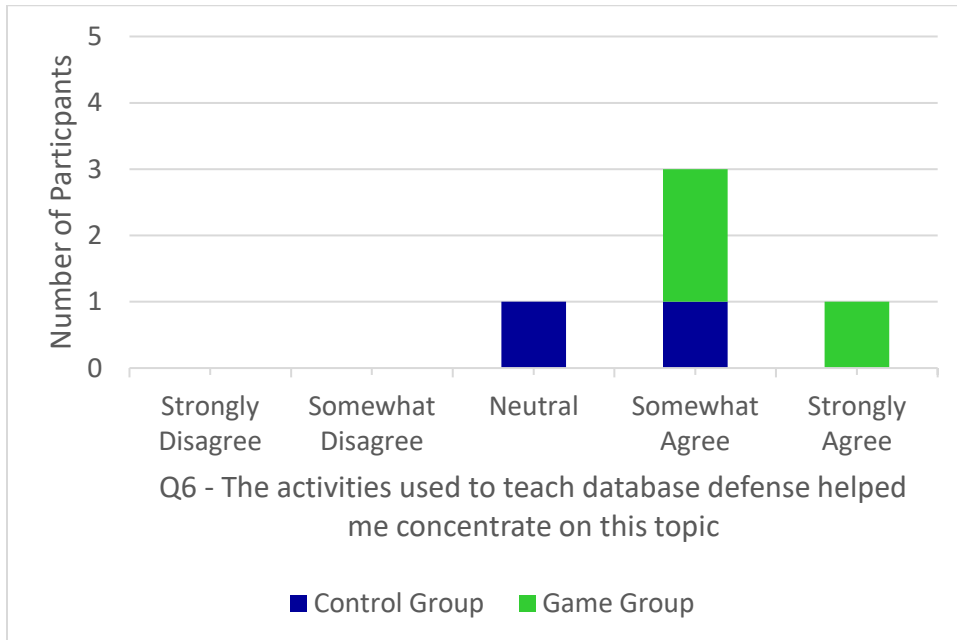


Figure 20

Learning Survey Likert Question 7 – When I played the game, "Database Defender", I did not think of anything else

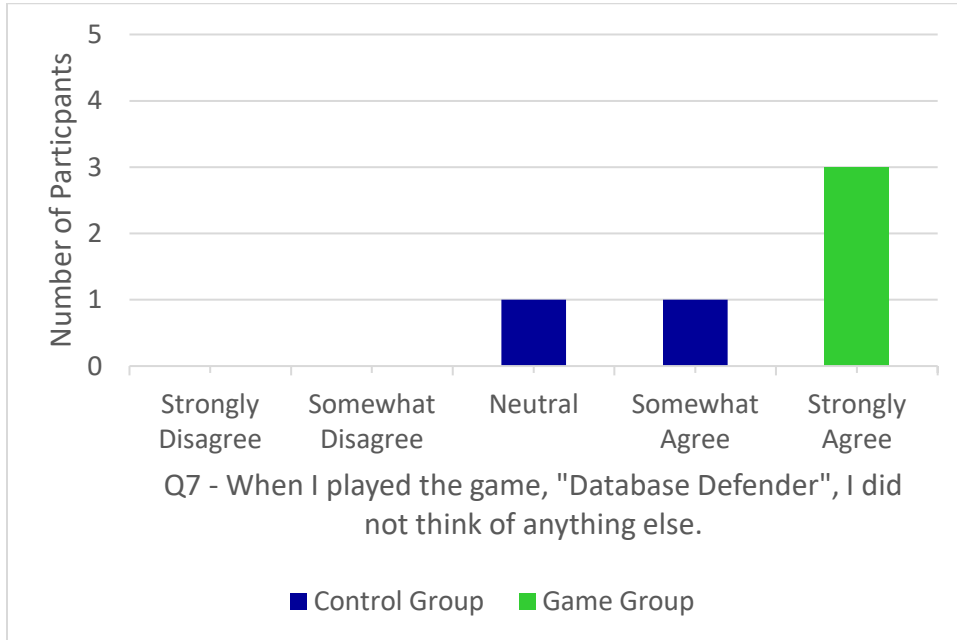


Figure 21

Learning Survey Likert Question 8 – I was very involved while playing the game, "Database Defender"

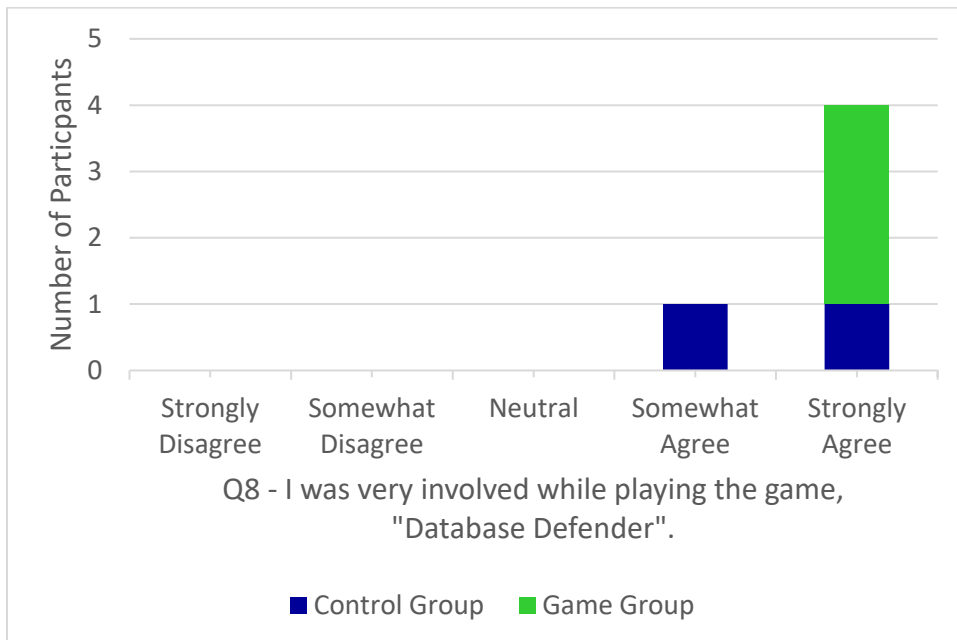


Figure 22

Learning Survey Likert Questions Relating to Enjoyment

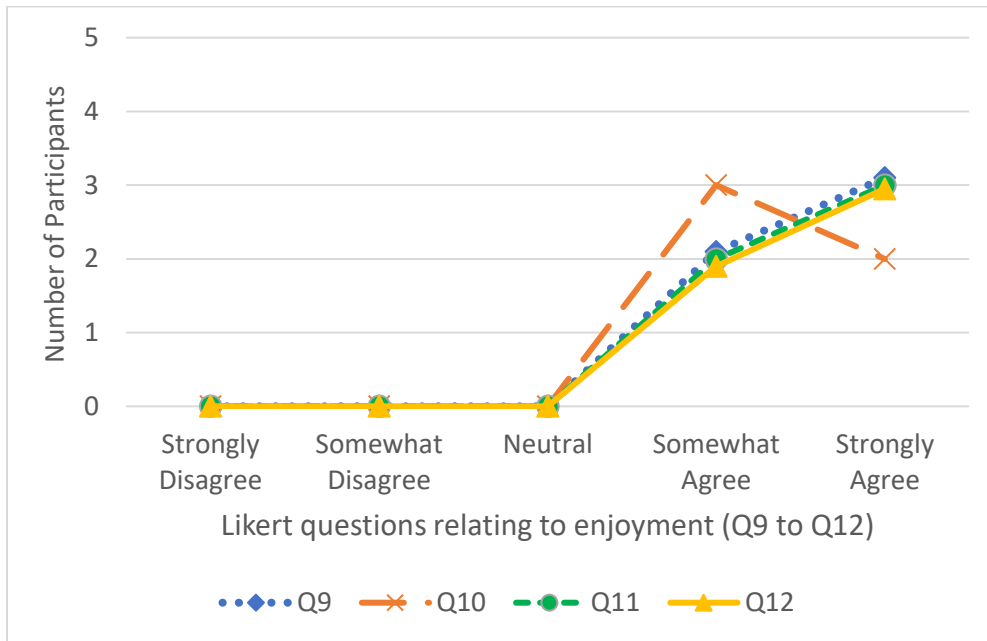


Figure 23

Learning Survey Likert Question 9 – The activities about database defense were fun

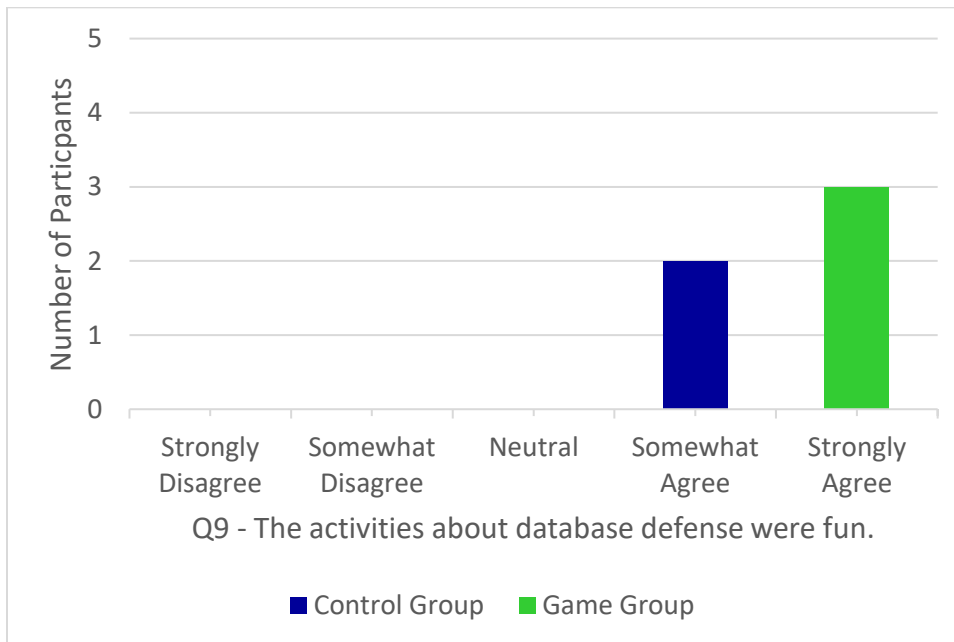


Figure 24

Learning Survey Likert Question 10 – I liked the activities used to teach database defense

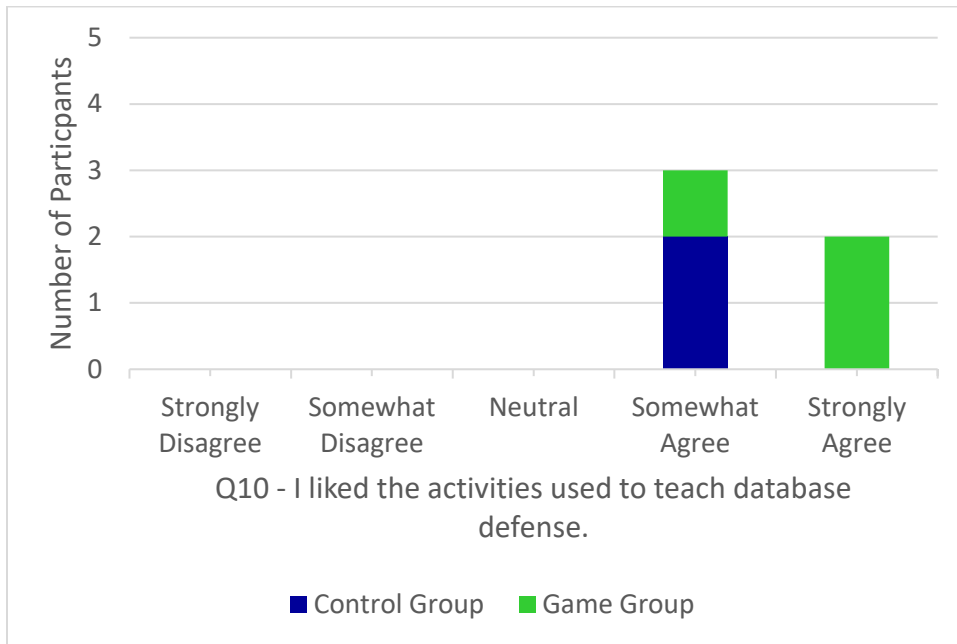


Figure 25

Learning Survey Likert Question 11 – Playing the game, "Database Defender", was entertaining

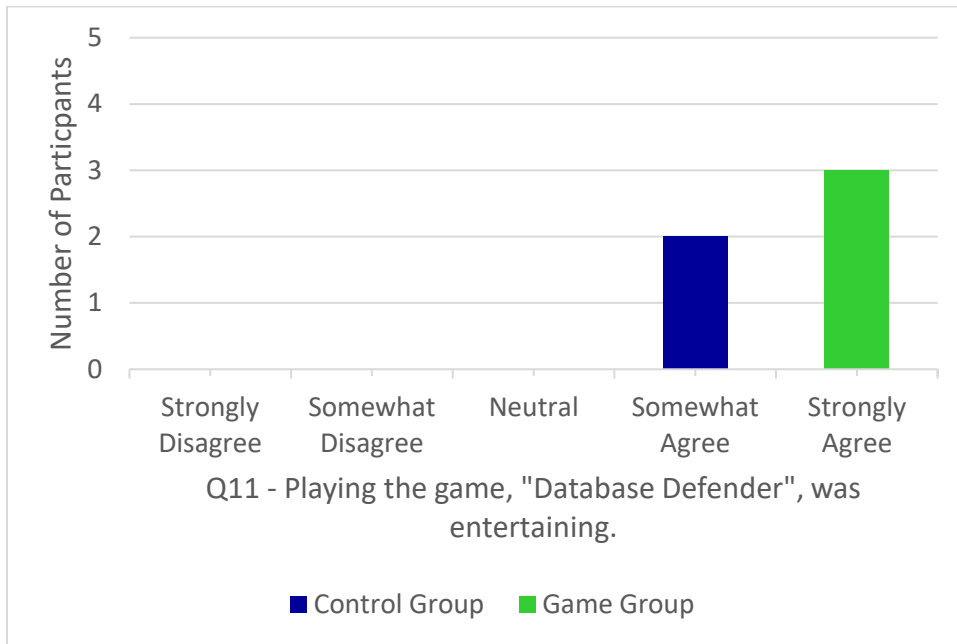


Figure 26

Learning Survey Likert Question 12 – I liked playing the game, "Database Defender"

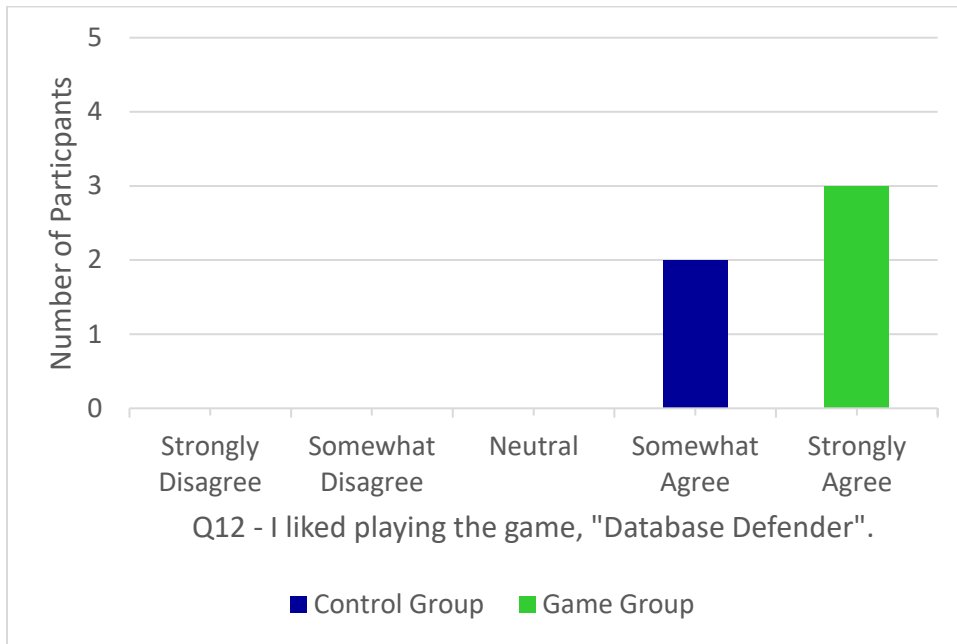


Figure 27

Learning Survey Likert Questions Relating to Perceived Learning

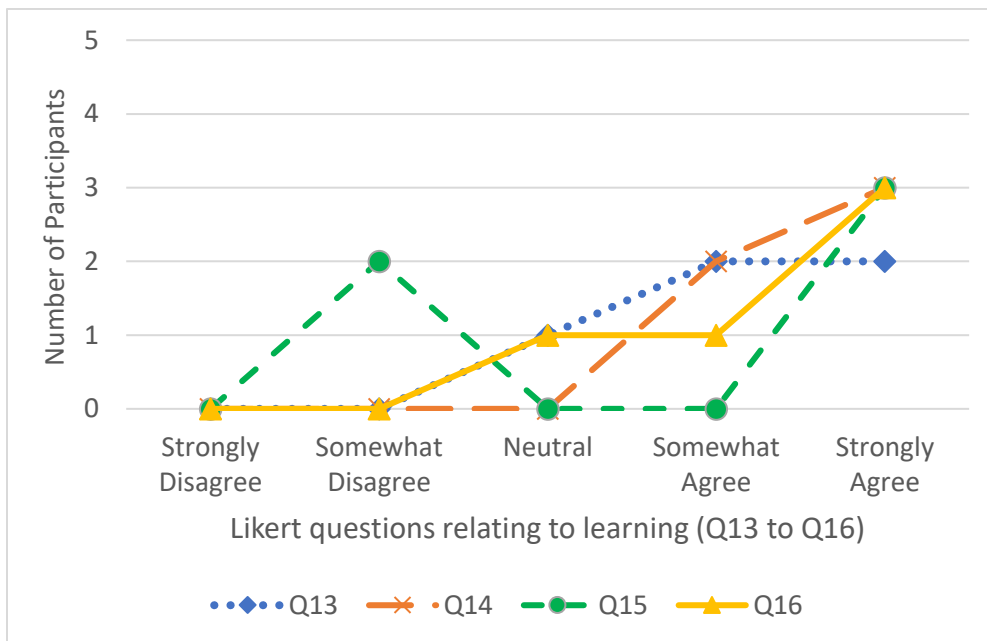


Figure 28

Learning Survey Likert Question 13 – I feel I have learned something useful from the activities used to teach database defense

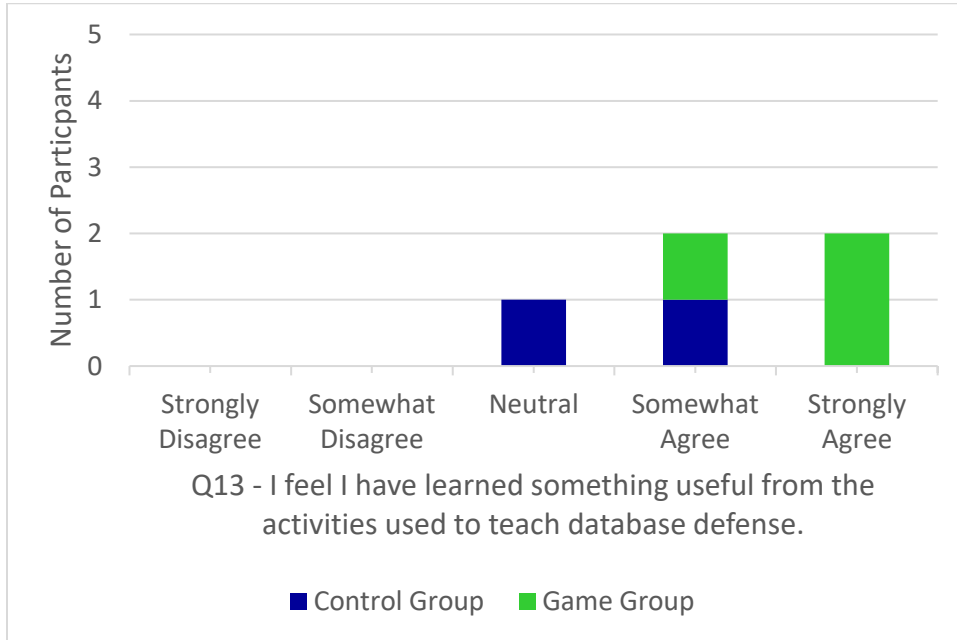


Figure 29

Learning Survey Likert Question 14 – The activities used to teach database defense helped me to learn effectively

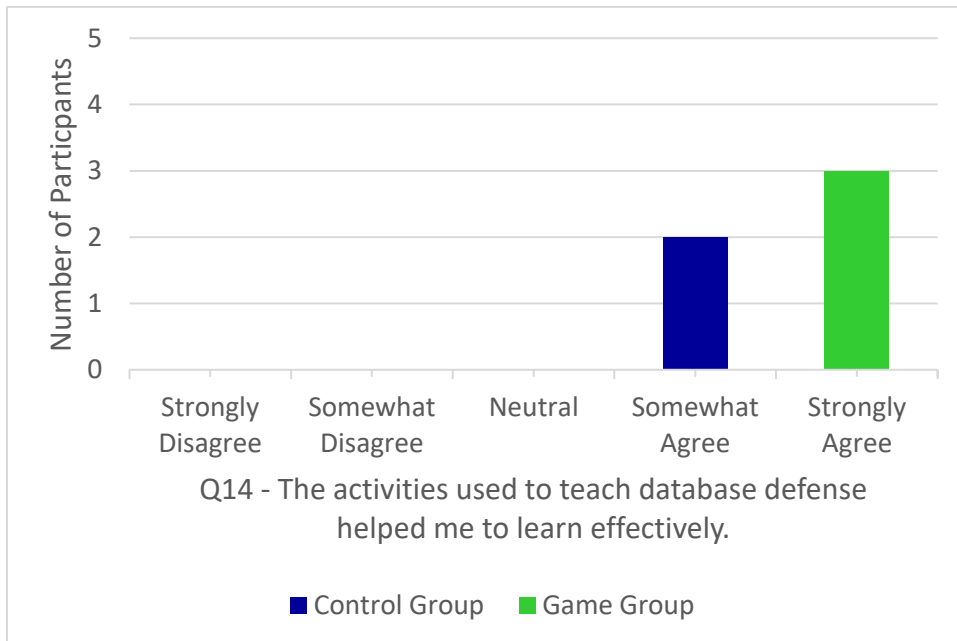


Figure 30

Learning Survey Likert Question 15 – I learned new things about database defense by playing the game, "Database Defender"

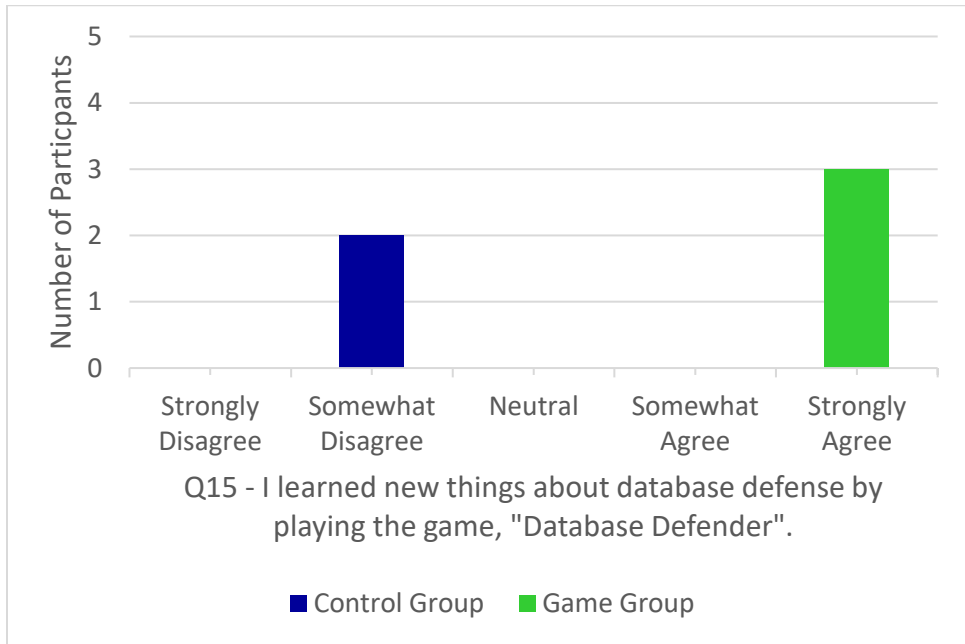
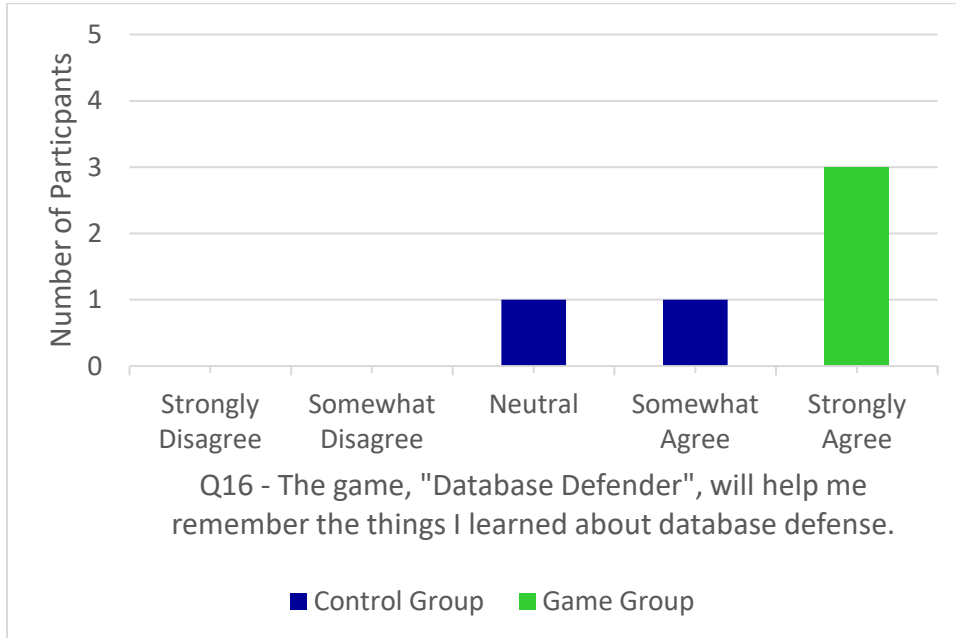


Figure 31

Learning Survey Likert Question 16 – The game, "Database Defender", will help me remember the things I learned about database defense



Learning Survey and Interview Thematic Analysis

Through the thematic analysis, codes were identified and categorized into themes as they related to the research questions and attitudes towards game-based learning. As shown in Table 7 and Table 8, when codes appear in multiple student responses, the frequency was recorded as additional occurrences. See Figure 32 for a word cloud of the thematic codes and Appendix J for examples of codes and their corresponding student responses.

Motivation

In terms of motivation, the codes that appeared most frequently were the desire for the game, *Database Defender*, to have more levels. Motivation came up several times during the interview. The interviewee mentioned that the game, had a positive effect on their motivation, encouraging them to want to learn more about database defense. Another frequent occurrence, was that a few students (2)

were already fairly interested in the topic of database defense prior to learning about it in class and playing the game. Many of the students found *Database Defender* increased their level of interest, their level of motivation, or their desire to learn more about database defense as a result of playing the game.

Engagement

For engagement, the codes recorded show multiple occurrences of students thoroughly being engaged when playing the *Database Defender*, saying it was active, interactive, and hands-on, and that they were focused, engaged, persisting, and anticipating their next move while playing. All of the responses were positive, often finding the game to be highly engaging and no one indicated the game was not engaging.

Enjoyment

As for enjoyment, all of the codes within this theme show students found *Database Defender* to be entertaining, fun, enjoyable, and even awesome. Fun was the most frequently appearing code (6 occurrences), entertaining was next most frequent (3 occurrences) and all other codes only a single occurrence. There was a single occurrence of a student who self-reported as not playing games in a typical week, but that in spite of this, thought the game was fun.

Learning with DGBL

As part of the open-ended questions and the interview, students' perceptions of digital game-based learning were coded and added to the Learning with DGBL theme. The code with the most appearances was that of learning more, with four occurrences and another code with learning better, with a single occurrence. In contrast, there was a single occurrence of someone not learning anything new. Closely related to this code, is the code of reinforcement, which was mentioned three times. Despite not learning anything new to them, the game was still useful to reinforce what was previous learned. A few students mentioned that typical traditional learning is not as engaging as digital game-based learning and that learning using the game was better. In the open-ended questions, students

mentioned that digital game-based learning might be best suited for dull or hard to learn topics (with one occurrence each). Students also mentioned the game was effective, good visualization, and good for memorization.

Gameplay

When considering the design and gameplay of *Database Defender* a few codes came up. There was one occurrence of the game being a bit simplistic and another occurrence mentioning the game was not full consumer quality. This is not entirely surprising, since the development time for *Database Defender* was only 3 months, by a single part-time developer, myself, and this is significantly less than what many high quality commercial serious games require (Kupiainen, 2020; Laning, n.d.). Despite of this short development time, the game, was also mentioned twice in the interview as being a good game design, and once as a good educational design. This supports the conclusion that it at least satisfies enough elements of a successful serious game.

Database Concepts Learned

As far as concepts learned from *Database Defender*, students mentioned using the right backup for the correct threat the most, with 5 occurrences in the Learning Survey, and five occurrences within the interview. The next most frequent code was a sense of urgency to restore the database servers after a database threats. The longer a server is down, the more likely you are to have a customer want the data and the greater the chance of losing the level. In addition, the importance of remote backups was mentioned as part of the interview. Remote backups are important because a natural disaster can easily destroy both your database and the backups at the same time. It was good to see that the lessons that the game was intended for were reflected as part of the student responses.

Attitude

Lastly, in the thematic analysis, responses were coded with "positive", "slightly positive", "neutral", and "positive, but it depends". As shown, most of the responses were positive with 31

occurrences. Responses such as: "I found out playing the *Database Defender* game was more engaging than traditional non-game-based learning activities..." -Diane, "I definitely think it, it accomplished what it was intended for." -Charlie, and "I learned more..." -Alice, were considered positive. There were two responses coded with "slightly positive" because of the language used included "mildly positive effect" - Bob, and "Maybe a little" -Alice. There was a single response that coded as "positive, but it depends" because the student replied "I believe under the right context... a game setting might be helpful to keep students engaged." -Bob, and it was positive, but conditional under the right circumstances. One of the two occurrences of neutral attitude was Ellen that said "I believe having both a formal classroom setting and engaging in serious games can both be useful...". There were no responses saying that serious games were worse than traditional teaching, or that playing *Database Defender* had an adverse effect on motivation, engagement, enjoyment, or learning database defense concepts.

Table 7

Thematic Analysis: Codes, Themes, and their Occurrences – Motivation, Engagement, and Enjoyment

Code	Survey	Interview	Theme
Already Interested	2		Motivation
Desire to Learn More	1		
Interest	1	1	
Motivated		3	
More Levels		3	
Engaging	1	1	Engagement
Active	1		
Hands On	1		
Focused		1	
Interactive		2	
Persistence		2	
Anticipation		1	
Entertaining	3		Enjoyment
Fun	3	3	
More Game Based Learning	1		
I don't play games, but was fun	1		
Awesome	1		
Enjoy		1	

Table 8

Thematic Analysis: Codes, Themes, and their Occurrences – Perceptions and Attitudes

Code	Survey	Interview	Theme
Learned More	4		Learning with DGBL
Learned Nothing New	1		
Reinforcement	3	1	
Learned More from Labs	1		
Good for Dull Topics	1		
Good for Hard to Learn	1		
Traditional Learning not Engaging	2		
Learned Better	1	1	
Visualization	1		
Memorization	1		
Effective	1	3	
Games not for Everyone		1	
Better than Traditional Learning		1	
Simple	1		Gameplay
Not consumer quality	1		
Good Game Design		2	
Good Educational Design		1	
Urgency	1	1	Database Concepts Learned
Different Backups for Different Threats	5	5	
Importance of Remote Backups		1	
Positive	20	11	Attitude
Slightly Positive	2		
Positive, but Depends	1		
Neutral	2	1	

Figure 32

A Word Cloud Showing the Thematic Codes and Their Relative Frequency



Note. The words in this word cloud reflect the codes from the thematic analysis within the survey and interview responses. Words are larger if their occurrence is high and smaller if their occurrence is low. For example, fun and effective appeared more times in the thematic analysis than codes such as focused, motivated, and active.

Student Profiles

In this student profile section, the data for each student participant will be presented across the different data collection points (Likert survey responses, open-ended question responses, pre-test and post-test results, gameplay data, and interview [where applicable]). While the previous section analyzed the qualitative data horizontally (looking at each data collection point [such as Likert questions, open-ended questions, and gameplay data], across the students), this section will look at the data vertically (looking at each student in turn, across the different data collection points [such as Likert questions,

open-ended questions, gameplay data, and interview]). This systematic dual analysis of the qualitative data encourages "one to make all potentially fruitful comparisons of incidents in the data" (Spiggle, 1994, p. 496) and to "harness the richest insights possible out of each dataset" (Canadian Hub for Applied and Social Research, n.d., Why choose us for your qualitative data analysis? section).

Alice

Alice is a mature student (aged 31 to 40) who graduated from some other post-secondary program before attending BCIT. She is an avid gamer (up to 15 hours per week) who plays a variety of game genres (action, RPG, simulations, and strategy). Alice was part of the control group, and had a low pre-test score of 4 out of 10 and saw no increase in her post-test score (post-test score was 4 out of 10 as well). Alice was the most successful of all participants at playing *Database Defender*, playing in the shortest amount of time and with the fewest number of failed attempts (only one failed attempt on levels 4 and 6 each). In response to the Learning Survey Likert questions, Alice consistently picked "agree" for all questions, with the exception of questions 1 and 2, which she answered strongly agree, question 7 and 16, to which she answered neutral, and question 15, disagree. Alice strongly agreed that she was interested and saw the relevance of the activities used to teach database defense (questions 1 and 2). Alice, in question 7, responded neutral to not thinking about anything else while playing the game, and neutral to the game helping her to remember. In question 15, Alice disagreed that *Database Defender* taught her something new.

In the open-ended questions, Alice learned more about the urgency of restoring databases after disasters by playing *Database Defender*. For what she retained from playing the game, Alice said she it reminded her why the different "types of backups are important". She describes that she would have liked "a more cybersecurity aspect to the game" including concepts such as SQL Injection. Alice said *Database Defender* was "nice and engaging, but perhaps very simple". Despite not being console quality, it was "a nice casual learning experience". When asked about the effect the game had on her

motivation, Alice described she was "already interested", so it have only maybe a small effect, if at all.

And lastly, when asked about serious game being more effective than formal classroom, Alice liked *Database Defender* because it was "more kinetic and fun". She said, "it is the best way to learn".

Bob

Bob is in the same age category as Alice, mature 31 to 40 years old, who has some (two years) post-secondary education. Bob plays a more moderate amount of games (6 to 10 hours per week), and a different set of game genres including puzzle, idlers, and collectible card games. Alice and Bob both share a like of strategy games. Bob, also part of the control group, scored a 4 on the pre-test, and significantly increased his test score to 9 out of 10. Bob scored the highest of all participants on his post-test score. Bob was one of the players that played *Database Defender* the longest. He had no troubles in any level up to level 6, however, he needed 7 tries to finish the final level. In response to the Learning Survey Likert questions, responded with a mixture of strongly agree, agree, neutral, and disagree, however, most responses (9 out of 16) were agree. Bob strongly agreed that the activities used to teach were relevant (question 2) and that he was highly involved while playing the game (question 8). Bob was neutral in his response to the motivation question (question 4) asking if the game made him curious to learn more, and also responded neutral to engagement questions (questions 5 and 6) regarding enthusiasm and concentration. Bob disagreed that *Database Defender* taught him something new (question 15), and felt neutral about feeling that he learned something useful from the activities.

In the open-ended questions, Bob, further explains that *Database Defender* did not teach anything new, but rather reinforced existing knowledge learned in class by saying, "the same topic was covered in class" (question 1), and "the second time learning the material" was good for knowledge retention (question 2). In question 3, Bob said the game was more engaging than traditional non-game-based learning, but not a replacement for learning through the previous lab format – "you learn more from the lab compared to the game". Again, like Alice, playing *Database Defender* only had a mild

positive effect on Bob's motivation, as he says he was "already fairly interested" (question 4). Bob provided some great critical thought on digital game-based learning describing it is best "under the right context and for covering certain dull topics". Games, in his opinion help engagement and interest, but students might learn more from "an environment that's a closer approximation to the workplace" (question 5).

Charlie

Charlie was in the middle age group (26 or 27 years old), who graduated from another post-secondary program. Like Alice, Charlie is an avid gamer who plays games 11 to 15 hours per week, with the largest variety of game genres played including: action, shooter, RPG, simulations, and strategy games. Charlie was part of the game group, and started with a 2 out of 10 for the pre-test, which increased by 5 points to 7 out of 10 for the post-test. In the Learning Survey, Charlie answered strongly agree to all questions except five questions, to which he answered simply agree. Those five questions were questions 3 and 4, in the motivation section, questions 5 and 6 in the engagement section, and question 10 in the enjoyment section. The questions that were answered as agree for motivation related to finding the gameplay rewarding, and that the game left him curious to learn more. For engagement, Charlie agreed that the game helped him be enthusiastic and helped him concentrate on the topic. Lastly, he agreed that he liked the activities used to teach database defense.

In the open-ended questions of the Learning Survey, Charlie spoke very favourably about *Database Defender* and game-based learning. He said he learned which backups were best for which threats, by stating in question 1 that the Workbench backups are best for accidental deletes and updates, full raw backups are best for hardware failures, and remote backups are best for catastrophic events. In question 2, Charlie goes on to say, "playing the game was not only a more entertaining way to absorb the information, but it helped me to synthesize more information about database defense". Charlie found playing the game "to be significantly more engaging than traditional non-game-based

learning activities" and enjoyed the balance of entertainment and education within the game (question 3). When describing the effect the game had on his motivation in question 4, Charlie explained that he wanted to learn more about database defense and cybersecurity. Charlie felt playing serious games are very effective compared to traditional teaching since "students would be entertained and participating in their learning rather than trying to memorize or take notes on textbooks or videos". In question 5, he says serious games are a great and effective supplement to formal classroom environments.

Interview

Charlie also volunteered for the interview. During the interview, the themes of motivation, engagement, and enjoyment were fairly equally represented including codes for wanting more levels in the motivation theme; being focused, finding the game interactive, persisting, and anticipating his next move for the engagement theme; and fun and enjoyed the game, mentioned in the enjoyment theme.

Charlie found the game, *Database Defender*, to be very motivating; much more motivating than learning about database defense through traditional teaching such as "just reading about it or watching a video". He said, "I was definitely motivated to a point to learn more about it", and "if I hadn't played the game, I would definitely be much less motivated to learn about database defense". He expressed a desire for more levels in the game so he could learn about more database threats and ways to recover from them saying, "more threats and more counters would be great", and "expanding on the game and giving more levels ... there were only six". He wished there was also an endless mode common to many games (Cao, 2016), where "the game would just throw a bunch of threats at you ... that lasted until you until you lost". He mentions also that he did research into what other threats could be added to the game.

In terms of engagement, Charlie indicated a high level of engagement by expressing the game was interactive, kept him focused, and encouraged persistence and anticipation. Charlie said the game was the "ultimate example" of an interactive learning experience. Charlie specifically said, "I'm a big

believer in interactivity and learning, I think the more interactivity you can give to student, the better".

Charlie, from the gameplay recorded data, played the game twice and had multiple attempts in the sixth level. This persistence came up a number of times in the interview as well, where he expressed, he was engaged with the game, and attempted to optimize his performance within the game, saying, "I'm constantly thinking about how can I do this better?", and, "How can I optimize things?". He said that this persistence was definitely one of the strengths of the game. Charlie also said that this anticipation and prediction of the upcoming threats helped him better understand "how you protect a database against everyday real-life threats". Charlie twice mentioned the game was very engaging and kept him focused.

It was clear that Charlie enjoyed the playing *Database Defender*. He mentioned he "very much enjoyed it", "it was just a great experience in general", and "it was a fun game!". It is interesting to note that when asked if he enjoyed or disliked the game, aside from saying he did indeed enjoy the game, Charlie talked about enjoyment as being a strength of serious games, it "really keeps you focused on what you're doing, keeps you focused on the concepts". He saw the enjoyment of the game to be a big contribution to the success of the game by saying, "keeping the player or the student focused is definitely a big strength and learn [sic] using serious games". Charlie mentioned how the game was both fun and educational, and thought that game was a positive overall experience saying, "I learned from it, you know; that's a success in my book".

Returning back to the main goals of the game, of attempting to teach about the different types of threats to the data within a database and the three corresponding types of backups, it was apparent that Charlie had retained this information. He says in the interview, "we had the three different threats, and then, we had the three different counters", and, "very clear ways to combat each threat". One of his takeaways from the game was: "What's the best way to defend this database against a combination of threats?". Charlie learned the importance of a remote backup, because the first time playing one of the levels, "the tornado wiped out the local backup". He expressed how the visual representations within

the game helped make it clear to him "how that kind of disaster can really affect the database". Charlie explicitly linked the success of the game (i.e. the completion of the levels) to the success of learning the concepts the game is being used to teach (i.e. the threats and the backups used to recover from them). He said, "if your goal is to succeed in the game, then you really have to pick up on the concepts that the game is trying to teach you".

Charlie really appreciated the design of the game, not only was the game enjoyable and worth playing on its own, but also effective from an educational perspective. He said, "I thought that [it] was, one, very good game design and, two, very good educational design". He thought the game was short, but thought the "game mechanics were explained really well" and "the core of the game is really solid". When asked if there were any changes he would make to improve upon the game, he had only one thing to say. He would have liked a way to restart a level midway through if you had made a mistake. He said, "it took a very long time for me to actually fail a level". Having an extra button on the screen that reset the current level back to the beginning would be a simple fix for this issue. Charlie continually praised the game for being highly effective saying, "it accomplished what it was intended for". He felt the game was really good learning experience and that the game reinforced what was taught in class. As someone who is "really into video games", Charlie said that serious games are "definitely a better way to learn".

Diane

Diane is the youngest participant (aged 22 or 23 years old) with only 1 year of post-secondary outside of BCIT. Diane does not play games very much (only 1 to 5 hours per week) and plays only puzzle games. Diane was in the game group, and scored a 4 out of 10 for the pre-test, and saw no increase on the post-test (also 4 out of 10). Diane really appeared to struggle with the game right from early on. She attempted level 3 sixteen times before completing it on the 17th attempt, and attempted level 4 only once before giving up. She played for almost 15 minutes, but never completed the game. Despite not completing the game, she responded the most favourably of all students in the Learning Survey Likert

questions, with strongly agree for all of them, with the exception of question 13, to which she answered agree. Question 13 relates to learning something useful from the activities used to teach database defense.

In the open-ended questions, Diane felt the game taught her how to properly backup the system fully and that she retained the information, "because I learned so much about backing up database structure from game" (question 2). Diane saw *Database Defender* as "more engaging than traditional non-based learning activities because it brings more fun" and liked the game better than reading because of the engaging visual aspect. Diane expressed that the game enhanced her motivation because it was "engaging, fun, awesome, [and] learned the materials better" (question 4). In question 5, Diane mentioned the need for a balance between serious games and formal classroom setting, saying they can both be useful because some topics are hard to learn and game can help improve engagement to help students learn more.

Ellen

Ellen is in the second most mature age group (28 to 30 years old) and graduated from some program before coming to BCIT. She is the only participant to say that she does not play games at all during a typical week, and as such, has no preferred game genres. Ellen, as part of the game group, started with a 2 out of 10 for the pre-test score, and raised her score by 4 points to 6 out of 10 on the post-test. Ellen, like Bob, played the game the longest at just over 15 minutes and again similarly to Bob, had no problems with all levels (1 through 5), but needed 8 attempts to complete the final level, level 6. Ellen strongly agreed with all the Learning Survey Likert questions, with the exception of questions 3 through 6, where she responded neutral. Questions 3 and 4, which related to motivation, Ellen felt neutral finding *Database Defender* rewarding and curious to learn more. For questions 5 and 6, Ellen responded neutral to questions regarding engagement about her level of enthusiasm and concentration.

Ellen had the least to say of all participants for the open-ended questions, however provided some good insight into a non-gamer. Question 5 which asked if serious games are more effective than a formal classroom, she simply answered "Yes". Probably the most encouraging finding, is that despite her not being a regular gamer, she still enjoyed the game and saw the educational benefit of it, "I don't play games so for me it is fun to play it" (question 3). She thought the game was good visualization and helped reinforce the knowledge learned saying "knowledge is visualized and memorized during playing" (question 4). In questions 1 and 2, she repeats the same idea, that game effectively helped her learn that you need to choose the right backup for the right threat, "three different types of backup and when to use them". Overall, Ellen, despite not being a gamer, still enjoyed and found *Database Defender* to be an effective teaching tool.

Chapter 5: Discussion

This study asked the question: what effect does a serious game have on a higher education student's ability to learn and apply concepts of database defense to real-world scenarios? The sub-questions addressed the effect playing a serious game had on students' motivation and engagement, their perceptions of playing the game, and the students' ability to learn and apply this knowledge. Overall, students found the game increased or maintained a high level of motivation, they reported that the game was highly engaging and very enjoyable, and that it was an effective learning tool for reinforcing knowledge learned from lecture and labs in the usual instruction. The importance of different database backups being required for different database threats was impressed upon students through the urgency and immediacy game mechanic within the game.

Motivation

The first research sub-question addresses the effect *Database Defender*, a serious game, had on student motivation to learn about database defense and apply that knowledge. As mentioned in the Self-Determination Theory of Motivation, intrinsic motivation is doing an activity out of interest (Ryan & Deci, 2002) and when the rewards are inherent in the activity (Deci & Ryan, 1985). The Likert scale questions show indications that students had a high level of interest, and saw the relevance of the activities used to teach database defense. Albeit, slightly less so, than interest and relevance, students still found the game *Database Defender* rewarding and that it helped them to be curious to learn more, responding with moderately strong agreement. The open-ended questions revealed that some students were already fairly motivated to learn, with Alice and Bob saying they were already interested in learning about database defense before playing the game. Alice found the urgency within the game a motivator to learn within the game, while Bob found the game useful as a reinforcement of topics already covered in class. The other three students, Charlie, Diane, and Ellen found the game to increase their motivation to learn about database defense. Charlie during the interview expressed numerous

times the desire for the game to be expanded to include more levels, more threats and defenses, and even perhaps an endless mode where you could play as long as you could survive the ongoing barrage of threats. Charlie explaining he wanted more out of the game shows he was motivated and actively involved within the game (Camilleri et al., 2011; Koppolu, 2016). As a whole, students either were fairly motivated before playing the game and the game was able to maintain this motivation, or students said that the game improved their motivation.

Engagement

The second sub-question asked about the affect the serious game had on the level of engagement to learn cybersecurity and database defense and the ability to apply that knowledge. Of the three factors examined in the Likert questions: motivation, engagement, and enjoyment; engagement appears to be the least affected by the introduction of the serious game, however, is still a positive response. Despite having more students responding neutral (25% of responses in this category were neutral), still none of the students responded with disagree or strongly disagree, and most answered agree or strongly agree that the game increased engagement. Students found they were very involved and did not think of anything else when playing the game. Involvement and thinking only about the game are aspects related to Mihaly Csikszentmihalyi's Flow Theory of Engagement and indicate a high level of engagement (Csikszentmihalyi, 1990; Nakamura & Csikszentmihalyi, 2014). The open-ended questions revealed students found the game very engaging, much more so than traditional instruction. Alice, expressed that the game was simple and not full console quality, yet still a nice casual learning experience. An increase in game quality could increase the immersion and engagement (Bedwell et al., 2012) which might be a contributing factor as to why responses in the engagement section of the Likert questions was slightly lower than other sections. Within the interview, there was a strong conveyance of how the game was interactive and this led to it being thoroughly engaging. Dickey (2005) explains that interactivity (and the inclusion of hooks) is key to engagement, by saying hooks are "anything that

requires the player to make a decision that relates to the game and thus keeps them playing" (Dickey, 2005, p. 77). In summary, students generally found the game to be engaging, though, with more development time to improve the game quality, the game could be even more engaging.

Perceptions

The third sub-question explored the student's perceptions of playing a serious game to learn concepts of database defence. A number of different themes emerged from student perceptions including: enjoyment, comparison to traditional teaching, and what students felt they learned from playing the game.

Enjoyment

As discussed in the literature review, enjoyment and fun, play an important role in keeping students motivated and engaged. Serious games should have a careful balance of fun and learning to be successful (Barzilai & Blau, 2014; Boller & Kapp, 2017; Caserman et al., 2020; Dimitriadou et al., 2021; Gee, 2007). *Database Defender*, as a serious game, was well received by students in the Likert questions with all students saying they agreed or strongly agreed that the game was fun, entertaining, and that they liked playing it. The enjoyment category of Likert questions was the strongest category out of motivation, engagement, and enjoyment. Another important observation to be made is that the game appealed to gamers who enjoyed strategy games (Alice, Bob, and Charlie) and puzzle games (Diane). It even appealed to Ellen who did not identify as a gamer and does not play games in a typical week. In the open-ended questions, Ellen said, "I don't play games so for me it is fun to play it". Charlie, in the interview, said the game was fun, he learned a lot, and it was a "very good educational design... and that's a success in my book". It was clear that students found the game to be very fun and entertaining for gamers and non-gamers alike.

DGBL vs Traditional Teaching

In general, students found *Database Defender*, as an example of serious games, to be better and resulted in them learning more from it, as compared to traditional teaching. Diane responded in the open-ended questions that she "learned so much about backing up database structure from [the] game". And Charlie, in the interview, said, "I'd say it's a really good alternative to kind of the more traditional [teachings], like readings". Despite many students seeing the benefits of digital game-based learning, some students offered some caution as well. Students mentioned that games may not be received well by non-gamers, though, as previously discussed, from Ellen as our example of a non-gamer, it is still possible for non-gamers to enjoy the game. Students also mentioned that serious games might be best for dull or hard to learn topics. Diane said hard to learn topics can be taught by games, and Bob said, "for covering certain dull topics, a game setting might be helpful to keep students engaged". Students mentioned that the motivation, engagement, and enjoyment of the game led to better learning experience over traditional learning. Diane sums up her experience by saying, "playing the *Database Defender* game was more engaging than traditional non-game-based learning activities because it brings more fun and you want to learn more stuff by playing". Al-Azawi et al. (2016), Annetta (2008), and (Van Eck, 2006), all support the concept that students are ready for and welcome alternatives to traditional teaching (such as digital game-based learning), which is reflected in the findings of this study.

Learning

It was clear that students learned what the game intended to teach. This is reflected in their open-ended question responses and in the interview transcript. Students were able to identify the three database backup types (workbench backup, full raw backup, and remote backup), the three database threats (junior programmers, failing hard drives, and tornados), and which backup was best at recovering after which threat. Caserman et al. (2020) explains the importance of integrating the learning

objectives with the motivational elements of gameplay to achieve high-quality serious games. According to Charlie in the interview, *Database Defender* achieves this: "if your goal is to succeed in the game, then you really have to pick up on the concepts that the game is trying to teach you and you actually have to learn about the subject matter". As mentioned by Bob, in the open-ended questions, *Database Defender* is probably best used as a reinforcing tool, as he felt "the same topic was covered in class", but he continued saying "additional reinforcers will probably strengthen the memory". Ellen said the game was a great way to visualize and memorize the information while playing.

Pre-Test and Post-Test

The research question of this study (and its related sub-questions) investigated the effect a serious game might have on higher education student's ability to learn and apply concepts of database defense to real-world scenarios. The open-ended and Likert scale questions asked students about their perceived learning, while the experimental design had the goal of determining whether students actually learned and could apply this knowledge. The experimental pre-test, post-test design was used to help corroborate the qualitative data and to help triangulate the results. If the students in the game group had shown a significant increase in their post-test scores as compared to the control group, there would have been supporting evidence to infer that the game helped improve knowledge acquisition and retention. However, this was not the case, as no statistical significance was found. There are a number of possible explanations for why the quantitative data does not support the qualitative data including: the validity of the pre-test and post-test question as a form of assessment and the variance within the data.

The validity of the pre-test and post-test question as an assessment of the students' knowledge is brought into question because there were two students who showed no increase whatsoever in the post-test score (one student was in the control group, the other in the game group). Also, both of these students only scored 4 out of 10 (below passing grade) on this question. It was my expectation that

students even in the control group would have learned something about database defense and would see an increase in their post-test scores (at the very least from the usual instruction on database defense). Perhaps they did not take the pre-test and post-test seriously, and thus put little effort into answering it, because they were told it was not for marks within the course and only used as part of this research study. Perhaps the question was too general, too abstract, or too holistic, and students were unable to or were unclear of what knowledge should be demonstrated and how to clearly state it. Failure to achieve clarity on what is to be evaluated and the expected requirements threatens the validity of the assessment (Brookhart & McMillan, 2019; Gardner, 2012). The pre-test and post-test did not explicitly ask students to name database threats and their corresponding defenses. It did not ask them about the importance of remote backups. It did not enquire about the importance and urgency of restoring data before customers arrive. Perhaps, if the pre-test and post-test question were constructed to more directly incorporate the concepts that the game was designed to teach, higher and more significant differences between pre-test and post-test scores would have been observed.

Another reason why statistical significance was not achieved could have been due to a small sample size with high variance. Bonate (2000) explains that there are two ways you can increase the possibility of achieving statistical significance: 1) increasing the sample size, and 2) increasing the effect size. The small sample size is in part a result of low participation rates and this is further discussed in the limitations section. The high variance is in part due to some students showing no increase in their post-test score and others seeing a 4-to-5-point increase. This created a high level of variance within the distribution of mean differences of pre-test to post-test scores. A decreased variance, increases the effect size which increases the possibility of statistical significance. Thus, if the question were redesigned and most or all students saw at least some increase in their post-test scores, this would increase the possibility of statistical significance.

Despite not seeing a statistical significance within the experimental design, it is important to note that of the game group, Charlie and Ellen (those that showed increases in their post-test scores) related the post-test responses directly back to the game. This was exclusive to the game group, as it was not observed in the control group. Ellen in the post-test question mentioned the importance of having all three backup types "workbench backup, full raw backup, [and] remote backup". Charlie, correctly identified the three backup types and corresponding threats in his answer to the post-test:

To provide up-to-date, consistent backups that will minimize downtime in the event of a disaster, I would first protect the database against accidental deletion of data by creating a Workbench Folder Backup. This would allow for deleted tables to be easily restored. Next, I would create a full raw backup on-site, which could be easily restored in the event of hardware failure, such as hard drive failure. Next, I would create a remote full raw backup, which could be restored on new hardware in the event of a catastrophic accident or natural disaster that destroys all on-site data and backups.

This indicates that some members of the game group had learned the importance of the different backups and their role in protecting against the different threats, and that they were able to apply it to a real-world scenario of database defense.

Demographics Trends

There appeared to be little difference between age, gender, and post-secondary education in terms of motivation, engagement, and enjoyment. Nor did demographics have any noticeable effect on pre-test and post-test scores, typical gameplay, or typical game genres. *Database Defender* gameplay data (number of failed attempts and game duration) seem unaffected by demographics. Although, those that were older (and perhaps wiser) made observations that serious games used to teach may not appeal to all audiences, i.e. non-gamers, however, this was not directly observed (the non-gamers

seemed to enjoy the game regardless). The game was very fun for many students, even those who do not regularly play games. The two students who said they did not or rarely played games still enjoyed and learned from the game. Gamers seemed to pick up the game a little faster (fewer failed attempts and in less game time) than those that played games less often, however, non-gamers still were able to finish the game within a reasonable amount of time. As mentioned in the limitations section of the methodology, with such a small sample size, subdividing the data by demographic is not likely to provide highly reliable data.

Chapter 6: Recommendations and Conclusion

Recommendations

This recommendations section consists of two parts. The first part includes recommendations for future research to replicate the results. The low participation rates (small sample size) and the specificity of this case study invites more research in order to corroborate the findings. The second part is a set of recommendations and considerations for those instructors who wish to incorporate DGBL into their classroom. DGBL and the interactions it has on motivation, engagement, enjoyment, and learning are complex and may vary greatly depending on audience, instructor, the content being taught, and the environment it is being taught in. This part attempts to use the experiences and what has been learned in this thesis to provide advice to those who wish to investigate DGBL further.

Future Study and Replication

Despite the results showing a positive increase to motivation, engagement, and enjoyment as a result of the introduction of a serious game to teach database defense, much more research is required. This study had a single instructor teaching a single course, at a single institution, and in a single country. Replicating this study and having a larger sample size (higher participation rates) will help confirm (or refute) these findings. Replication helps reduce the possibility of random or fluke events and rare human errors (Rosenthal, 1990). Replication across different instructors, schools, and countries would also be beneficial to further validate the findings in other settings. Further investigation is required to determine if other topics in IT, aside from database defense, would also benefit from DGBL. Perhaps rerunning this study again (with the same or very similar methodology) at a later date will result in increased participation when COVID is less of a health concern and in-class student attendance is higher. Even still, a few modifications to the methodology may improve the student participation and the findings of the study. Some considerations for future study include: 1) improving the game design; 2)

redesigning the Likert scale questions, 3) redesigning the pre-test, post-test question; 4) making the serious game mandatory; and 5) having the instructor be present in the class.

The first consideration is improving the game design. As mentioned earlier, *Database Defender* the game, was designed and developed in a short period of time, by a single person, me. Due to the delimitations of this thesis, the game was not play tested nor piloted ahead of time. Had the game had some additional development time, improvements could have been made to it, thereby possibility increasing the enjoyment and engagement of the game. This would address some of the comments from Alice and Charlie about the game being simple and not consumer quality. Some additional levels could be added, more threats and defenses, and even an endless mode could be added, as Charlie suggested. Also, I would add the feature Charlie mentioned to add a button on the screen to restart the level.

The second consideration is redesigning the Likert scale questions. Because the Likert scale questions were all positively coded, perhaps adding some of the questions as negatively coded would reduce acquiescence bias. Using balanced scales as described by Kuru and Pasek (2016) may reduce the effect this bias. For example, one of the Likert questions asked if students agreed with the statement: "When playing '*Database Defender*', I found the gameplay rewarding". This question could be rewritten as negatively coded as: "When playing '*Database Defender*', I found the gameplay a waste of time". Those who always agree to the positively coded statements would have their responses balanced out on the next negatively coded one. Another method discussed by Kuru and Pasek (2016) is not to use the words "agree" and "disagree", and instead have questions rank an extent of a behaviour. For example, the question from the previous example could be rewording as: "I found '*Database Defender*', to be:" and then have the answers range from: "a big waste of time", "a bit of a waste of time", "neither a waste of time nor rewarding", "somewhat rewarding", to "very rewarding".

The third consideration is redesigning the pre-test, post-test question. Since some of the students in the control group showed no increase in their post-test question score, the validity of the post-test question as an assessment was brought into question. The question was perhaps too abstract and the requirements unclear, leading students to provide incomplete answers and not providing what was expected. A different pre-test, post-test question, one that focused more closely on the concepts the game intended to teach, might provide a better insight into the differences between the control and game group in the ability for the game to teach and for students to retain this information. The pre-test, post-test question to be more in line with the knowledge taught within the game could include the identifying different types of backups, the different types of threats, which backups helps recover from which threats, and the urgency of restoring data before the data is needed.

The fourth consideration is making the game a mandatory class activity. If the game, *Database Defender*, was made into a mandatory activity, this might lead to an increase in participation and thus a larger sample size. Assigning an achievement or participatory mark worth a small portion (~1%) of the students' final course grade might be enough to establish the expectation that the activity is mandatory. Indeed, if there is not a grade associated with the game, students may believe that there is no benefit in using it (Kapralos et al., 2011). Because this study required students to participate in person, and some students were self-isolating due to illness or absent from class, providing a way for students to participate online could help improve participation and help reduce penalties to grades. The methodology would need to be adjusted, either to remove the pre-test, post-test experimental design or to find an alternate activity for the control group of equivalent learning and worth. This would also require careful considerations for the ethics application to ensure if an alternate activity was used that it be equivalent and not cause any harm (e.g., decreased learning potential, increased complexity, increased time requirement, etc.) for those in the control and game groups, as compared to each other. Despite motivation being closely associated with autonomy and freedom of choice (Ryan & Deci, 2000),

there is supporting literature that it is possible to make a serious game mandatory and not reduce the enjoyment, engagement, motivation, or learning effect (Kuindersma et al., 2016).

The fifth and final consideration was having the instructor observe the in-class activities as they relate to the study (either in person or recording the session). As part of the methodology and ethics application for this study, I chose to have a neutral third-party facilitate all in-class activities. This way, the effect of my influence in the classroom would not affect the students or the results of this study. However, I wonder if there is a way that the first-hand experiences of the students as they play the game could have somehow been captured and analyzed as part of this study. The observations of students playing the game could reveal their surprise, satisfaction, frustrations, hesitations, difficulties, and so much more. Students might exclaim in enjoyment, laugh at the gameplay, grunt in disappointment, and exhale a sigh of relief when completing levels. Could the methodology be adapted to allow for the instructor to be a part of the gameplay experience and still be able to make the environment safe and ethical?

Recommendations for Those Implementing DGBL

As mentioned in this research, DGBL has a number of advantages. Serious games can improve motivation, engagement, and enjoyment, which in turn can be an effective teaching tool. However, serious games should not be a replacement for good teaching (Annetta, 2008). Also, as revealed in this study, serious games, might not well suited to completely displace traditional teaching, but rather may be best as a supplement to existing teaching materials and used as a reinforcement of existing knowledge. As noted in previous literature and enforced by comments from students within this study, serious games may be best reserved for dull or difficult to learn processes or topics.

This study is unique in that, I, as the researcher, possess many skills in order to design, development, and integrate a serious game into my classroom. As discussed by Dimitriadou et al. (2021), some of the challenges of creating successful serious games and the resources required; "very few

educators had all the components required for the development of quality [serious games]" (p. 142).

Developing high quality serious games often involves many roles implemented by many different people such as educator, instructional designer, game developer, graphics designer, script writer, game testers and more, but not all these skills are common to the same person (Dimitriadou et al., 2021; Kapralos et al., 2013). It is important to note that without careful instructional design a serious game may not be an effective teaching tool as explained by Kapralos et al. (2013) "knowledge in game design solely is not sufficient to develop an effective serious game" (p. 106) and "serious game designers/developers must possess a working knowledge of instructional design" (p. 108). Another important aspect of *Database Defender* that is unique is that it closely mirrors the topic it is attempting to teach. The topic of database backups, recovery, and cybersecurity threats, lends itself well to the tower defense strategy game type where there are attackers and specific defences for each. Where possible to improve balance of fun and learning, and to improve the integration of the learning within the game (Caserman et al., 2020), serious games might be best for topics that can be easily modelled within a game setting (Bellotti et al., 2010). Find the game mechanics and genres that are best suited to teach your specific topic (Marklund & Romin, 2020; Nagarajan et al., 2012). *Database Defender*, in attempting to teach the importance of restoring the data quickly after a disaster event, used the game mechanic of careful timing urgency.

Creating effective serious games for the classroom can bring other challenges as well. Consider the time it takes to develop or find existing games, the cost of purchasing or paying for the development, the technology used, how the game fits within the curriculum, how easy is it to update and maintain the game content, and the ability to adopt new technology within your school or institution (Calvo et al., 2016; Del Blanco et al., 2010; Dimitriadou et al., 2021; Fernández-Manjón et al., 2015; Van Eck, 2006; Yoon & Park, 2013). As discussed by Fernández-Manjón et al. (2015) and Dimitriadou et al. (2021), while games have been accepted for use in early stage education, there is stigma against their use in higher education and more rigor is involved in justifying its need,

appropriateness, and effectiveness. *Database Defender* is a highly specialized serious game, designed specifically to teach the importance of having multiple types of backups to defend against the many different and very real threats to a database. It is not uncommon for serious games to have very niche applications and be tailored for a specific audience (Dimitriadou et al., 2021; Fernández-Manjón et al., 2015). Keep in mind the resources required when considering implementing a serious game into your curriculum. With all things considered, there are a number of benefits and affordances of DGBL, such as the potential for improved motivation, engagement, and enjoyment, and improved learning, when applied as a supplement to existing teachings for difficult to learn and dull topics.

Contributions and Impact

This study adds to the knowledge base of DGBL and attempts to fill a research gap specifically at the intersection of DGBL to teach IT related topics and to an audience of higher education students. The significance of this study is in its ability to apply DGBL theory to the combination of a new discipline and new target audience. This study enforces previous studies by confirming serious games have the ability to increase motivation, engagement, and enjoyment. This increased motivation, engagement, and enjoyment was also shown to improve perceived and actual learning. This specific topic in cybersecurity as it relates to database backups, threats to data, and data recovery, is a difficult topic to teach and perhaps a dull and uninteresting one. Database defense appears to be a good topic to be taught using DGBL. I encourage those with dull or difficult to learn topics in higher education to explore serious games as a possibility and to push past the negative impressions some people may have to avail of the potential affordances of this technology.

Conclusion

There is a significant amount of literature supporting the use of digital game-based learning with the ability to increase motivation, engagement, and enjoyment, which often leads to improved learning experiences. Literature is limited, however, when considering IT related topics and for students in higher

education. This study was an exploration into digital game-based learning within the IT field for higher education students. The findings of this study indicate that the addition of a serious game as a form of digital game-based learning was beneficial for students alongside the usual instruction for database backups and recovery labs and lecture. From the survey responses and the in-depth interview, students responded that the serious game improved or maintained a high level of motivation, increased their engagement, and it was a fun, entertaining, and an effective way to visualize the key differences between the database backups and how each one is specialized to defend against specific threats. Further research is recommended to replicate this study to increase the sample size and confirm the findings. Any instructor that is considering incorporating serious games in their courses, to avail the potential affordances of digital game-based learning, should also consider the time required to build the game, the quality of the game, and determine if the topic would be a good fit for digital game-based learning.

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[9_24](https://doi.org/10.1007/978-94-017-9094-9_24)

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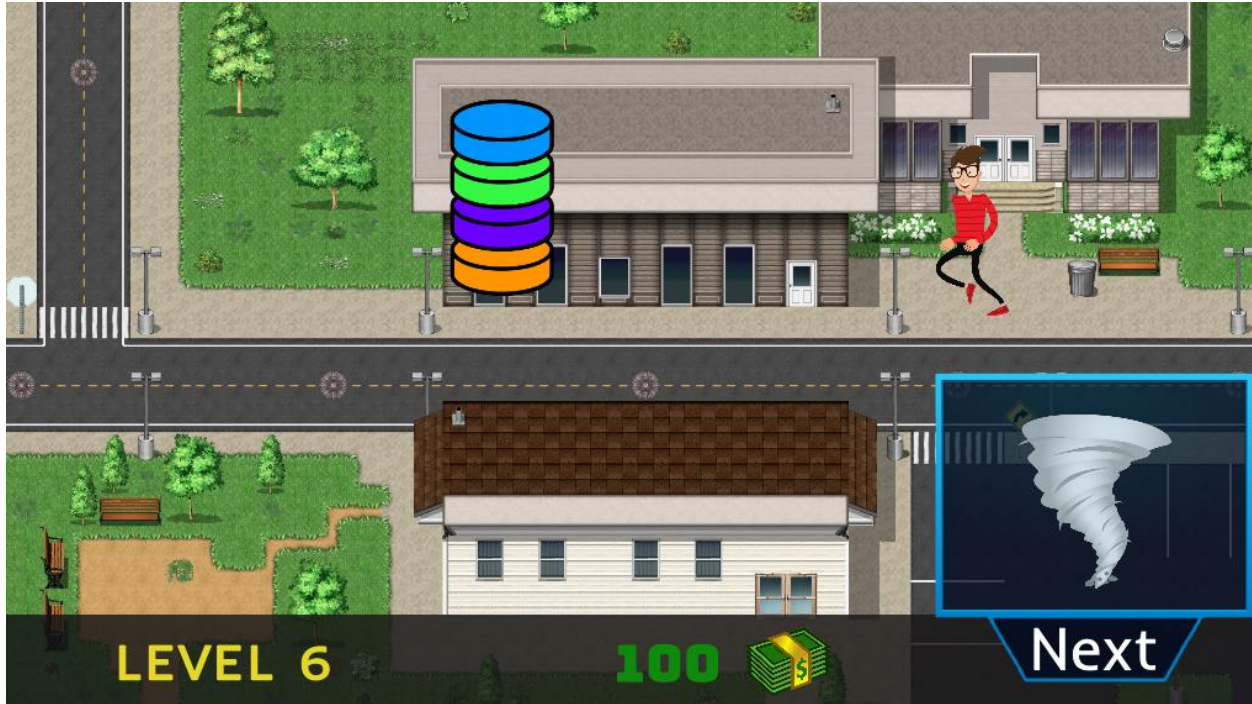
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Appendices

Appendix A - Database Defender Types of Databases Backups, Threats, and Recoveries

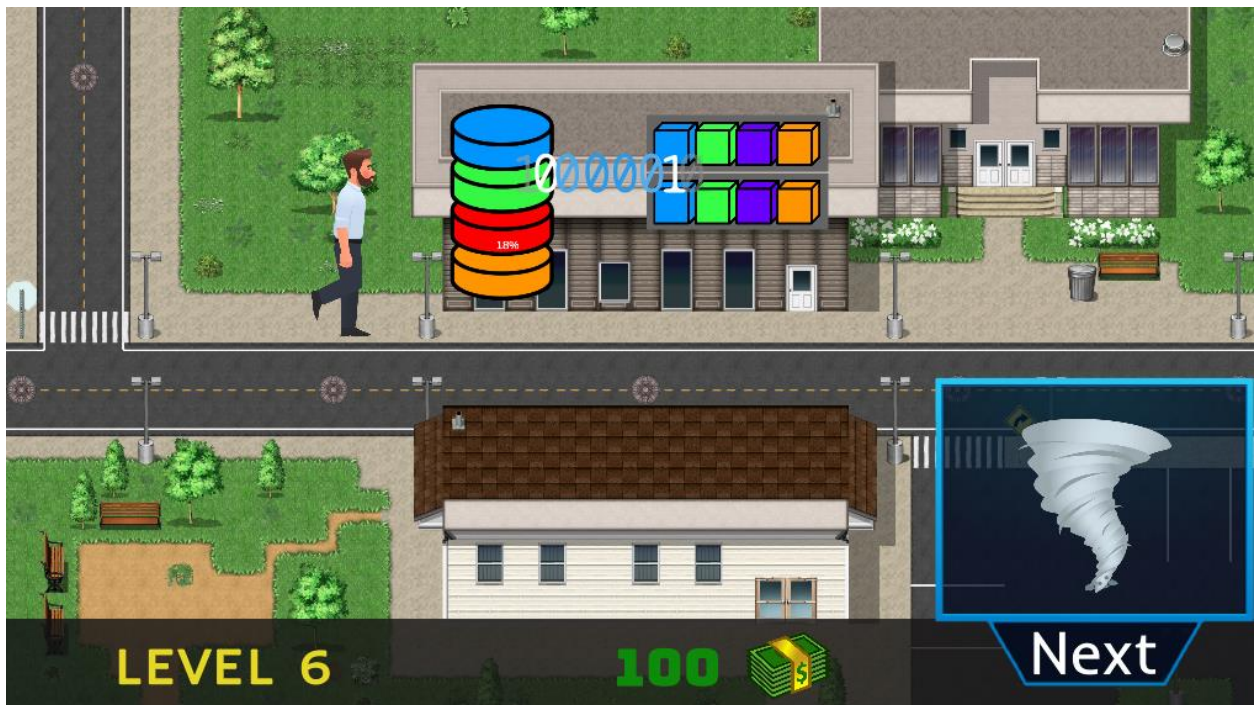
The following screenshot from shows a junior programmer approaching the database.



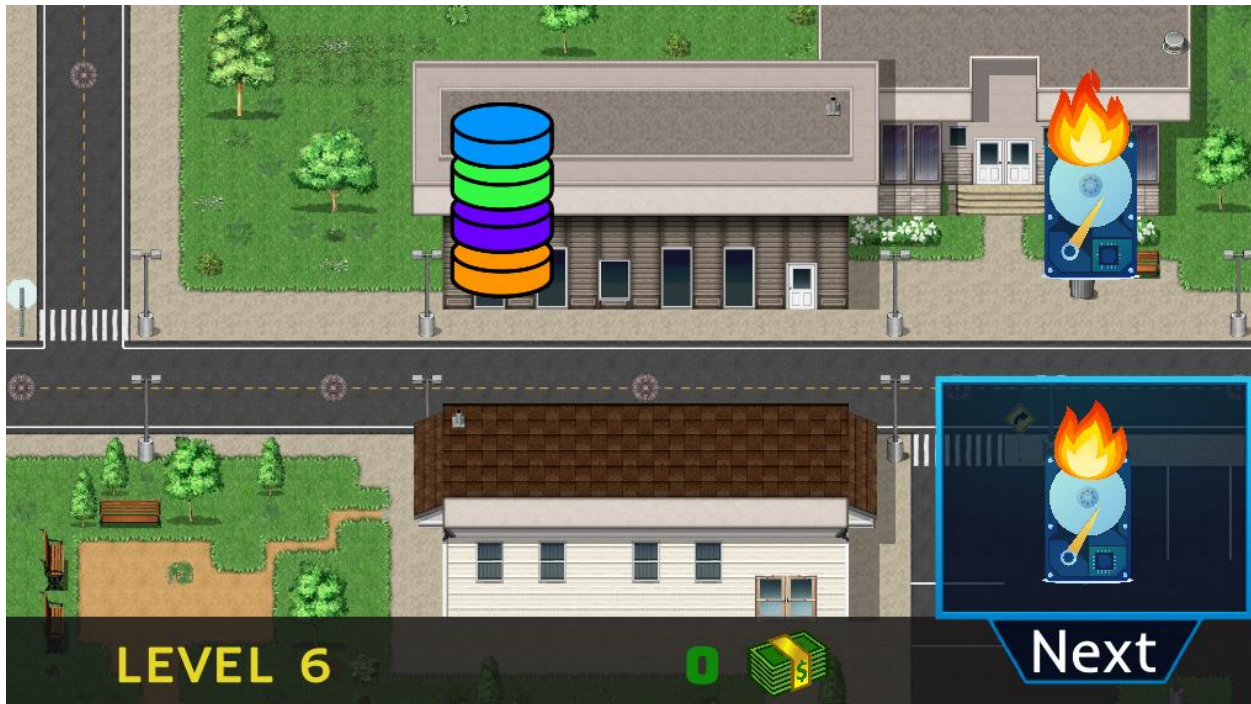
The following screenshot shows the junior programmer reaching the database and destroying some of the data in the database (the broken data in the database is indicated with a flashing red color).



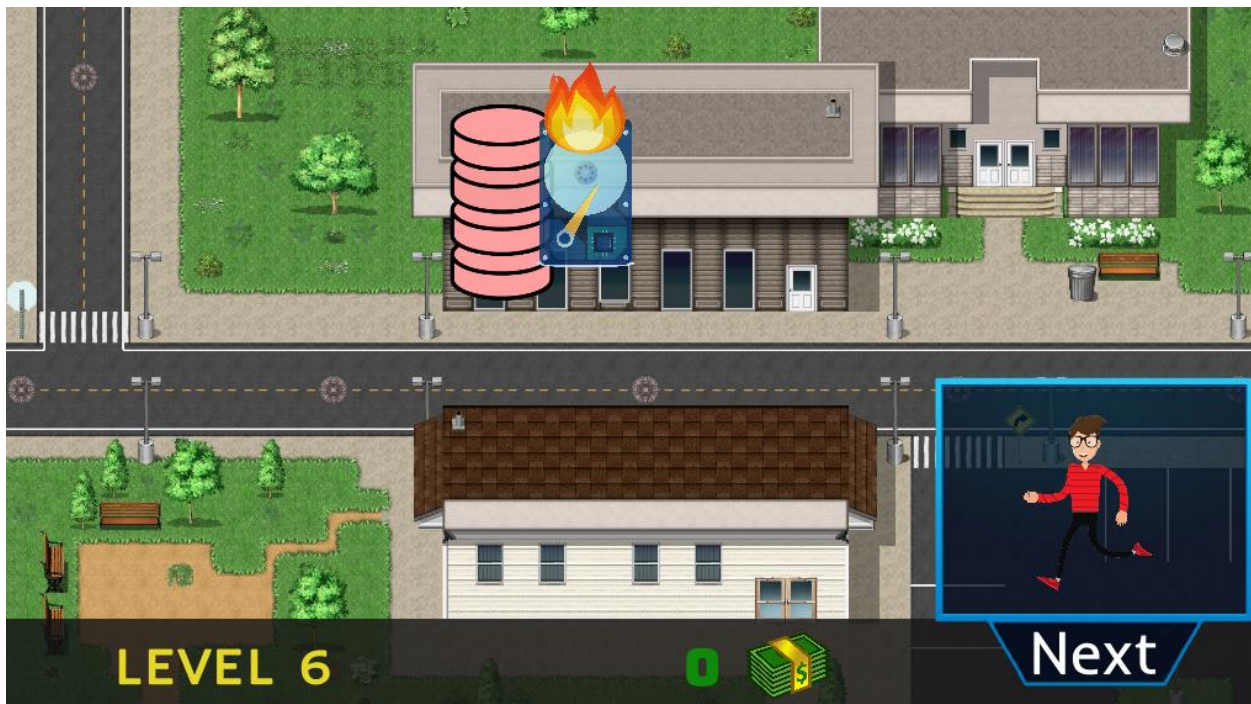
The following screenshot shows the broken database being restored (with a partial restore) before the customer arrives.



The following screenshot shows a failing hard drive approaching the database.



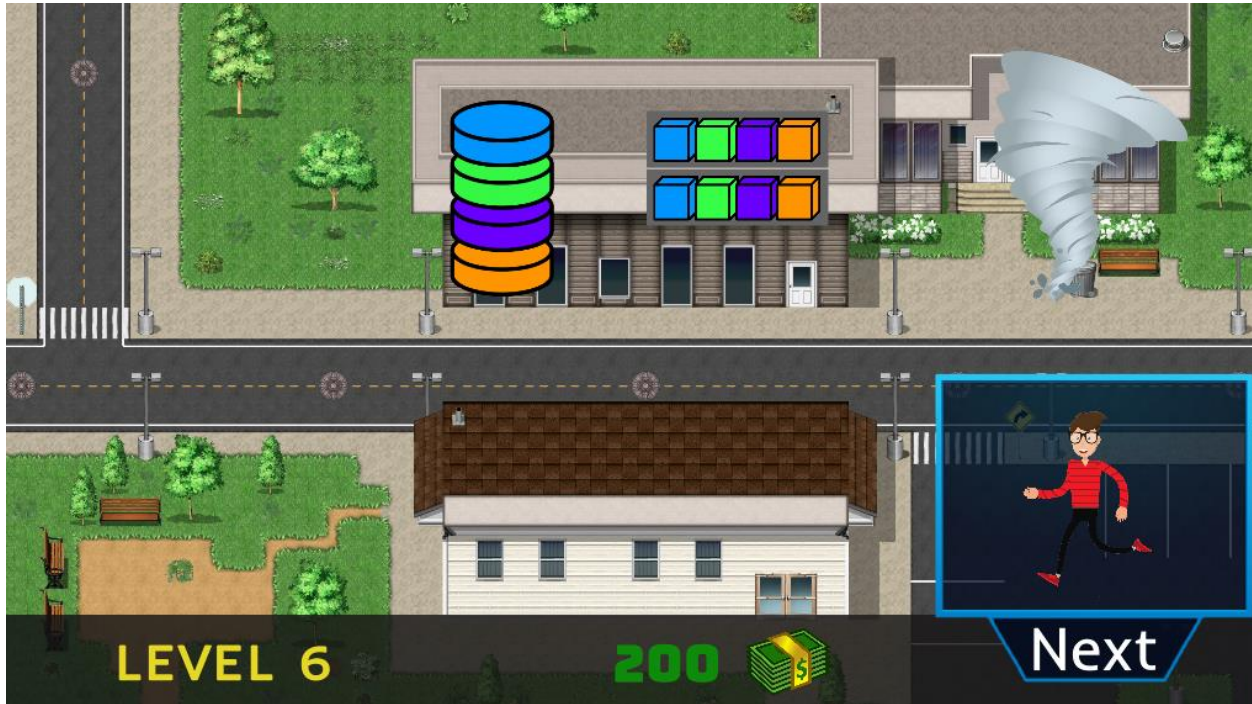
The following screenshot shows the failing hard drive reaching the database and destroying the data in the database (a broken database is indicated with a flashing red color).



The following screenshot shows the broken database being restored (with a full restore) before the customer arrives.



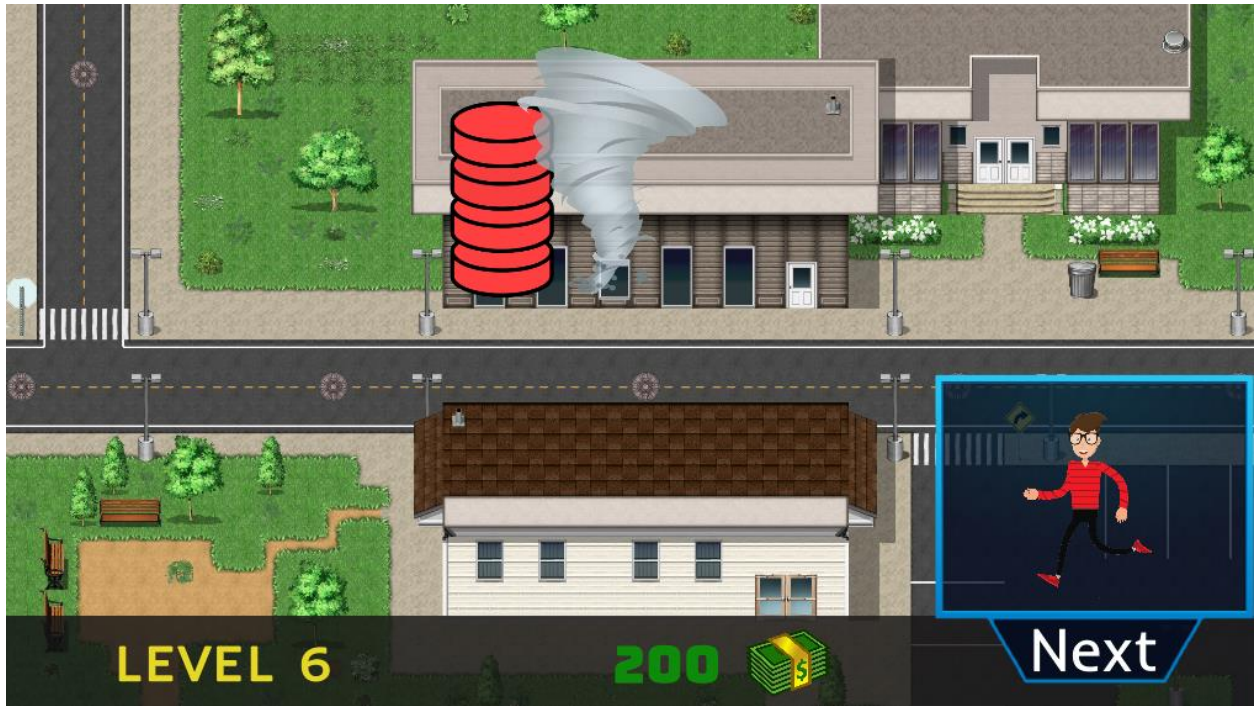
The following screenshot shows a tornado approaching the database.



The following screenshot shows the tornado reaching the local backups and destroying them (tornadoes destroy both the local backups and the database).



The following screenshot shows the tornado reaching the database and destroying it (a broken database is indicated with a flashing red color).



The following screenshot shows the broken database being restored (with a full restore from a remote backup) before the customer arrives.



Appendix B - Lessons to be Learned Within the *Database Defender* Game

Each level in the *Database Defender* game has a lesson (or multiple lessons) to be learned.

Level 1 - "Intro to Database and Customers": The database is represented by a set of colored stacked cylinders in the game. Customers are represented by people walking towards the database. Customers need access to (once they reach) the database in order for you to get money.

Level 2 - "Intro to Backups" - Backups of the database can be created by clicking on the database and selecting which type of backup you want to create. Backups appear as sets of cubes next to the database.

Level 3 - "Intro to Restoring" - A junior programmer that accidentally deletes some data is a threat that we need to protect our database against. We can ensure our data does not get destroyed, by backing up our database before the junior programmer deletes the data, and by restoring the missing data before the customers arrive.

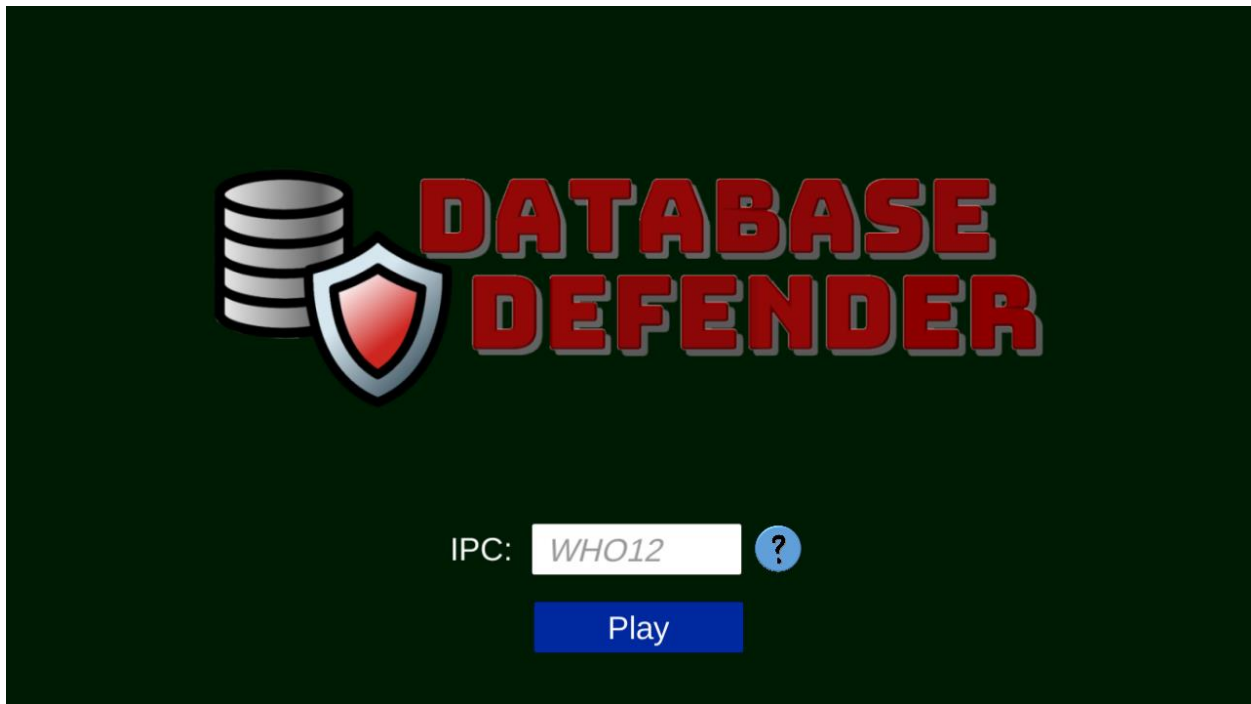
Level 4 - "Intro to Full Restore": A failed disk drive can destroy all data in a database. A new backup type is available to restore all data at once (called full restore). Doing a project backup (which allows for only a partial restore) will not work here - it will be too slow.

Level 5 - "Intro to Remote Backups": Natural disasters such as tornados can destroy your database **and** your backups. Performing a Full Raw Backup and storing it offsite allows for recovery when your onsite backups are destroyed.

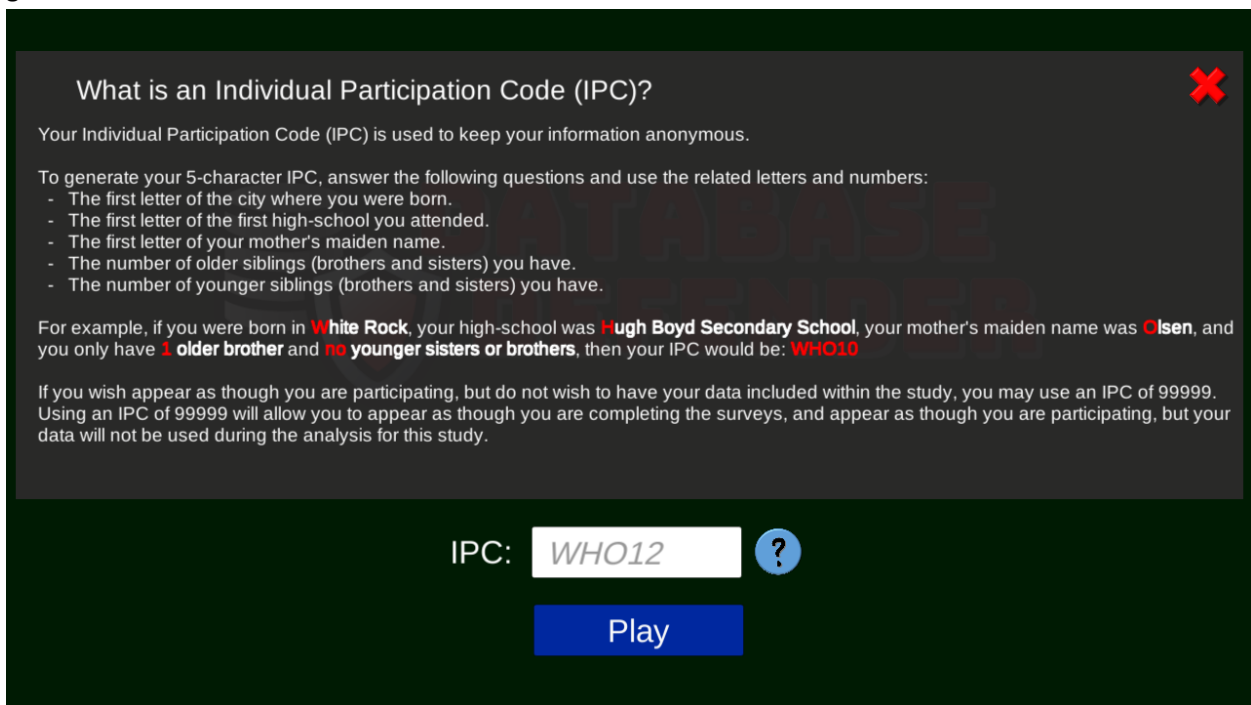
Level 6 - "The correct backup for the correct threat": Each threat needs a different kind of backup to restore from. The best way to recover from a junior programmer deleting data, is by doing a partial restore from a Workbench Project Folder Backup. The best way to recover from a failing drive is to do a full restore from a Full Raw Backup. The best way to recover from a tornado, is to do a full restore from a Full Raw Backup stored remotely.

Appendix C - Database Defender Log In and IPC Screen

The following is the login screen which prompts for the IPC to log in with.



Clicking on the blue question mark button opens the following screen describing how to generate an IPC.



Appendix D - Database Defender Tutorial System Level 1

The following 5 screenshots show the multipage tutorial for Level 1 in *Database Defender*.

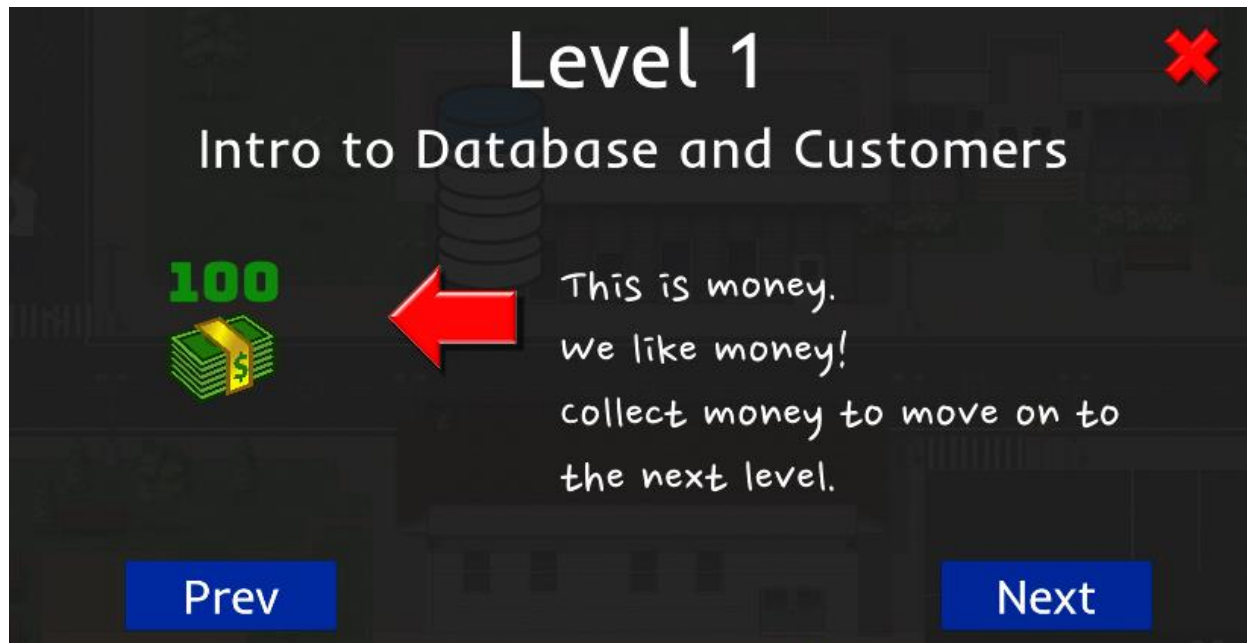
Page 1 – Explains how the database is represented within the game.



Page 2 – Explains how customers are represented within the game.



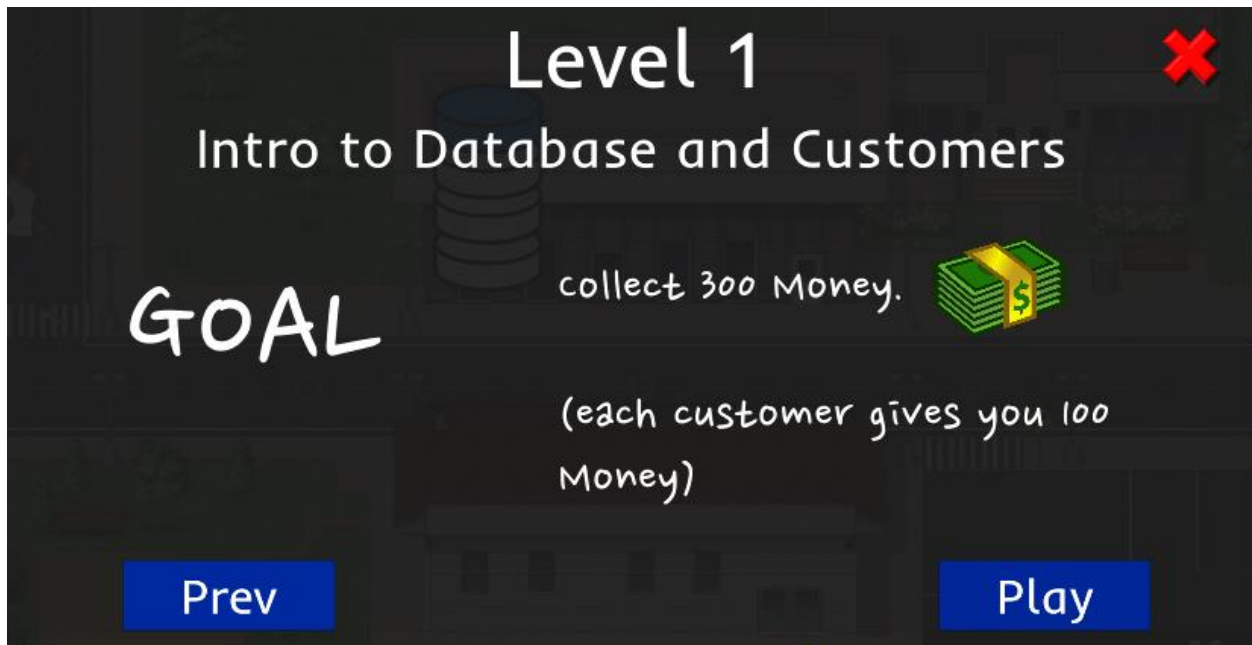
Page 3 – Explains what money is in the game.



Page 4 – Explains how to earn money.



Page 5 – Explains the goal of the level.

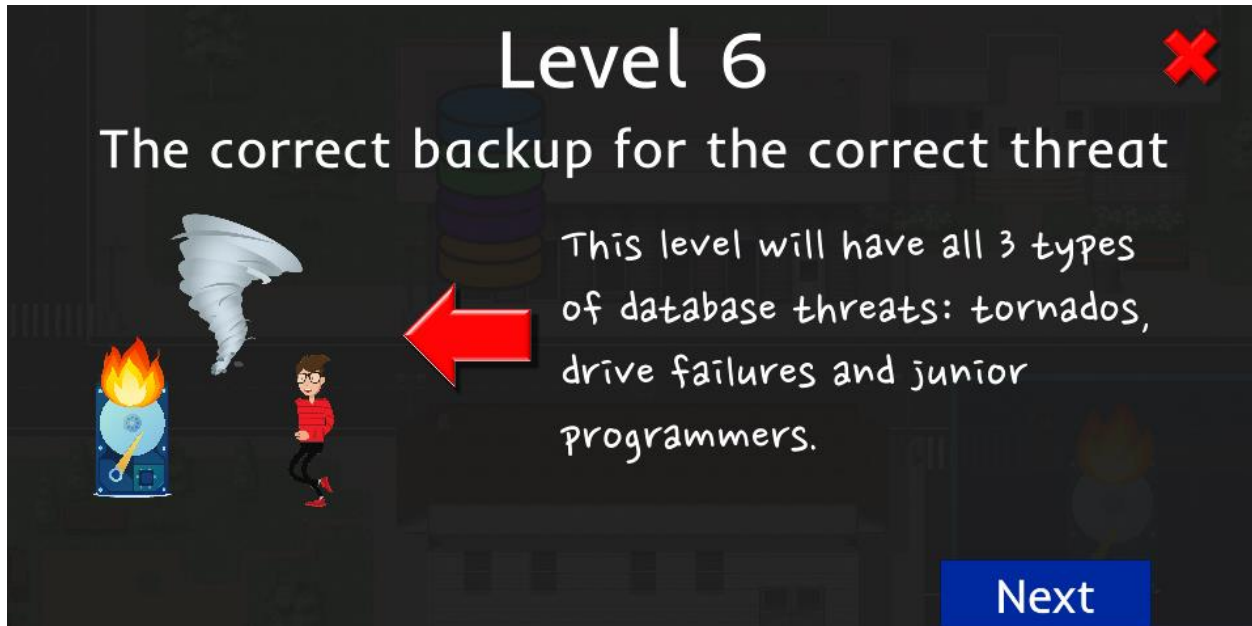


The screenshot shows a dark-themed interface for a game level. At the top center, the text "Level 1" is displayed in a large, white, sans-serif font. Below it, the subtitle "Intro to Database and Customers" is written in a smaller, white, sans-serif font. In the top right corner, there is a red "X" icon. On the left side, the word "GOAL" is written in a large, white, hand-drawn font. To the right of "GOAL", the text "collect 300 Money." is written in a white, hand-drawn font, followed by an icon of a stack of green money. Below this, the text "(each customer gives you 100 Money)" is written in the same hand-drawn font. At the bottom left, there is a blue button with the text "Prev" in white. At the bottom right, there is a blue button with the text "Play" in white. In the background, there is a faint icon of a database cylinder.

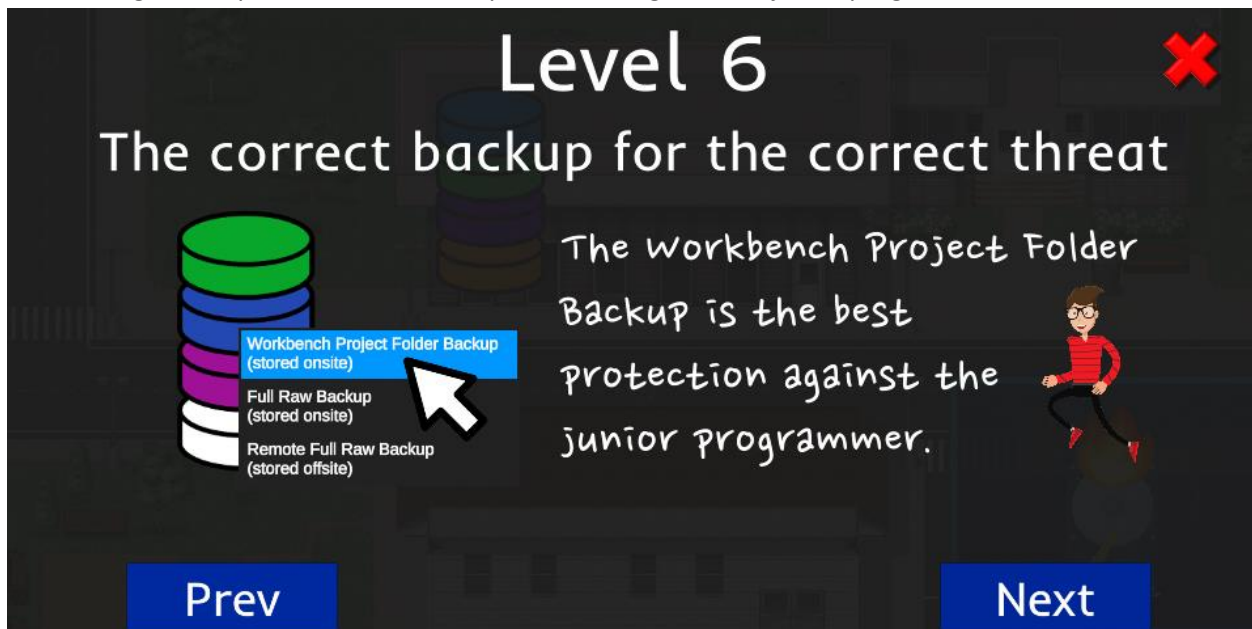
Appendix E - Database Defender Tutorial System Level 6

The following 5 screenshots show the multipage tutorial for Level 6 in *Database Defender*.

Page 1 – Explains that Level 6 will contain all three types of database threats.



Page 2 – Explains the best backup to defend against the junior programmer.



Page 3 – Explains the best backup to defend against a failing hard drive.

Level 6

The correct backup for the correct threat



- Workbench Project Folder Backup (stored onsite)
- Full Raw Backup (stored onsite)**
- Remote Full Raw Backup (stored offsite)

The Full Raw Backup is the best protection against a failed drive.

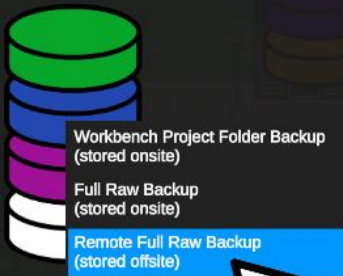


Prev Next

Page 4 – Explains the best backup to defend against a tornado.


Level 6

The correct backup for the correct threat



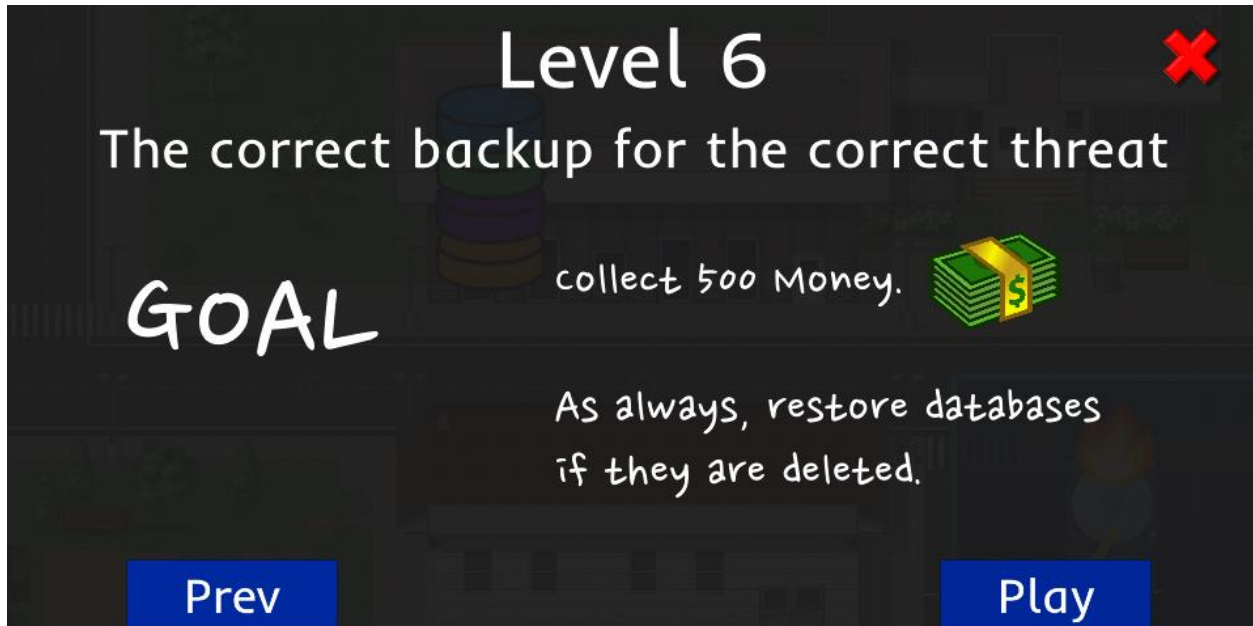
- Workbench Project Folder Backup (stored onsite)
- Full Raw Backup (stored onsite)
- Remote Full Raw Backup (stored offsite)**

The Remote Full Raw Backup is the best protection against a tornado.




Prev Next

Page 5 – Explains the goal of the level.





The screenshot shows a dark-themed interface for a game level. At the top center, the text "Level 6" is displayed in a large, white, sans-serif font. To the right of this text is a red "X" icon. Below "Level 6", the text "The correct backup for the correct threat" is written in a white, sans-serif font. On the left side, the word "GOAL" is written in a large, white, handwritten-style font. In the center, there is a small icon of a database cylinder. To the right of the cylinder, the text "collect 500 Money." is written in a white, handwritten-style font, followed by a small icon of a stack of green money. Below this, the text "As always, restore databases if they are deleted." is written in a white, handwritten-style font. At the bottom left, there is a blue button with the text "Prev" in white. At the bottom right, there is a blue button with the text "Play" in white.

Level 6 

The correct backup for the correct threat

GOAL

 collect 500 Money. 

As always, restore databases if they are deleted.

[Prev](#) [Play](#)

Appendix F - Pre- and Post-test Question and Associated Rubric**Introduction:**

This post-test will present you with a fictional but realistic scenario of an IT specialist working for a company that needs its servers' data backed up to prevent data loss in the event of a disaster event or cybersecurity threat. You are being asked create a database backup and recovery plan to protect against as many cybersecurity threats as possible.

Answer the following question to the best of your ability.

You are reminded that:

In open-ended answers, do NOT provide any information that could identify yourself.

You should NOT take part in this study if you are not willing to participate voluntarily.

Do NOT participate if you feel pressured or coerced into participating.

There is no penalty if you opt-out and do not participate in this study.

The mark you get on this test will NOT affect your grade in the course.

Question: You are an IT specialist working for a company with offices in Vancouver, Ontario and Montréal. There is a data center housing several servers in all 3 cities with a secure, highspeed VPN connection between them all. You are responsible for maintaining server uptime on a number of different servers including a Linux MySQL database in the Vancouver Branch. The MySQL server is responsible for keeping track of online sales for a busy website which receives traffic throughout the day and night with over 50,000 sales per day. The company's sales department runs weekly, monthly and yearly reports on the sales data to get accurate projections for the future and there is a team of several web developers which are frequently updating code to maintain the front-end with new versions coming out at least twice a year.

Describe how you would create a backup plan for the MySQL data on this server in Vancouver. Include as much detail as required to provide up-to-date, consistent backups that will minimize downtime in the event of a disaster. Explain why you are making the choices you are (and the advantages of your solution above other solutions).

For full marks, provide **5 aspects** of backups or system configuration to consider and explain why each one is important for proper backup and recovery of the database system. Marks are only applicable for this research study and DO NOT affect your mark in the course.

[2 marks for each aspect: /10 marks total]

Rubric:

Students will earn up to 2 points for each of the following items that are explained in their answer [2 marks – 1 mark + 1 mark for explanation]:

- How often to backup.
- Time to keep backups.
- Hot/Cold.
- Full/Partial.
- Location to store backups.
- Backup Users, Roles and Privileges.
- Backup My.ini configuration.
- Review Users/Roles – limit ability to DROP, ALTER, etc.
- Time of day to run.
- Test backups to see if they can be restored.
- Encrypt backups so no one has access to the data.
- Use a backup user with a strong password and limited access.
- Do a backup before Development changes.

Appendix G - Learning Survey Questions

1. What gender do you identify as?

- | | |
|---|--|
| <input type="radio"/> male | <input type="radio"/> female |
| <input type="radio"/> trans-gender | <input type="radio"/> non-binary |
| <input type="radio"/> prefer not to say | <input type="radio"/> other (please specify) |

2. How old are you?

- | | |
|--------------------------------|---|
| <input type="radio"/> Under 18 | <input type="radio"/> 26 to 27 |
| <input type="radio"/> 18 to 19 | <input type="radio"/> 28 to 30 |
| <input type="radio"/> 20 to 21 | <input type="radio"/> 31 to 40 |
| <input type="radio"/> 22 to 23 | <input type="radio"/> 41 or older |
| <input type="radio"/> 24 to 25 | <input type="radio"/> prefer not to say |

3. What is the highest level of education you have completed?

- | | |
|---|---|
| <input type="radio"/> Graduated from high school | <input type="radio"/> Master Degree |
| <input type="radio"/> 1 year of college or university
(other than the BCIT CIT program) | <input type="radio"/> PhD or higher |
| <input type="radio"/> 2 years of college or university
(other than the BCIT CIT program) | <input type="radio"/> Prefer not to say |
| <input type="radio"/> 3 years of college or university
(other than the BCIT CIT program) | |
| <input type="radio"/> Graduated from college or university
(Certificate, Diploma or Bachelors) | |

4. In a typical week, about how much time do you spend playing video games?

- | | |
|---|--|
| <input type="radio"/> 0 hours per week | <input type="radio"/> 16 to 20 hours per week |
| <input type="radio"/> 1 to 5 hours per week | <input type="radio"/> 21 or more hour per week |
| <input type="radio"/> 6 to 10 hours per week | <input type="radio"/> prefer not to say |
| <input type="radio"/> 11 to 15 hours per week | |

5. What types of games do you typically play? (select all that apply)

- Action
- Simulation
- Strategy
- Puzzle
- Shooters
- Role Playing Games (including MMORPGs)
- Sports
- Other (please specify)

6. For the following questions, rate your level of agreement:

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
1. The activities used to teach database defense helped me be interested in the topic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. The activities used to teach database defense helped me see the relevance of this topic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. When playing " <i>Database Defender</i> ", I found the gameplay rewarding.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Playing the game, " <i>Database Defender</i> ", made me curious to learn more.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. The activities used to teach database defense helped me be enthusiastic about this topic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. The activities used to teach database defense helped me concentrate on this topic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. When I played the game, " <i>Database Defender</i> ", I did not think of anything else.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. I was very involved while playing the game, " <i>Database Defender</i> ".	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. The activities about database defense were fun.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. I liked the activities used to teach database defense.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Playing the game, " <i>Database Defender</i> ", was entertaining.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I liked playing the game, " <i>Database Defender</i> ".	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I feel I have learned something useful from the activities used to teach database defense.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. The activities used to teach database defense helped me to learn effectively.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I learned new things about database defense by playing the game, " <i>Database Defender</i> ".	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. The game, " <i>Database Defender</i> ", will help me remember the things I learned about database defense.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. What do you now know about database and cybersecurity threats and defences that you did not know before playing the *Database Defender* game?

8. Do you think you have retained the information learned by playing the *Database Defender* game? Why or why not?
9. Did you find playing the *Database Defender* game more or less engaging than traditional non-game-based learning activities? Why or why not?
10. Please describe the effect (if any) that playing the *Database Defender* game has had on your motivation to learn concepts of database and cybersecurity threats.
11. Do you believe that playing serious games can help you acquire certain knowledge or skill more effectively than in a formal classroom setting? Explain.

Appendix H - Interview Questions

1. "*Database Defender*" is a serious game designed to help educate students about the concepts of database and cybersecurity threats and defences. Do you think the game accomplished what it was intended for? How did it succeed or fail?

2. What do you feel were strengths about learning using a serious game such as "*Database Defender*"?

What do you think was a weakness about learning this way?

3. Did you enjoy or dislike playing "*Database Defender*"?

What was it about the game that you enjoyed or disliked the most?

4. Did playing "*Database Defender*" help you to be motivated to learn more about database backups, recovery, and defense?

Why or why not?

Did playing "*Database Defender*" make you more interested in learning about database backups and recovery?

5. Do you agree or disagree with the following statement?

Playing "*Database Defender*" made me excited to play more.

Why or why not?

6. Do you recall anything you learned from playing "*Database Defender*"?

If Yes, what was the most valuable thing that you learned from playing the game?

Did playing "*Database Defender*" help you better understand how you would protect a database against everyday, real-life threats?

7. What would you change about "*Database Defender*" to make it better?

Did you experience any difficulties while playing "*Database Defender*"?

Appendix I - Student Instructions for Creating an Individual Participation Code (IPC)

Your Individual Participation Code (IPC) is used to keep your information anonymous.

To generate your 5-character IPC, answer the following questions and use the related letters and numbers:

- The first letter of the city where you were born.
- The first letter of the first high-school you attended.
- The first letter of your mother's maiden name.
- The number of **older** siblings (brothers and sisters) you have.
- The number of **younger** siblings (brothers and sisters) you have.

For example, if you were born in **White Rock**, your high-school was **Hugh Boyd Secondary School**, your mother's maiden name was **Olsen**, and you only have **1 older brother** and **no younger sisters or brothers**, then your IPC would be: **WHO10**.

If you wish appear as though you are participating, but do not wish to have your data included within the study, you may use an IPC of 99999. Using an IPC of 99999 will allow you to appear as though you are completing the surveys, and appear as though you are participating, but your data will not be used during the analysis for this study.

Appendix J - List of Thematic Analysis Codes and Example Quotes

Code	Quote
Already Interested	"...that I'm already fairly interested in databases prior to playing the <i>Database Defender</i> ..." -Bob "I was already interested." -Alice
Desire to Learn More	"Playing the <i>Database Defender</i> game made me want to learn about more strategies for database defense ..." -Charlie
Interest	"...helpful to foster interest in students..." -Bob
Motivated	"... was definitely motivated to a point to learn more about it" -Charlie
More Levels	"... want to play more levels, and there are only six." -Charlie "... more threats and more counters would be great..." -Charlie
Engaging	"The effect that playing the Database Defence game had ... was engaging" -Diane "...I thought it was a very engaging game and kept me focused." -Charlie
Active	"... as students would be entertained and participating in their learning ..." -Charlie
Hands On	"I think making learning more kinetic and fun is important." -Alice
Focused	"...it was a very engaging game and kept me focused." -Charlie
Interactive	"...I'm a big believer in interactivity and learning,..." -Charlie
Persistence	"...[I] ended up playing it like three or four times." -Charlie "I'm constantly thinking about how can I do this better?" -Charlie
Anticipation	"...I could prepare for the different threats ahead of time." -Charlie
Entertaining	"Playing the game was not only a more entertaining way..." - Charlie
Fun	"I think making learning more kinetic and fun is important." -Alice "The effect that playing the Database Defence game had ... was ... fun" -Diane "I really liked the game it was really fun" -Charlie
More Game Based Learning	"I would like a more cybersecurity aspect in the game..." -Alice
I don't play games, but was fun	"i dont play games so for me it is fun to play it" -Ellen
Awesome	"The effect that playing the Database Defence game had ... was ... awesome" -Diane
Enjoy	"I very much enjoyed it." -Charlie
Learned More	"...it helped me to synthesize more information about database defense..." -Charlie "...playing the <i>Database Defender</i> game because I learned so much about Backing up database ..." -Diane
Learned Nothing New	"... same topic was covered in class..." -Bob
Reinforcement	"... this is the second time learning the material ..." -Bob "... But additional reinforcers will probably strengthen the memory..." -Bob
Learned More from Labs	"... you learn more from the lab compared to the game." -Bob
Good for Dull Topics	"... the right context and for covering certain dull topics..." -Bob

Good for Hard to Learn	"...can be useful, especially topics that are hardest to learn ..." -Diane
Traditional Learning not Engaging	"...the game is more engaging than traditional non-game-based learning activities..." -Bob "Traditional non-game-based learning activities tend to not be very entertaining." -Charlie
Learned Better	"...learned the materials better." -Diane
Visualization	"...knowledge is visualized and memorized during playing..." -Ellen
Memorization	"...knowledge is visualized and memorized during playing..." -Ellen
Effective	"Playing serious games in place of traditional readings ... would likely be effective." -Diane "I think the game is quite effective." -Charlie
Games not for Everyone	"...people who really aren't into video games ... may or may not get that same effect of learning." -Charlie
Better than Traditional Learning	"...it's a really good alternative to kind of the more traditional..." -Charlie
Simple	"..., but perhaps very simple..." -Alice
Not consumer quality	"... if it were to become a full console quality ..." -Alice
Good Game Design	"...I thought that [it] was very good game design..." -Charlie
Good Educational Design	"... and very good educational design..." -Charlie
Urgency	"How can I make sure that I have a remote backup ready for each tornado?" -Charlie "I learned more about the urgency of restoration ... prior to customer interaction" -Alice
Different Backups for Different Threats	"...choose different types of backup based on different needs and situations" -Ellen "...we had the three different threats, and then we had the three different counters..." -Charlie
Importance of Remote Backups	"...you have to make a remote backup to to deal with that threat." -Charlie
Positive	"I found out playing the <i>Database Defender</i> game was more engaging than traditional non-game-based learning activities..."-Diane "I definitely think it, it accomplished what it was intended for." -Charlie "I learned more..." -Alice
Slightly Positive	"...very mildly positive effect on my motivation to learn databases." -Bob "Maybe a little? [Re: Effect of game on your motivation]" -Alice
Positive, but Depends	"I believe under the right context ... a game setting might be helpful to keep students engaged." - Bob
Neutral	"I believe having both a formal classroom setting and engaging in serious games can both be useful..." -Ellen